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Awareness and Use Perception towards Complementary and Alternative Medicines (CAM) in Saudi Arabia

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Abstract

Complementary and Alternative medicines are becoming prevalent methods of treatment among the users in the world. As it has high acceptance to treat many types of ailments which cannot be cured by the modern medicines. In the Kingdom of Saudi Arabia (KSA), this path is also prevailing in the society but due to the lack of awareness, unavailability of professional practitioners and some other factors it is not appropriately adopted. In the region, a descriptive study had been carried out to understand the awareness level, its uses and perception towards CAM among the users. The study aimed to provide an in-depth understanding of males' and females' perceptions towards awareness and applications of CAM in the region. For the purpose, a survey sample of 120 respondents in Jeddah city at convenience bases were taken during September to November 2016. Data collection with using a structured and close-ended questionnaire was carried out. The received data were coded and analysed with appropriate statistical tools. It was investigated that the majority of the respondents were aware of the CAM. And its uses and benefits in particular ailments were highly noticed by them. Moreover, they were also positive about the benefits of CAM treatment system.

Keywords:

Complementary alternative medicine; Herbal Medicines; Consumer Perception; Saudi Arabia.

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1. Introduction:

The term complementary alternative medicine (CAM) includes many types of treatments and procedures that are usually not incorporated in conventional medicine. There is a broad range of alternative medicine such as acupressure, aromatherapy, reiki, massage and so on are seriously considered as a medical form of treatments to help cure health ailments. These alternative medicines are based on irrational belief systems, traditional ethnic systems, spiritual energies, holistic therapy, or/and religion, faith healing, and prayer (Alam M Z, 2008). According to Jones (2016). Complementary and alternative medications are the form of remedies that are also termed as herbal or spiritual healing as duly mentioned by (Kelnerand Wellman, 2014). Complementary and alternative medicine (CAM) is widely used, both as a supplement to conventional or central stream health care and as part of traditional healthcare systems and practices (Bodekeretal. 2005). Australian data, published in 2007, reported that 69% of the people had used one o more modes of CAM in the previous 12 months. However, the use of CAM varied with age, sex, and a range of other factors (Xue et al . 2007; Alam M Z, 2003). Those with chronic health issues, cancer, and chronic pain, in particular, were found to have made more excellent use of CAM (Sayadahelal. 2006). Most of these studies revealed a surprisingly high predominance and an overall positive attitude toward the use of CAM. For example, a survey conducted by the Centers for Disease Control and Prevention (CDC) in the United States showed that 40.0% of adults had used CAM in 12 months (Barnes et al., 2007).

A study conducted in Ajman, United Arab Emirates, showed that approximately one-third of the seekers of modern medical care also use CAM, mostly without physician advice (E. Mathueetal., 2013). CAM is used widely for treatment of chronic diseases in many parts of the world. In a study conducted in the Muscat region of Oman, almost half of the patients used CAM therapies for diabetes mellitus, and they had a strong faith in its effectiveness in treating patients (R. M Al Kinda et al., 2011). A study conducted in Malaysia showed that there was a high prevalence of CAM use by the population, particularly the use of herb-based therapies for health issues (Z. M et al., 2009). The use of herbal remedies is widespread in the Arab world, and Saudi Arabia is no exception to it. Anecdotally, it is considered that herbal products are favourite because of a full spread belief that the preparations are natural and therefore safe. Another important practice in Saudi Arabia is the increased prevalence of self-medication, along with the concomitant use of herbal and conventional medicines. This is an area of high concern due to its

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potential for herb interactions (Al Braiketal., 2008; Al Arifi 2013). One particular study performed in the Kingdom of Saudi Arabia showed a 68.0% prevalence of CAM use among the Saudi participants living in the region of Riyadh who showed favourable opinions toward it, relating to it as "natural materials" (Al Faris et al. 2008). Knowledge and awareness of complementary and alternative medications have significantly increased in the Saudi Arabia region (Jaziehetal., 2012).

According to Elolemy and AlBedah (2012), about 90% of the people who participated that a good knowledge about complementary and alternative medications and about 75% people use complementary and alternative medicines as primary medications within Saudi Arabia. Rahman et al. (2004) showed that Saudi people tend to use additional and alternative drugs as they feel safe when using natural herbs such as using vitamins and mineral supplements. In Saudi Arabia, Tibbu Nabawi or prophetic medicine is broadly accepted and practised by most physicians and the public. This is indicated in a report by the study of National Center for CAM in Saudi Arabia 2010 (Albedah 2010; Alfaris et al.,. 2008) who recorded that more than 70% of the public in the Riyadh region had used practices related to prophetic medicine in their lifetime.

One of the excellent medical markets growing at a massive rate by allopathic treatments today is complementary and alternative medications as indicated by (Synovitz and Larson, 2013). Aloft the last 15 years, there has been a steady rise with regards to global marketing ratio for complementary medicines (Greene, 2016). The CAM market continues to be profitable as the worldwide yearly market for these products approaches US$ 60 billion (United Nation Report, 2000) Recent statistics have revealed that the sales growth of these medications has risen from $5 billion per annum to $7 billion per annum magnanimously (SynovitzandLarson, 2013). It has been estimated that over 68 percent of the global population are into one or other form complementary medication (Cahill, 2017).

Saudi Arabia is considered to be one of the fastest growing markets for complementary and alternative remedies and has gained a good ranking on the worldwide marketing platform for these medications (Al-Rowais, 2002). As per Holmes and Cherniak (2017), indeed, rising knowledge about complementary and alternative medicine will help Saudi Arabia lead the global markets shortly (Parker, 2016). In line with this trend, the present work aimed at studying awareness, perception, and general attitudes respondents towards CAM related to herbal medicines particularly in Saudi Arabia.

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2. Research Method:

For the study, a close-ended questionnaire from 120 participants was used to capture the data from the respondents that purchased, used herbal medicines and herbal dietary supplements. The survey was done based on convenience sampling method in Jeddah Saudi Arabia in 2016. The questionnaire involved four parts the socio-demographic characteristics of the buyer, the origin of advice for the advantage of the obtained herbal products, the consumer's attitude towards the safety, of awareness, the effectiveness of herbal remedies and herbal dietary supplements and their combination with conventional treatments, and assessment of the purchased herbal products. The data from each of the recovered questionnaire were coded and entered into Excel, and statistical analysis, JAS and SISA software were used. Moreover, results were summarised using with descriptives statistics as appropriate.

3. Results and Analysis:

Table 1: Demographic Information of Respondents

	Variables	Frequency	%
Age	Below 20	76	63.333
	20-30	32	26.667
	30-40	8	6.667
	40-50	4	3.333
	50 and Above	0	0
Gender	Male	28	23.333
	Female	92	76.667
Educational Level	Uneducated	8	6.667
	Elementary	12	10
	Intermediate	16	13.333
	High School	20	16.667
	Bachelor and above	64	53.333
Total Number of Respondents		120	100

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Table 2: Respondent's Opinion Regarding The Alternative Therapy Treatment Adopted By His Family Members

Answer	Frequency	%	Sum%
Yes	40	33.333	33.333
No	80	66.667	100
Categories 2 , Mean: 1.66667, SD: 0.47338		120 cases	100%

Figure 1: Respondents Opinion, Regarding The Effectiveness Of The CAM/ Alternative Medicine:

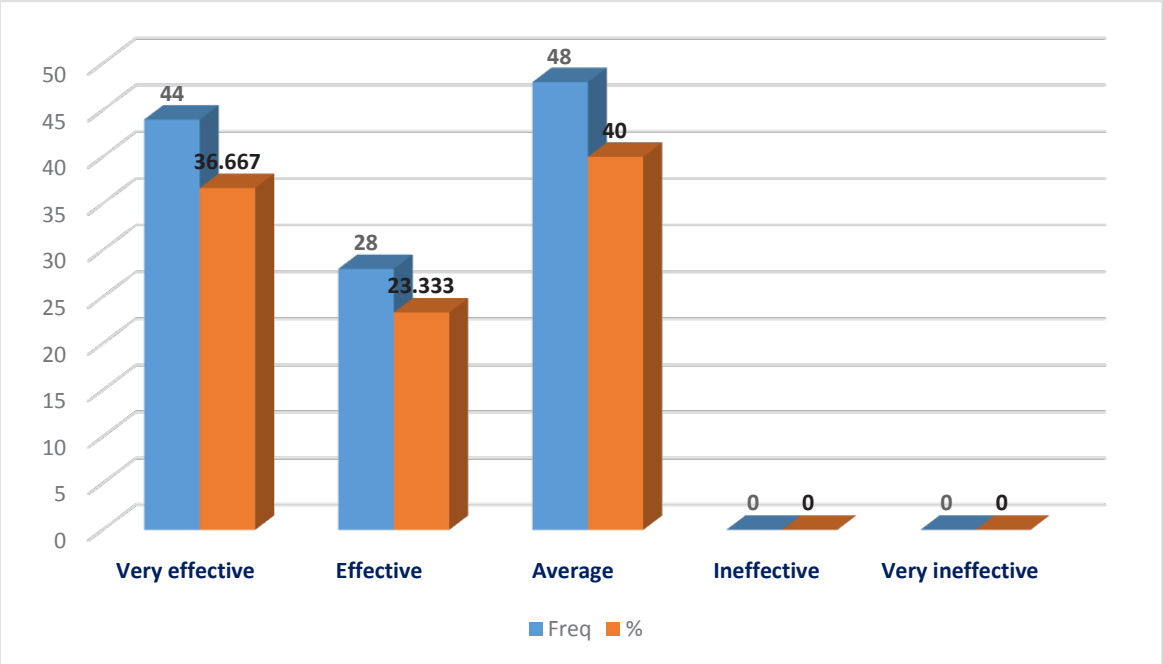

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Figure 2: Opinion Regarding The Effectiveness Of (Cam) Treatment With Ailments

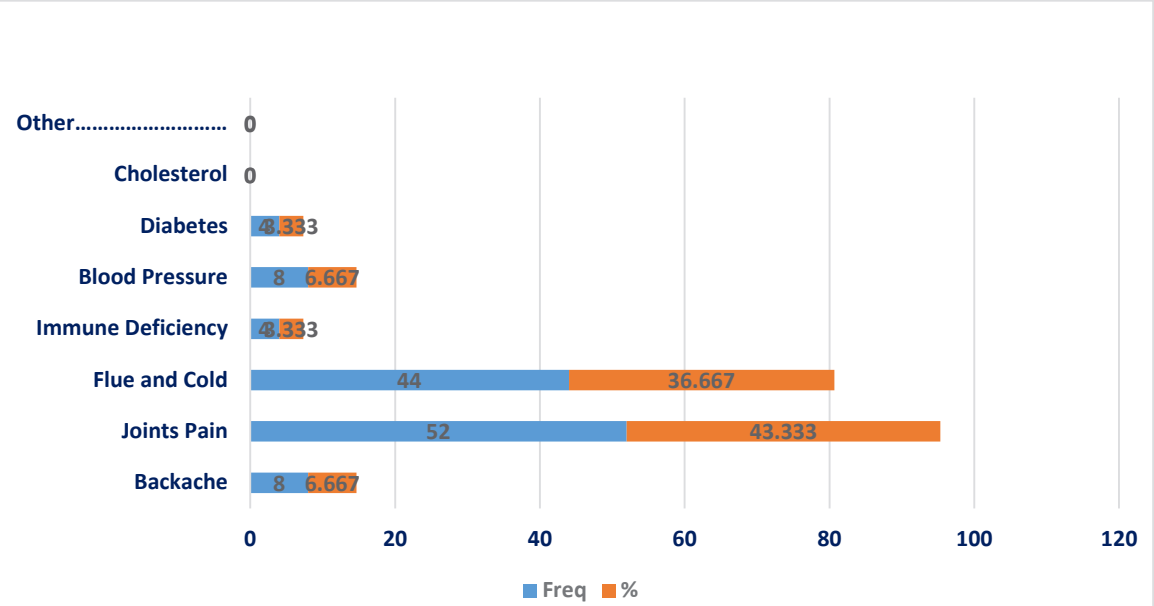

Figure 3: Opinion Regarding The Preference Of This (CAM) Treatment As Compare To Modern Treatment

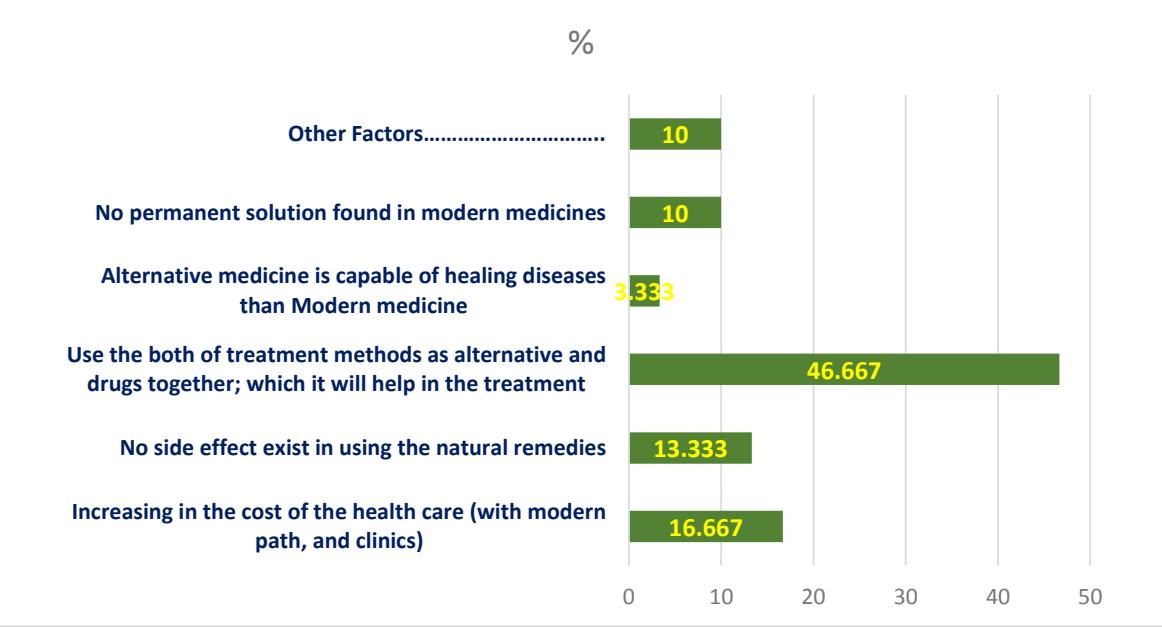

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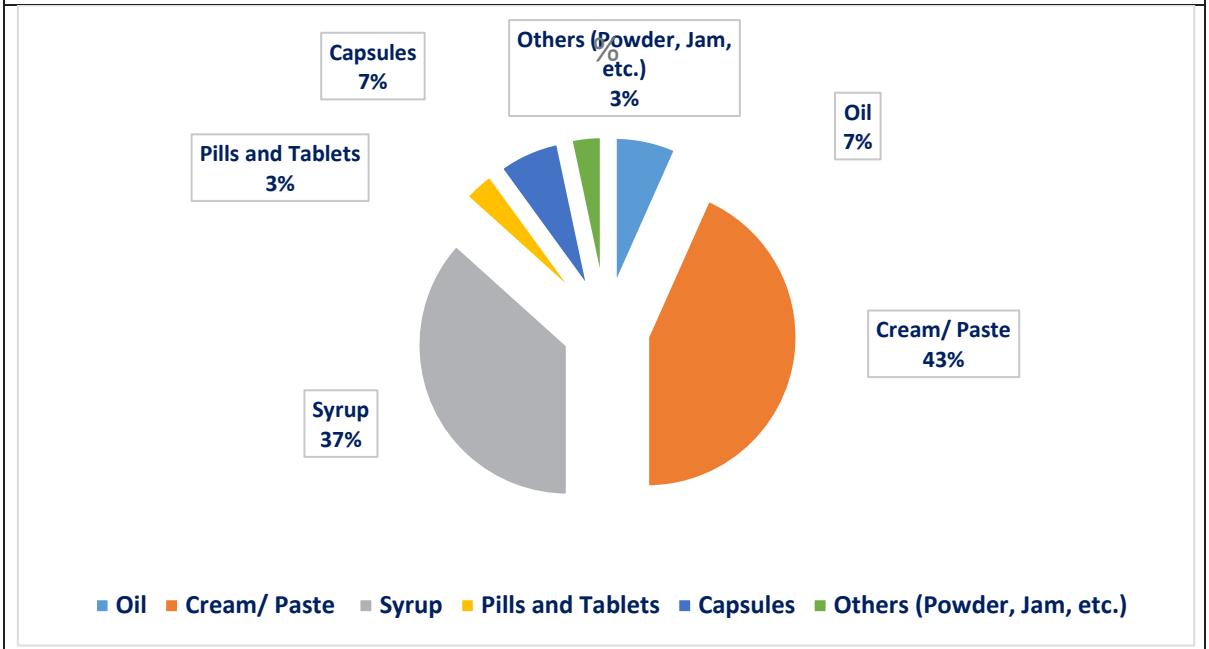
Figure 4: Desirable form of Alternative Medicine Product



Result Discussion:

Regarding the age of the participant's majority, belong to less than 30 years of age that is 90% of the sample population. The rest 7% were between 30-40 years followed by the 40-50 (3%) respectively. Around 92% of them were female, and only 28% of the respondents were male. Of the participants, 53.33% had bachelor's degree while only 13.33% had intermediate 10 % had elementary and 8% of the respondents were stated that they are uneducated (See Table- 1). Participants of this study expressed their views regarding the adoption of alternative medicines in his family in this respect majority 67% indicated that their family did not adopt ever to this therapy, however, 33% were confident that their family had chosen alternative treatment (CAM/ Herbal Medicines) for the treatment. This is at least good sign of awareness and trust regarding the alternative medicine in the region (See Table 2).

The study was to understand consumer perception of CAM products in Saudi Arabia with particular reference to herbal medicines. The research study was carried out using three overall objectives. The attributes suggested by the respondent to use herbal products are prepared from the natural ingredient, free from the side effect, fit for health and non-chemical. Most of the respondents mentioned herbal products are made from natural element so; they faced no side effect (Kumar & Janagam, 2011). From the figure 1, it is

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indicated that perception regarding the alternative medicines for the treatment is very positive as is observed that majority hundred percent people feel that alternative medications are beneficial for the treatment of ailments. The attitudes towards herbal products (measured on a five-point Likert scale) respondent agreed with most of the statement. It was indicating that respondent holds a positive attitude towards herbal products. Regarding the effectiveness of alternative treatment with ailments, it was observed that respondents agreed on that this treatment is beneficial for joints pain (43.33%) followed by flue and cold 36.67 %, backache and blood pressure 8% both and diabetes as well as immune deficiency treatment were 3. 33%. (Figure 2).

The reason for the choosing and selection of CAM / herbal treatment as compared to modern medicines, the majority claim that they were using some time both of the therapy. That helps to quick response on the cure of ailments followed by claiming that allopath treatment costly (16.5%), no side effect existing in natural treatment (13.33%) and no permanent solution with modern medicines and other factors were the cause to select this treatment (See Figure 3). Majority of respondents declared that the paste/ cream form of the herbaceous product (43%) were preferable followed by Syrup (37%), Capsules and oil represent equally (7%), and Tablets and another form (3%) were preferred each respectively (Figure 4).

4. Conclusion:

In the study majority were below the 30 years of age as this study was conducted with convenience methods of sampling. Moreover, the majority of them belong to the Bachelor degree, and the highest majority of the respondents were female. Regarding the adoption of alternative medicines within the family member's majority indicates that their family did not adopt ever to this therapy, however, there was positive feedback that one-third of the respondents' family member was engaged and used/ adopted alternative treatment (CAM/ Herbal Medicines) for the treatment. This is at least good signal of awareness and trust regarding the alternative medicine in the region. Despite the high provision of herbal remedies through community pharmacies in Saudi Arabia, majority respondents believe that herbal products were a useful therapeutic option and a considerable proportion of people thought they natural and safe in use. The attitude of the respondents towards herbal/ nutritional supplements and alternative medicines are confident with a high percentage, being of the opinion that they are useful, natural and safe. There are a high

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level and very positive perception regarding the alternative medicines for the treatment of the respondents. Regarding the effectiveness of alternative treatment for ailments, it is perceived that this treatment is beneficial for joints pain followed by flue and cold, backache and blood pressure both and diabetes. The majority pretend that they use some time both of the therapy because that helps to quick response on the cure of ailments followed by claiming that allopath treatment costly, no side effect existing in natural treatment and no permanent solution with modern medicines and other factors are the cause to select this treatment. The paste/ cream form of the herbal product is highly preferable followed by Syrup, Capsules and oil represent respectively. It is, therefore, recommended from this study that since such a high proportion of the populace use CAM, that at the local, state and national levels government should find acceptable ways of incorporating their use in the region. The hospital should focus to open the department of CAM-related to specific problems that are highly perceived useful and highly acceptable by the respondents. The supplier should centre to prepare the natural product form in paste/ cream form, Syrup, Capsules and oil as per the suitable ailments and age bases. Besides respondents need to be better informed about herbal products, which are seeking alternative remedies for chronic health problems and especially those using both treatments for a cure.

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Corporate Governance and Board of Directors Responsibility in Appointing Senior Managers: A Case in Saudi Arabia

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Abstract

Corporate governance is a cornerstone in improving efficiency and creating confidence to attract investors. After collapses of giant companies, worldwide business community are trying to infuse a culture of honesty and integrity in business. Commitment of board of directors and willing of top management and employees to strength corporate governance is essential. Failure to compliance with corporate governance rules will increase operational risk and hence impacting interests of stakeholders.

Saudi Arabian Monetary Agency (SAMA) which is the central bank in the Kingdom of Saudi Arabia with Capital Market Authority (CMA) are thriving continuously to strength corporate governance rules for banks and financial institutions. One of the circulars for banks and financial institutions is the requirements for appointments of senior positions in financial organizations with the objective of appointing persons who possess integrity, honesty, and good reputation. Companies should obtain written non-objection form for the appointment of senior managers and it is the responsibility of board of directors to ensure compliance with this regulation. In addition, SAMA issued several guidelines for anti-money laundering, rules for countering fraud and a code of professional ethics of staff. Recently, banks are required to form compliance unit to make sure banks prepare their financials according to International Financial Reporting Standards (IFRS).

The aim of this paper is to highlight a case of corporate governance and board responsibilities in one of the financial institutions in Saudi Arabia. The case will be presented to show the mechanism followed by the financial institution and whether it is complied with rules in appointing senior managers and if not what corrective actions are done in order to strength corporate governance principles.

Keywords: Board of director's responsibilities; Saudi Arabian Monetary Agency, Corporate Governance

1. Introduction

Corporate governance had gain popularity nowadays specially after the collapses of many companies who appeared giant and efficient while actually they were fragile. Expropriation of stakeholders by senior managers is widely evident with the collapses of companies such as Enron which is symbolic of shareholders failure to protect their interests due to asymmetrical information and conflict of interest in board of directors (Heath and Norman, 2004). The inefficiency of corporate governance mechanisms in banks and financial institutions are blamed in each crises. However, after absorbing the impact of failure, many opinions call for re-designing corporate governance mechanisms to ensure board responsibility, accountability, risk management, transparency and disclosure in financial reports (Jensen, 2002). Despite the negative impact of Enron collapse, the case "has done for reflection on corporate governance what AIDS did for research on the immune system" (Norman, 2004). The ties between executive managers and shareholders were destroyed because of manager's greed and willingness to benefit themselves over shareholders interest. Although shareholders should be supported by board and have a special position in the front line of interest to managers as providers of capital, sometimes board of directors do not choose to act and other times were myopic. Ibid (2004, p.6) states:

Boards of Directors often conspired with the executives (because the executives and their friends sat on the

Board, controlling the agenda and directing important committees), or failed to exercise sufficient diligence in monitoring the executives; the shareholders, especially large institutional shareholders, paid insufficient attention to the quality of the Boards and to the reports of external auditors.

According to stakeholders' theory, managers should make decisions that are in the best interest of stakeholders. However, Jensen (2002) criticizes the ability of managers to satisfy all stakeholders at the same time and in this case the theory is "unassailable" (Ibid, 2002, p.241). As when a manager is trying to maximize shareholders wealth, current profits, market share, future growth in profits can destroy his ability to take the right decision. As "A manager directed to maximize both profit and market share has no way to decide where to be in the range between maximum profits and maximum market share" (Ibid, 2002, p.238). Managers under the supervision of the board should take all different dimensions in mind for the well-being of the firm and welfare of society. It is necessary to have internal control system to limit managerial actions. He states (p.242):

Because stakeholder theory provides no criteria for what is better or what is worse, it leaves boards of directors and executives in firms with no principled criterion for problem solving … it leaves managers and directors unaccountable for their stewardship of the firm's resources. With no criteria for performance, managers cannot be evaluated in any principled way. Therefore, stakeholder theory plays into the hands of self-interested managers allowing them to pursue their own interests at the expense of society and the firm's financial claimants.

The size and magnitude of Enron's failure challenges academic beliefs about the role that could be played by board of directors. The aligning of manager's interests with stakeholder's interests need more solid foundations other than assuming that it is easily being aligned. Enron highlighted the way in which loose regulations had led auditors to allow accounting methods that promote overstating profits while analysts remained positive and sometimes silent in spite of un-logical financial results. The changes in executive compensation in the 1990s in USA, designed to align executive interests with those of shareholders, provided a strong incentive to managers to overstate earnings, even if this was not sustainable and illusionary. When chief executive officers spend three to four years in companies and cash their stock options and then markets are not quick to respond then stakeholders face the consequences (Clarke, 2005; Coffee 2004).

Board of directors should play different roles in organizations in order to maintain their sustainability. They have to plan strategic direction, advising, active monitoring and disciplining roles. Also the board should control the process of appointing executives and assessing their actions. Adams et al., (2010, p.65) state:

Assessment can be seen as having two components, one is monitoring of what top management does and the other is determining the intrinsic ability of top management. The monitoring of managerial actions can, in part, be seen as part of a board's obligation to be vigilant against managerial malfeasance. Yet, being realistic, it is difficult to see a board actually being in a position to detect managerial malfeasance directly; at best, a board would seem dependent on the actions of outside auditors, regulators, and, in some instances, the news media. Indirectly, a board might guard against managerial malfeasance through its choice of auditor, its oversight over reporting requirements, and its control over accounting practices.

This research proceeds as follows. Section two, is going to explain responsibility of board of directors in appointing and monitoring managers. Thirdly, the case of one of financial institution in the Kingdom of Saudi Arabia is presented. The fourth section, discusses whether the board of directors fulfill their responsibilities by adhering to corporate governance rules of appointing senior executives and if not what corrective actions are done in order to strength corporate governance principles. Finally, fifth section is a conclusion and recommendations for the paper.

2. Responsibility of Board of Directors in Appointing and Monitoring Managers

In many countries shareholders have a dominant role in appointing board of directors. Shareholders believe that appointed board and senior managers will act in their interests. Senior managers are responsible of directing, planning and controlling work and take corrective actions necessary. They should manage risk, have appropriate control systems, provide accurate information and act ethically. Shareholders place their trust in board's decisions in supervising senior manager's actions and proficiency. However, in many incidents this is not the case and agency problem persist. When existing and potential investors are considering buying or selling stocks of any companies, they often rely on financial information which is not forward looking, subjective and sometimes incorrect. In this case, shareholders confidence for an effective role and responsibilities of the board in supervising and selecting senior managers is crucial. In order for corporate governance to function efficiently, several dimensions might be taken into consideration including role and responsibilities of the board, board composition, management process, relationship between board members, and duality of CEO and Chairman (Jan and Sangmi, 2016). Güner et al., (2008) conducted a study covering 282 companies over 14 years to explore

board composition when appointing financial expertise and the conflicts of interest due to commercial bank and investment bank affiliation. They argued the financial expertise tend to benefit their own banks by giving loans instead of increase shareholders value in companies who are part of their board. Firms and policy makers should think again about increasing financial expertise in board of directors if they are going to make shareholders' interests as second priority.

The roles and responsibilities of a board of directors are different, depending on the nature and type of organization and the laws applied in a certain country. Similarly, the establishment of different committees is a means to channel the functions of a board into expertise groups of directors that focus on specific issues in organization. The role of the board is critical for the success of companies. According to UK Corporate Governance Code (2016), the board should make sure that financial and human are available to fulfil companies objectives. The board is responsible for making sure an amalgam of skills and experience is present for running companies smoothly and efficiently (Gibbon et al., 2017). The role of the board had changed from passive role to become more active in monitoring and disciplining managers while overseeing their actions. They have evolved from "managerial rubber-stamps to active and independent monitors", thus allowing more effectiveness for corporate governance (Adams et al., 2010, p.64). Kaplan and Bernadette (2006) examine all Fortune 500 firms during period from 1991-2005 to determine CEO turnover internally through board driven or externally through takeover or bankruptcy. They state (p.2, emphasis added):

Annual CEO Turnover is 14.9% from 1992 to 2005, implying an average tenure as CEO of less than seven years. In the more recent period since 1998, total CEO turnover increases to 16.5%, implying an average CEO turnover of just over six years. **Internal or board driven turnover also rises substantially, increasing from 10.3% in the first part of the sample to 12.8% in the latter part of the sample**…. previous work suggests a modest relation between internal (board initiated) turnover and firm performance ….. We find a stronger and significant relation between internal turnover and firm performance.

Corporate governance can be viewed as a nexus of relations between board of directors, company management, shareholders, debtholders, customers, government and other stakeholders within a social, legal and political framework. The effectiveness of corporate governance flourish in an environment of compliance, transparency and accountability. Board of directors has a control, strategic and resource provision roles. The supervisory board "can help the firm connect with the relevant segments and environmental constituencies" (Tomsic, 2012, p.74). Isik and Ince (2016) argued that board of directors is a cornerstone in the governance mechanism. Different critical areas should be taken into consideration by the board such as emphasizing ethical values, standards in the work environment and overseeing strategies that address sustainability and stakeholder interests. Bernardi and LaCross (2005) surveyed a sample of quarter of Fortune 500 companies in order to explore their concern about publishing their codes of ethics to strength corporate governance. They discovered, that since the collapse of Enron in 2002, companies generally give increasing emphasis to code of ethics, which can be seen as a positive sign. There were also no significant differences in the disclosure rates between different industries. One astonishing finding was that in 2002 none of the former companies audited by Arthur Andersen revealed ethics policies on their websites. Fung (2014) argued for the need of board of directors to monitor and control senior manager's performance. He (p.73, emphasis added) states:

Corporate governance highlights the important principles of **oversight and control over the executive management's performance and strategic directions**; and their accountability to the shareholders. A code of ethics, which clarifies and stipulates adherence to some of more abstract ideals of trust and accountability, is essential for good corporate governance. **The board and management should endeavor to uphold and nurture accountability, transparency, fairness, and integrity in all aspects of the company operations**.

Onetto (2007) argued that two agency problems exists one where the board is the agent for shareholders and at the same time assumed to be principal to directors. The board monitors management on behalf of its principals – shareholders, and trying to monitor and deduct managerial inefficiency and abuse. Sometimes managers have power over the board as it manifested in Enron. He states (p.416):

A board's independence depends on a bargaining game between the board and the CEO … Of the many responsible parties implicated in Enron's scandal, it could be said that the board's inactions, up to a certain extent, led the company to its demise in December 2001. Enron's board approved a disclosure policy that made the firm's financial results substantially opaque to public capital markets. It also approved a compensation strategy that made managerial payoffs highly sensitive to stock price changes and it also failed to engage in an intense monitoring of business results and financial controls.

In Saudi Arabia, The General Department of Finance is in charge of controlling the financial sector and has the

authority to supervise the activities of finance companies according to Finance Companies Control Law (2016). Although rules and regulations are available, monitoring implementation is necessary when managers and board try to manipulate it whether intently or by ignorance and this will be the concern of the case going to be presented.

3. X Financial Institution and Board Responsibilities

Corporate governance regulation has been issued by Capital Market Authority (CMA) in November 2006, in response for Saudi Stock market crash. However, corporate governance in Saudi Arabia is still a fairly new concept, the Saudi Arabian Monetary Agency (SAMA) and Capital Market Authority (CMA) are still in the process of organizing the financial markets and highlighting the benefits of applying good corporate governance and many of the laws and institutions are still relatively new with little experience; awareness of the importance of good corporate governance is low, and implementation by companies is in its early stages (Al-Matari et al., 2012).

The Saudi Arabian Monetary Agency (SAMA), the central bank of the Kingdom of Saudi Arabia, has been entrusted with performing many functions. The most important two of those functions are: licensing financial institutions to operate in the kingdom financial sector and supervise those finance institutions' activities in accordance with the following rules and regulations:

- Real Estate Finance Law issued with the royal decree Number\50, 13\08\1433H (Islamic year), and its implementing regulations number\1229 issued on 10\04\1434H.
- Finance Lease Law issued with the royal decree Number\48, 13\08\1433H, and its implementing regulations issued on 14\04\1434H.
- Finance Companies Control Law issued with the royal decree Number\51, 13\08\1433H, and its implementing regulations issued on 14\04\1434H.

The General Department of Finance is in charge of controlling the financial sector and has the authority to supervise the activities of finance companies, including the following:

- Extend license to engage in one or more finance activities (there are currently 47 financial institutions licensed to operate in the kingdom);
- Take necessary measures for maintaining the integrity and stability of the finance sector and fairness of transactions;
- Take necessary measures for promoting fair and effective competition between finance companies;
- Issue required rules and instructions to regulate the finance sector; and
- Take proper means for the development of the finance sector, Saudization, and raising the employees' competency through regulating the obligations of the finance companies regarding the training of human resources, improving their skills and developing their knowledge.

Our concern is one of the financial institution supervised by SAMA that has failed to undertake the necessary measurements to comply with some of SAMA regulations. The company name and person's names have been altered for privacy purposes. We will call it X Company which singed on 20\6\1435H an acknowledgment and pledge form in which clause (5) reads "the company shall have in independent department or a position to deal solely with the compliance obligations by 13\1\1436H". SAMA off-site team conducted a supervisory visit on the company's premise on 09\11\1435H, and noticed that the company had assigned a Jordanian national named Mr. CCC to handle the obligations of the compliance officer without requesting SAMA's non- objection form. Note that the company on the acknowledgment and pledge form also pledged to hire two compliance officers in the compliance department before the implementation of the finance companies control law takes effect. On the second supervisory visit to the company's premise on 22\10\1436H, the off-site team noticed that Mr. CCC was Still assigned to handle the obligations of a compliance officer without requesting SAMA's non- objection form.

The company later updated its data of the occupiers of the leadership positions and inserted Mr. CCC as the assigned compliance officer and attached his certified "fit and proper form" to SAMA's license division without obtaining SAMA's non- objection form to his assignment as it is required according to the implementing regulation of the finance companies control law. SAMA sent an official letter number (000) on 18\3\1437H to the company's CEO Mr. BBB requesting a statement to address the justifications of the company's failure to comply with clause (1) of article (42) of the implementing regulation of the finance companies control law and article (5) of the above mentioned acknowledgment and pledge form. On 18\03\1437H, SAMA received a letter from Mr. BBB stating that the company did comply with clause (1) of article (42) of the implementing regulation of the

finance companies control law and clause (5) of the acknowledgment and pledge form because a position to deal solely with the compliance obligations was established since October 2014, and the officer reports directly to the audit committee whose recommendations regarding compliance reports are submitted to the board of directors. He also stated that the separate position to deal solely with the compliance obligations was occupied by an assigned employee who is on probation and does nothing except dealing solely with the compliance obligations since the day of his assignment. Moreover, they are currently considering appointing him full time for the compliance officer's position after a year passes to his assignment.

On 19\03\1437H, Mr. SSS from the internal examination division at SAMA notify the company that SAMA has not yet received a formal request to obtain SAMA's non- objection form to place Mr. CCC on the position of the assigned compliance officer and therefore, the company is in violation of article (1) of the requirements for appointments of senior positions in financial institutions supervised by SAMA.

In the responded letter received from Mr. BBB on 19\03\1437H, he stated that it was an un-intentional mistake the company has made and he promised to take the necessary measurements immediately to fix this un-intentional mistake. On 20\03\1437H, SAMA received a formal request from the company to appoint Mr. CCC Officially to the compliance officer's position.

According to rules and regulation, Article (1) of the Finance Companies Control Law senior management includes: "The managing director, chief executive officer, general manager, their deputies, the chief financial officer and heads of major departments, in addition to risk management, internal audit and compliance officers in the finance company". The requirements for appointments to senior positions in financial institutions supervised by SAMA issued in 1434H states that (Saudi Arabian Monetary Agency, 1434H).

- Clause (9) Candidates for senior positions shall not assume the charge of their respective roles until receipt of a written non-objection from SAMA.
- Clause (11) The financial institution is required to obtain SAMA's written non-objection prior to reassigning responsibilities of a senior position to any of its employees for a period exceeding (30) days, provided that the period of such reassignment does not exceed (6) months which can be renewed for another period after SAMA's approval.

Article (41) of the Regulation of the Finance Companies Control Law "The finance company shall comply with applicable laws, regulations and instructions and shall take necessary measures and controls to prevent violations."

Article (45) of the Regulation of the Finance Companies Control Law "The compliance department must have staff and resources commensurate with the business model and size of the finance company. Compliance employees shall report solely to the compliance officer."

Article (76) of the Regulation of the Finance Companies Control Law "A violation of the provisions of the Law and Regulation or non-compliance with any of the rules or instructions issued by SAMA shall be deemed a professional misconduct".

The following section discusses whether the board of directors fulfill their responsibilities by adhering to corporate governance rules of appointing senior executives and if not what corrective actions are done by Saudi Arabia Monetary Agency (SAMA) in order to address the violation to corporate governance principles as addressed in Finance Companies Control Law.

4. Discussion

Board of directors is the cornerstone in effective corporate governance. Efficient roles and responsibilities for the board with commitment to comply with rules and regulation can help in creating value and protect interests of stakeholders. The position of compliance officer is a senior management position that is considered to be one of the leadership roles in financial companies as it was articulated in the definitions section in the first article of the Finance Companies Control Law. Assigning Mr. CCC to handle the obligations of the compliance officer required from the company an obtainment of a written non-objection from SAMA as the requirements for appointments to senior positions in financial institutions. Also, the requirement number (11) of this same regulations stated" The Financial Institution is required to obtain SAMA's written non-objection prior to reassigning responsibilities of a senior position to any of its employees for a period exceeding (30) days, provided that the period of such reassignment does not exceed (6) months which can be renewed for another period after SAMA's approval" (Saudi Arabian Monetary Agency, 1434H).

Moreover, the company's CEO in his letter received on 18\03\1437H confessed that the duties and obligations of

this senior management position was assigned to Mr. CCC since 28\10\1437H up until the present date, a period exceeds a year and four months. In addition, the company made no effort what so ever to obtain SAMA's written non-objection form prior to assigning the responsibilities of the compliance officer position to Mr. CCC or during his assignment, and when the company was notified by the enteral examination division at SAMA that SAMA has not yet received a formal request to obtain SAMA's non- objection form to assign Mr. CCC, it simply justified that it was an unintentional mistake.

Therefore, it was a negligence from the company's side as its duty is to obtain SAMA's non- objection form prior exceeding the permissible period which is 30 days. The company's negligence is deemed as a failure to comply with the requirements for appointments to senior positions in financial institutions, and also it appears that the company failed to comply with clause (11) from three other aspects:

- Assigning Mr. CCC for a period more than the permissible one.
- Not obtaining SAMA's non- objection form to extend the assignment to another six months before the end of the first six months.
- Exceeding the maximum permissible period without officially appoint him in charge as the compliance officer or occupying the position with another qualified candidate.

Furthermore, the company's justification that it did comply with what it pledged for by assigning Mr. CCC as the compliance officer is not accepted because what pledged for was not assigning one officer to handle the duties and responsibilities of the compliance, rather establishing a compliance department and appointing two officers in it by 13\1\1436H. In addition, Article (45) of the Finance Companies Control Law stated "The compliance department must have staff and resources commensurate with the business model and size of the finance company", and on 20\12\1435H, an agreement was reached on the board of directors' meeting which highlighted the importance of hiring another compliance officer to help out Mr. CCC. Hence, the agreement indicates that the company' size and business model requires at least two compliance officers to handle the duties and responsibilities of the compliance department, yet the company did not nominate any candidate to take the charge of the compliance role. Thus, exceeding the specified permissible period without honoring its pledge is a violation of articles (42-45) of the implementing regulation of the Finance Companies Control Law. Because the compliance officer position is not yet occupied by an official one as a request was received on 29\05\1435H from the company to change its former request of appointing Mr. CCC to the compliance officer's position into extending his assignment as a compliance officer, then, consequently, that is considered as failure to comply with the legal requirements and a violation of article (41) of the Finance Companies Control Law which states" The finance company shall comply with applicable laws, regulations and instructions and shall take necessary measures and controls to prevent violations."

The accusations of X company have been affirmed for committing a violation of article (42-45) of the regulation of the Finance Companies Control Law, and a violation of clause (9-11) of the requirements for appointments to senior positions in financial institutions supervised by SAMA. Also, because X company has yet not requested to obtain SAMA's non- objection form to assign or appoint a compliance officer since it was licensed to operate until 20\03\1437H, despite it was notified twice in the supervisory visits is deemed a failure to comply with the legal requirements, and as a result, the enforcement division are to factor that for an appropriate measurement to be executed against the company. Therefore, the company's undertakings mentioned-above are deemed professional misconducts in accordance with article (76) of the regulations of the Finance Companies Control Law issued by SAMA and a professional misconduct violating corporate governance rules.

5. Conclusion

Sustainable accountability of senior management nowadays, especially with the recent collapses of companies who appeared giant and efficient while actually they were fragile, is necessary. It is essential to design a system of governance, in which it will be easily to the board of directors to monitor and ensure managers are fulfilling their responsibilities. Also, board of directors should control the process of appointing executives and assessing their actions. But designing a system, without a regulatory body acting as a disciplinary power for organizations actions, will be worthless. In Saudi Arabia, Saudi Arabian Monetary Agency (SAMA) role is important and it should be strengthen with suitable economic resources and professional expertise to help in organizing the financial market. The benefits of applying good corporate governance rules for encouraging investment and stock market development are crucial in order to improve macroeconomic growth.

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Enron of Saudi Arabia: Corporate Accounting and Auditing Failures

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Abstract

Accounting and auditing failures are still a hot topic despite strong efforts for efficient corporate governance. The motives and attitudes behind decisions and events leading to Enron's eventual downfall appear to be simple. It is individual and collective greed born in an atmosphere of market loose of regulation. The financial results of the company were too good to be true and no sound was heard to criticize the company albeit very few opinions. It was a network to deceive stakeholders. Saudi Arabia government has sought to change its oil-based economy into a modern diversified economy with a more trend towards privatization consistent with 2030 vision "a vibrant society, a thriving economy and an ambitious nation" and in this situation an effective, transparent, accountable, enabling and high-performing government and corporations are an essential pillar for success in order to advance economy including stock market. Corporate governance is intended to increase accountability of corporations and to avoid problems before they occur. An accounting scandal at one of Saudi Arabia's largest telecommunications companies is posing pressure on regulators, as Saudi Arabia moves to open up the Arab world's largest stock market to foreign investors. The Capital Market Regulator in Saudi Arabia banned Deloitte's firm (Bakr Abulkhair & Co.) from auditing public companies as of June 1st, 2015, on account of its work for the targeted loss-making company MMG (Mohammad Al Mojil Group). Another scandal in Saudi Arabia is Etihad Etisalat, known as (Mobily), as company's audit committee pointed in their perspective to accounting errors that decreased about $380 million in previous profits. The aim of this research is to explore what went wrong and the violations of corporate governance rules by highlighting corporate accounting and auditing scandals in MMG (Mohammad Al Mojil Group) and Etihad Etisalat, known as (Mobily). Although what happened at Enron is very well known worldwide, the corporate accounting and auditing failures in the case of Saudi Arabia is unprecedented territory of research.

Keywords

Corporate Governance, Accounting and Auditing Failures, Saudi Arabia

1. Introduction

Most studies about corporate failure are based on companies in western economics with well-established and solid financial infrastructure and despite this still misleading financial numbers are presented and stakeholders are left duped. It seems that the problem of corporate accounting and auditing fraud is increasing in intense and allover regions from Satyam (India) to Toshiba (Japan) just mentioning a few. Fraud can be seen as a deception or misrepresentation of financial numbers with and intention to make benefits. It involves different levels in organizations.

This study is different as it is going to explore corporate accounting and auditing scandals in other contexts than western economics which is Saudi Arabia. MMG (Mohammad Al Mojil Group) and Etihad Etisalat, known as (Mobily), are the concern of this study with their auditors and financial advisors. The collapses of Enron, WorldCom, Parmalat at the beginnings of the 21st century and recently Volkswagen and Toshiba scandals of 2015 shed lights about the applications of corporate governance rules and whether accounting is a tool for decision making that help investors or it is enhancing greed of management by presenting misleading financial numbers. Many participants contributed to financial scandals, it is not a responsibility of one party only. Accountants, auditors, management, regulators and banks are all contributed to the recipe of failure. It was a synergetic corruption where every party plays his role and enjoys the benefits. The concern here is to highlight what went wrong as well as lessons to be learned in Saudi Arabia in order to prevent such crises from happening in the future.

In today's world, business is connected. The slow-down in economic development in developed countries can lead the global economy to recession. The effects of misleading financial information are tremendous. Fraudulent financial information can impact users of financial information to make wrong financial decisions. Mathisen and Foley (2006: p. 5) state [1]:

> The devastating results of Enron improprieties affected employees' jobs, retirement funds as well as complete destruction of share values. Subsequently, the former Treasurer, Ben Glisan, pled guilty to criminal conspiracy and for which he received a prison sentence (Enron, 2006). Mr. Fastow, CFO, also pled guild to "fraud, money-laundering and conspiracy" for which he received a 10 year prison sentence and was forced to pay $24 million. Roughly twenty other Enron executives have been charged with felonies including Kenneth Lay, former CEO.

Mangers sometimes try to get maximum benefits by presenting false information

related to the financial performance and financial position of companies (ISA, 2011) [2]. Corporate financial scandals have negative impact on the value of organizations that are committing fraud. The drop of Enron Corporation's value from 70 billion dollars to nearly zero is an evident example. In Saudi Arabia, MMG (Mohammad Al Mojil Group) stock was offered in stock market at 20 dollars and few years later it is 30 cent while Etihad Etisalat, known as (Mobily) was nearly 20 dollars in 2012 and it reaches nearly 5.3 dollars on 12th January 2017 (**Figure 1**).

According to the Association of Certified Fraud Examiners (2014) [3], occupational fraud can be classified into three categories: Firstly, asset misappropriations which are related to misuse of organization's resources; Secondly, corruption schemes by employee's to get benefits; Finally, financial statement fraud schemes are those involving the intentional misstatement or omission of material information in the organization's financial reports. Common methods of fraudulent financial statement manipulation include recording revenues which are not existed, decreasing liabilities or expenses and mispresenting reported assets. It states (p. 12, emphasis added) [3]:

> Of the three primary categories of occupational fraud, asset misappropriation is by far the most common, occurring in more than 85% of cases analyzed for this Report; however, it is also typically the least costly of the three types, causing a median loss of $130,000. In contrast, financial statement fraud occurs much less frequently, accounting for 9% of the cases in our latest survey, but it causes the greatest financial impact of the three categories by far, with a median loss of $1 million. Corruption tends to fall in the middle in terms of both frequency and median loss.

Kassem and Higson (2012) [4] criticize Fraud Triangle Theory (pressure, opportunity, and rationalization) and argued for its extension to include all factors that help to understand why fraud occurs such as motivation, opportunity,

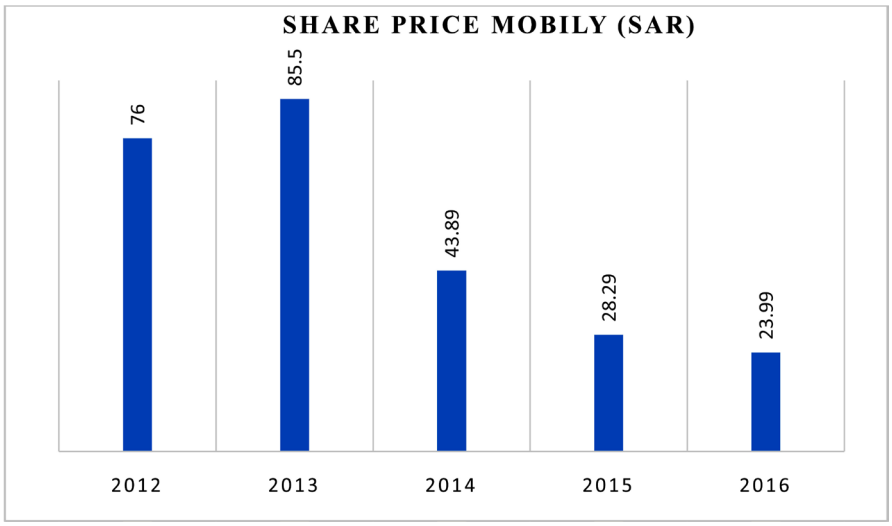

Figure 1. Stock Chart for Mobily Share price 2012-2016.

integrity, and fraudster's capabilities. This model should be called "the New Fraud Triangle Model". External auditors will consider all the necessary factors contributing to the occurrence of fraud. In the same vein, Wolfe and Hermanson (2004) [5] argued for Fraud Diamond Theory in which capabilities of the person committing fraud is very important. He/she capabilities in dealing with stress resulted from committing bad acts is vital in the process. A successful fraudster is an individual who has personality of convincing others to his way and line of thinking the he/she "must look at the auditors, investors, and others right in the eye and convincingly tell them lies. Thus, the fraudster should also possess the skill to keep track of the lies, so that the overall story remains consistent" (Abdullahi and Mansor, 2015: p. 40) [6]. The increasing intense of fraud cases, corporation began to hire forensic accountants to prevent and reduce the issues related to fraud.

The Fraud Theory provides the methodological framework for this study by highlighting real corporate accounting and auditing scandals in MMG (Mohammad Al Mojil Group) and Etihad Etisalat, known as (Mobily) in Saudi Arabia and describe what went wrong in accordance to violations to corporate governance framework. The paper proceeds as follows. Section two is going to explain corporate governance as a cornerstone in protecting stakeholders. Thirdly, accounting and auditing failure in developed countries is going to be highlighted. Fourthly, corporate accounting and auditing failure in some Saudi Arabia corporations is going to be explained. Finally, fifth section is a conclusion for the paper.

2. Corporate Governance as a Cornerstone in Protecting Stakeholders

The topic of corporate governance has received great attention lately due to collapse of popular companies and the question that raises in the media and by academic community is what about less notable firms? Corporate governance is a mechanism through which shareholders are assured that managers will act in their interests. Efficient corporate governance can help to prevent corporate scandals as well as support trust between companies and societies. It enhances image and reputation of a company and makes it more attractive to stakeholders. For investors one of the most important aspects when making an investment decision is level of implementation of corporate governance principles (public disclosure of information, protection of shareholder rights, equal treatment of shareholders) and profitability, which ensures adequate return on their investment (Todorovic, 2013) [7]. The relation between corporate governance and market value of Korean public companies is strong. Black *et al.*, (2003) [8] examined 531 of the 560 companies listed on the Korea Stock Exchange and found a positive correlation between corporate governance index and firm value. In Indonesia, Haryono and Paminto (2015) [9], examined the relation between corporate governance and financial performance and the impact on idiosyncratic

and systematic risk of 44 mining sector companies listed in the Indonesia Stock Exchange in the year period of 2009-2014. Their results clarified that corporate governance has positive significant effect to the financial performance and negative significant effect to the firm risk.

Accounting information is a cornerstone in the functioning of any economy. It should have certain qualities such as objectivity, reliability, relevance, completeness and accuracy. Corporate governance as a framework provides the foundations in managing companies and its relations with stakeholders. It has the potential to minimize conflicting interests between managers and shareholders and improves quality of financial reporting aiming to enhance accountability. Thus, internal and external governance mechanisms are designed to reduce the agency cost. The effectiveness of a board as a corporate governance mechanism depends on its composition, size and role. When the board of directors is independent, it improves companies' financial performance (Ho *et al.*, 2012) [10]. Klai and Omri (2011) [11] conducted a study to assess effectiveness of corporate governance on financial information quality for a sample of Tunisian non-financial companies listed on the Tunis Stock Exchange during the period 1997-2007. Their study clarifies that Tunisian firms are characterized by the lack of the board independence and the high level of ownership concentration which involves a poor quality of financial disclosure. Many companies are characterized by CEO duality. In the same vein in other context which is China, Firth *et al.*, (2007) [12] results find that companies with more independent directors that separate the roles of chairman and executive director have greater earnings informativeness. The board's greater independence is an issue accompanied a higher quality of accounting information.

Al-Twaijry *et al.* (2002) [13] argued through interviews with thirty three non-random sample who are academics, external and internal auditors that the relations between audit committee's members and executives of companies hinder internal control process but expertise is important for effectiveness of corporate governance. Alzeban (2015) [14] examined the effectiveness of audit committees in Saudi Arabia and concluded that a positive correlation exists between level of expertise of members in audit committee including professional expertise and effectiveness of internal control. Companies should hire members in audit committees who have audit and professional expertise.

Managers commit accounting and auditing frauds to hide and window dress true business performance, to preserve personal status, control and to maintain personal income and wealth and in some opinions to preserve their ego. Accountants present financial statements related to their area of responsibility to hide poor performance or to earn bonuses. Organizations try to obtain loans, or managers try to inflate stock prices they plan to sell in a "pump-and-dump" scheme (Kassem and Higson, 2012) [4]. Bhasin (2013) [15] highlighted fraud committed by the founders of Satyam (India) in 2009 which shows the weakness of corporate governance in emerging economics. Satyam Computer Services

Limited was developed as a pioneer in the Indian outsourced IT-services industry. The company was formed in 1987 in Hyderabad (India). It grew from just few people to an icon everybody wants to belong to. It won numerous awards for innovation, governance, and corporate accountability. Ironically, Satyam in the ancient Indian means truth. The company demonstrated an annual compound growth rate of 35% over that period from 2003-2008. Earnings per share similarly grew, from $0.12 to $0.62, at a compound annual growth rate of 40%. He states (p. 30) [15]:

> On January 7, 2009, Mr. Raju disclosed in a letter to Satyam Computers Limited Board of Directors that "he had been manipulating the company's accounting numbers for years". Mr. Raju claimed that he overstated assets on Satyam's balance sheet by $1.47 billion. Nearly $1.04 billion in bank loans and cash that the company claimed to own was non-existent. Satyam also underreported liabilities on its balance sheet. Satyam overstated income nearly every quarter over the course of several years in order to meet analyst expectations … The company's global head of internal audit created fake customer identities and generate fake invoices against their names to inflate revenue.

Ho *et al.*, (2012) [10] examine the effect of changes in corporate governance systems on the financial ratio disclosure practices in Malaysian firms. They found a statistically significant rise in the overall extent of financial ratio disclosure between 2001 and 2006. Alves (2011) [16], conducted a study on a sample of Portuguese companies for the years 2002-2007 and concluded that the ability of managers to manage an organization's reported results is limited by the effectiveness of internal controls, including that of boards. Boards are responsible for monitoring the quality of information contained in financial statements and thus controlling the behavior of managers to ensure that their actions are aligned with the interests of stakeholders. She provides evidence that both managerial ownership and ownership concentration reduce management flexibility in generating abnormal accounting accruals. Her study suggests that despite differences in institutional environments, ownership structure is important to ensure high-quality financial reporting. Also there is less earnings management when operating cash flows are high and that there is more earnings management when political costs, leverage and board size are high.

3. Accounting and Auditing Failure in Developed Countries

Fraudulent financial statement became a habit where every year the public witnessed spectacular business failures. The lost in confidence and trust undermined auditor's credibility and the public accuse accounting and auditing profession. So coupling problems in measuring and communication together with fraudulent financial statement, we will have a recipe of complete disaster. As pointed by Adkins (2009: p. 1) [17]:

> Financial statements manipulation is an ongoing problem in corporate America. Although the Securities and Exchange Commission (SEC) has taken many steps to mitigate this type of corporate malfeasance, the structure of management incentives, the enormous latitude afforded by the Generally Accepted Accounting Principles (GAAP) and the ever-present conflict of interest between the independent auditor and the corporate client continuous to provide the perfect environment for such activity.

One of the most prominent examples of corporate failure is Enron Corporation. Enron Company started in 1985 through the acquisition of InterNorth and Houston Natural Gas companies, which made Enron the leading natural gas pipeline system in the United States. All of a sudden SEC began to be suspicious about Enron valuations of assets and improper accounting practices. Arthur Anderson who was Enron's regular auditor became creative and innovative in dealing with financial numbers and instead of making sure they are true and fair. The company's managers were questioned for presenting misleading accounting information enhanced by their greed. Enron's CFO, Andrew Fastow was at the pivotal point of what appeared to be "off balance sheet liabilities". The results were complete devastation to share value, thousands of employees lost their jobs and retirement benefits and one of the big five accounting and auditing firms vanish in a very short time. Financial markets effected, cost of financing increased and accounting and auditing profession is under fire (Thomas, 2002) [18]. The use of Mark-to-Market accounting or fair value accounting in which companies can evaluate their trading securities and book unrealized gains or losses in the income. Although the technique may works well in trading securities because of the presence of quoted price, in energy and gas industry which is long term contracts the valuation is in doubt. Companies rely in valuation to their best judgment. In order for the company to glory their profits estimates and to please Wall Street fueled by senior manager's greed, the financial numbers instead of being true and fair became the imagination of managers. Instead of focusing on gas operation the company became a speculator with magical accounting tricks. Thanks to the rule of debits and credits. Enron's managers created many special purpose entities to hide debts and to keep leverage ratios normal to get the confidence of credit rating agencies and investors. Enron's Executives were working against the interests of shareholders. Enron favors "mark-to-market" for booking the value of contracts extending out into the future and calculates their value based on current market prices and hence increase profits and please Wall Street. Managers favor their self-interest instead of creating wealth to shareholders (L'Huillier, 2014) [19]. Edelman and Nicholson (2011: p. 3) state [20]:

> With debt still visible, financial analysis' ratings for Enron were lower than the company desired. Andy Fastow, Enron's CFO, led the company in the use of special purpose entities (SPEs) to increase capital and improve Enron's rating. SPEs are partnerships with an outside party that allow the

company to increase its ROA and leverage without required reporting of debt on the company's financial statements. Thus, Fastow was able to hide Enron's debt through approximately 500 SPEs.

On the other side of the Atlantic, Parmalat (Italy) is a prominent example for accounting and auditing fraud. In 2002 Parmalat was the listed holding of a multinational food group made up of more than 200 companies spread around 50 countries. The group was a world leader in the markets of milk, dairy products and beverages. It operated 139 industrial plants and more than 36,000 employees with a consolidated sales revenues 7.6 billion Euros. The company was accumulating debts and markets became suspicious about their transparency and ability to meet debt obligations. It did not comply with Italian Corporate Governance Standards of best practice and it was a "false accounting story" (Melis, 2005: p. 478) [21]. Investigators argued that Parmalat had only one profitable year from 1990 to 2002 despite the company showing profits in their financial statements each year (Roberts *et al.*, 2004: p. 219) [22]. The CEO/Chairman duality hinder corporate governance effectiveness and concentrates power. Deloitte when reviewing financial statements of the company said that they "could not give a "fairness opinion" of the true value of Parmalat's open ended mutual fund Epicurum" (Ferrarini and Giudici, 2005: p. 11) [10]. Duval (2016: p. 1) [23] pointed to the acts of big four companies by stating:

> In 2010, the Public Company Accounting Oversight Board (PCAOB), the US regulator of auditing professions, denounced an increase in errors of the Big Four firms (KPMG, E&Y, PwC and Deloitte) operating in the United States. Deloitte blithely achieved the inconceivable with 45% of copies for review, against 22% in 2009, followed closely by PwC with 39% of audits being unsatisfactory in 2010 (against 12% in 2009). Despite this, undaunted, the four multinationals in consulting and auditing, continued on their way, disdaining the scandals that marked their paths, their eyes riveted on austere accounting statistics and other profitability indicators at the antithesis of sustainable well-being …

Parmalat hide losses, overstate assets especially cash and understate liabilities. It recorded non-existent redemption of bonds. The internal control committee was composed of three members. Two of these members also was members in the executive committee and one was the company chief financial officer. Thus, non-executive directors did not represent the majority of the committee and has no active role. It could be described as having (Ferrarini and Giudici, 2005: p. 12) [24]:

> Questionable accounting and accountants, poor underlying performance, political connections, a dominating shareholder, complex corporate structures and operational mystery. In contrast with other bankrupt firms, however, Parmalat's governance structures did not appear to be well-designed or state-of-the-art.

In Japan, on July 21, 2015, Toshiba's CEO resigned after admitting that the company overstates its profits by approximately $4.1 billion USD between (2012-2015). Despite having four independent directors in the board which is 25% from board members, the misrepresentation of financial statements occurred. Audit committee members include two participants who lack accounting or auditing professional backgrounds and were diplomates (Chikatsu, 2015) [25]. Accounting method called "percentage-of-completion Method", which is commonly used in long-term projects played a role in overstating profits. The accountants lower expenses in early year's periods of future projects. The targeted profit levels that cannot be achieved by employees creates a pressure leads to fraud. Revenues were declining and demand fell for products, thus pressure built up. Internal control system was weak and the culture in the company was a leader follower where managers follow CEO without questioning (Khondaker and Marc, 2016) [26]. Ernst & Young (EY) ShinNihon, a leading audit company was the auditor of Toshiba and they "did not make any note of the anomalies" (Ibid: p. 92) [26]. The misrepresentation continued for seven years until Securities and Exchange Surveillance Commission investigated Toshiba's accounting practices and discovered the misconduct. They State (Ibid: p. 91) [26]:

> The nexus of the problem is that managers exercise their own discretion on whether to recognize these changes in values. Toshiba's managers decided to selectively adjust these changes in value to fraudulently over-report their profits. The discretion given to managers, with the acquiescence of auditors, means that there is a real danger of overstated profits and sales and corresponding understatements of expenses as well as under provisioning for soured contracts and negative adjustments to goodwill.

However, Toshiba scandal is not a single incident in Japan in violating corporate governance principles, for example in 2004 Nikko Cordial Corp. was inflating their profits and providing misleading information. The company issued 50 billion yen in corporate bonds in November 2005, and its fiscal 2004 business report was used to give false explanations about the brokerage's financial condition to prospective investors.

Next section is going explore corporate accounting and auditing scandals in MMG (Mohammad Al Mojil Group) and Etihad Etisalat, known as (Mobily) in Saudi Arabia and violations to corporate governance framework and how this crises effect society.

4. Mohammad Al Mojil Group (MMG) and Etihad Etisalat (Mobily) in Saudi Arabia

The interest in corporate governance has gained prominence in Gulf area and worldwide. Baydoun *et al.* (2013) [27] compare the dimensions of corporate governance in five countries which are Kuwait, Bahrain, the United Arab Emirates, Qatar and Oman. Saudi Arabia were excluded due to unavailability of comparable data. They examine shareholders rights and obligations; internal enterprise

processes, including management structures, reward systems; and transparency. According to their survey the highest country in corporate governance measurement scale is Oman (first country in the region to issue corporate governance standards in 2002) while the lowest country among the five countries is Qatar.

Mohammad Al-Mojil Group (MMG) started his company in Dammam city in the Eastern Region of Saudi Arabia on 1954 and was registered as a sole proprietorship on June 24th. They provide all construction activities and inspection services required for engineering and manufacturing projects. MMG offers certified calibration facilities. MMG is a leading contractor in the oil, gas and petrochemical sector. On 10th November 2007, MMG converted into a joint stock company in accordance with the resolution of the Ministry of Commerce and Industry in order for the company to offer its shares in the stock market in initial public offering (IPO). Revenues of the company grew from SAR 466 million in 2005 to SAR 1995 million in 2007 before the IPO with an increase 328% in just two years. During 2007, Sheikh Mohammad Hamad Al Mojil resolved to transfer the legal structure of Mohammad Al Mojil Company from a sole proprietorship to a Saudi limited liability company and increase the Company's share capital from SAR 4.4 million to SAR one billion from shareholders' current account and retained earnings. The "value of properties were determined through appraisals furnished by independent real estate agents" (MMG, 2008: p. 58) [28]. Property and equipment were increased from SAR 316 Million to SAR 1044 Million from 2005 to 2007 before the IPO with 223 percent increase. According to financial reports issued accompanying prospects for the IPO, the company argued that financial statements were prepared in confirmatory with generally accepted accounting principles and the use of estimates in reporting assets and liabilities. The Accountant's report states "estimates are based on management's best knowledge of current event and actions, actual results ultimately may differ from those estimates" (Ibid, 2008: p. 54) [28]. Deloitte (Bakr Abulkhair & Co) still issued unqualified report stating that financial statements present fairly in all material aspects the financial position of the company.

In 2008, MMG became a publicly traded company and the Founder Mohammad Al-Mojil took the decision to sell a 30% stake in the contractor through IPO. The company paid in capital was SAR one billion divided into 100 million shares with par value of SAR 10 per share and an issuing price SAR 70. The financial advisor was HSBC and the company was reevaluated by SAR seven billion and its financial statements were approved by Deloitte. The founding shareholders collectively own 70% of the share capital post IPO in May 2008. The share paid in capital in excess of par value SAR one billion and eight hundred million based on the 30% offered to the public. Three entities share the underwrite of stocks were made by HSBC Saudi Arabia Limited for 15,000,000 shares, National commercial Bank for 7,500,000 shares and Riyadh Capital for 7,500,000 shares. The following chart clarifies that the company was making profits in the

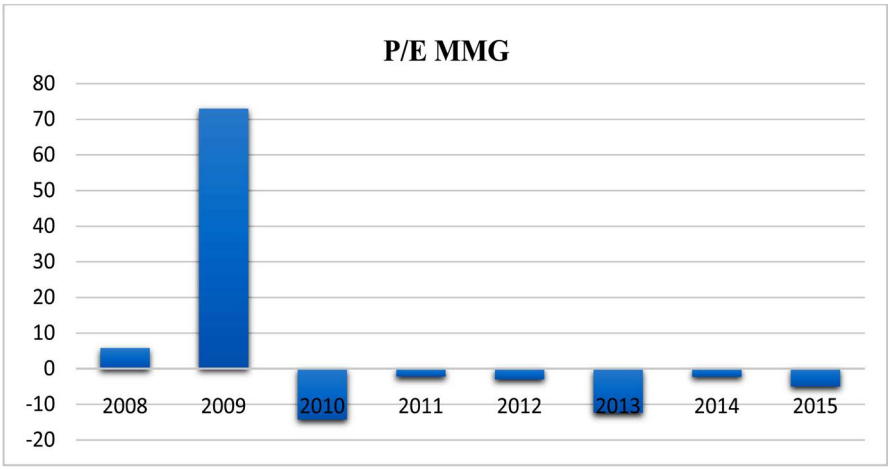

Figure 2. P/E Ratio Mohammad Al Mojil Group (MMG) (Arab Stock Market Analysis).

year following the IPO then it starts making losses from 2010 till 2015. The P/E ratio of MMG witnessed a sharp decline from 2009 till 2015 (Figure 2).

As the firm incurred significant losses in 2013, Capital Market Authority (CMA, hereafter) suspended trading of MMG shares on the Saudi Stock Exchange, Tadawul. Later that year, in conjunction with financial consultancy Protiviti Member Firm (Middle East) Ltd, the Saudi regulator began to investigate MMG's operations and financial reporting for the period 2005 to 2012. Once the investigation was complete, the CMA instructed Protiviti to document its findings in a report, which was delivered on 30 June, 2013. The investigation of the CMA continues its course with former leaders of Deloitte implicated for breach of the rules on the losses accumulated during the certification of the accounts of the Mohammad Al-Mojil Group (MMG), whose shares have been suspended since July 2013 for the presence of huge amounts of debts. KPMG which was appointed as external auditor for MMG group issued a disclaimer opinion on the consolidated financial statements of the company after losses exceed 75% of its capital and a negative working capital SAR 1.5 billion and made doubts that the company is going concern. According to CMA regulation for public listed companies, shareholders have to vote for the continuity of the company when losses exceed 75% of capital and the decision was to continue (MMG, 2012) [28]. Actually Sheikh Mohammad Hamad Al Mojil and family members owns more than 50% of the company and the vote was a big failure. CMA Board has issued its resolution Number (4-48-2013) Dated 18/11/2013 for listed Companies with Accumulated Losses reaching %50 or more of its Capital. These instructions should be effective 1/7/2014. The purpose of the instructions and procedures is to regulate the mechanism for dealing with a company whose shares are listed in the stock market when its accumulated losses reach 50% or more of its capital (Saudi Stock Exchange, 2013) [29]. In my opinion it is too long to wait for nearly seven months to deal with the situation and already stakeholders are duped and losing their fortune. Also companies are allowed to trade over the counter for two full financial years when accumulated losses reach 100% or more. The Equity

Figure 3. Shareholders Equity MMG 2011-2014.

of MMG reaches negative 2 billion Saudi riyals by 2014 (**Figure 3**).

MMG recognized revenues according to percentage of completion method. The company audit report prepared by KPMG admitted that its losses should increase in 2011 due to error of estimation by SAR 150 million to reach SAR 1.1247 billion. Unbilled revenues has to be restated and a decrease in assets due to error in revenue recognition. Write off accounts receivable for 2011 by SAR 289 million which represents almost 85.8% of the balance of receivables. Impairment losses due to re-measurement of property plant and equipment by SAR 135.1 million. The company violates its long term financing covenant with local commercial bank amounted SAR 169.8 million. KPMG cast doubts about the uncertainties surrounding the company and its ability to continue operation (MMG, 2012) [28].

The cumulative loss of MMG at the end of October 2014 amounted to 2.79 billion riyals, equivalent to 223% of its capital, according to the current stock exchange of November 13, 2014 (Duval, 2016) (MMG, 2012) [28]. Initial reports suggested that the Committee for the Resolution of Securities Disputes had banned Deloitte from providing auditing services in the kingdom for a period of two years for companies listed in Saudi Stock Market. The Capital Market Authority on a letter dated 11th of November 2014 to listed companies in Saudi Stock Market confirmed the "banning of Deloitte Saudi Arabia and two of the partners from legal accounting duties to any company listed or planned to be listed from 1st of June, 2015 until the MMG case is settled" (Capital Market Authority, 2014: p. 1) [30]. On 18 November, 2014, the CMA issued a charge sheet containing allegations against Mohammad Al-Mojil, his son Adel Al-Mojil, and others, in relation to MMG's IPO and CMA accused the company for guilty of manipulation and fraud relating to the MMG's initial public share offer in 2008. Mohammad and Adel Al-Mojil were each sentenced to five years' imprisonment for misrepresenting MMG's value. A third unnamed executive from the contractor received a three-year prison sentence, according to news agency, Reuters. Deloitte & Touche Bakr Abulkhair & Co, the Saudi Arabia arm of Deloitte Touche Tohmatsu Ltd, also came under fire, owing to its historic work with

MMG (MMG, 2012) [28].

According to Jones and Patrick (2015) [31], CMA in September 2015 suspended the HSBC unit (SABB, Saudi Arabia) from conducting some asset-management activities and is investigating whether it inflated the valuation of a construction firm's listing in 2008. SABB in Saudi Arabia began "to restructure its board and governance committees, and has hired new management at the division, according to Majed Najm, Chief Executive of HSBC Saudi Arabia. "The result of the reforms is a stronger, better managed business," (Ibid: p. 1) [32].

On 16 June, 2016, the Committee for the Resolution of Securities Disputes – part of Saudi Arabia's Capital Market Authority (CMA) penalized the local arm of US-headquartered Deloitte Touche Tohmatsu for its involvement in the case (Everington, 2016) [32]. The committee pointed that there is a misrepresenting in MMG's value. MMG was ordered to pay SAR 1.6 billion for illegal profits and imposed a separate fine of 2.7 million riyals. On 19th of June 2016 the board announces their resignation with a need to elect new board to run the company. According to Argaam after resignation of old board the founder Mohammed Al Mojil, didn't show up for a meeting to elect five board members and shareholders' spokesman Shakhbout Al-Dosari who were appointed as CEO for the company in 2016 and resigned in less than two months asked for the need to (2016: p. 1, emphasis added) [32]:

> Identify the person responsible for misleading investors, in the latest in the verbal war between the company and its shareholders…... Shareholders are in trouble situation because of the pre-IPO release approved by MMG, he added. Investors who bought stocks in the market didn't make decision based on rumors, but based on misleading financial information from the company. "We, as shareholders, had been deceived by the IPO's subscribers and traders until the company was suspended from trading".

Another accounting and auditing failure with tremendous impact on investors is Mobily Saudi Arabia's which is second largest telecommunications operator. The case Etihad Etisalat (Mobily) in Saudi Arabia is equivalent to what happened in MMG but the difference is that it is still operating and listed in Saudi Stock Exchange. It is a joint stock company started operation in 2005 and from 2006 the company began to show profits. Although the company belongs to telecommunication industry which requires huge investments and intensive capital and in its financial statement profits are increasing gradually after inception. During 2008 its profits increased 52% compared to 2007. Mobily stock is usually outperforming the Saudi Stock Market during the last years of the first decade in 21st century and through first half of second decade. In 2015 annual report of Mobily states that "Mobily faced difficulty related to accounting issue, which led to the restatement of its financial statements" (Annual Report Mobily, 2015: p. 14) [33]. Company in 2014 began to have negative working capital by nearly fifteen billion SAR and huge losses with mountains of debts. It "breached a certain financial covenant under its long-term financing facilities" (Ibid, 2015: p. 48)

[33]. The return on assets in 2015 was −2.58% and return on equity −7.03%. The EPS of the company decreased dramatically after restating financial statements (Ibid, 2015) [33]. Mobily fired Khalid al-Kaf as chief executive, and select his deputy, in temporary charge while the company's audit committee pointed to accounting errors that decreased about $380 m in previous profits. The capital markets authority in Saudi Arabia opened up an investigation into the accounting errors to determine whether the company violated the stock market's rules and announced more than one person was suspected of violating regulations on insider trading. Martin and Almashabi (2015: p. 1) state [34]:

> Abdulaziz Alsaghyir Commercial Investment, of which Alsaghyir is founder and chairman, last year sold about two-thirds of its stake in Mobily, Alsaghyir resigned as chairman due to health reasons …. Mobily has lost about $9 billion of its market value since the accounting errors were discovered four months ago. The Capital Market Authority is probing the company for suspected violations of rules related to the disclosure of financial information, market manipulation and insider trading. Its Chief Executive Officer Khalid Al Kaf left the company last month.

Mobily reported a sharp decline in profits in the third quarter 2014 and restated earnings through 2013. Restatement of income from a loyalty program since 2013 amounted to SAR 1.42 billion. Watfa (2015: p. 1) [35] pointed to irregularities done by Mobily and the responsibility of management and external auditor Deloitte Saudi Arabia:

> It seems that the company reported revenues on contracts that were yet to mature. These are the contracts in which future installments are recognized by the company in full value upfront as revenue. Obviously in accounting this is a big NO-NO as you only report revenues once the service has been delivered not contracted, especially when there are opt-outs in the contracts. You cannot treat Operating leases as Capital leases simply because ownership will shift at the end of a contract. I guess with so many bonuses at stake (CEO reportedly earned on average SAR 30 million every year).

Mobily appointed KPMG as an auditor in 2015 and Mr. Suliman bin Abdulrahman Al Gwaiz became Chairman of the Board who is also Chairman of Bank Saudi Fransi and Governor of the General Organization for Social Insurance (GOSI)!!!!. Mr. Al Gwaiz in addressing stakeholders in Mobily Annual Report (2015: p. 16) states [33]:

> Further reorganization of Mobily's corporate governance framework will ensure clearer policies and responsibilities for the future, and better define the rules by which the Company is managed. We have begun the process of instilling a culture of transparency across all departments, and are of the view that this culture should originate at the top. We look forward to playing a key role in a new chapter in the Company's continuing development.

Mr. Ahmad Farroukh was appointed as CEO for the company in July 2015 and resigned in 9th of January 2017 although he has strong and successful experience in KPMG, Deloitte and was working previously in auditing and financial control but it seems problems in the company are tremendous. On 20th of December 2016, CFO of Mobily announced that the company got two billion SAR from Alinma Bank without any guarantees and company debts are sixteen billions and all of it without any guarantees although the company revenues is decreasing. The new debentures 10-year loan facility from Alinma Bank will help the company's liquidity situation and meant to regain confidence with banks. The company is suffering from high debt ratio as well sharp decline in earnings per share (Figure 4, Figure 5).

On 23rd of December 2016, the management deal between Etisalat United Arab Emirates was not renewed and it was major shareholder. This pulling of Etisalat Holdings from Saudi Arabia will have impact on Mobily in 2017 (Wood, 2017) [36].

5. Conclusion

Strengthening corporate governance as well as more restriction to managers will help in regaining confidence of stakeholders. Underneath any corporate accounting and auditing scandals we have greed managers, an auditing office sharing the benefits and loose regulations. Corporate governance is intended to

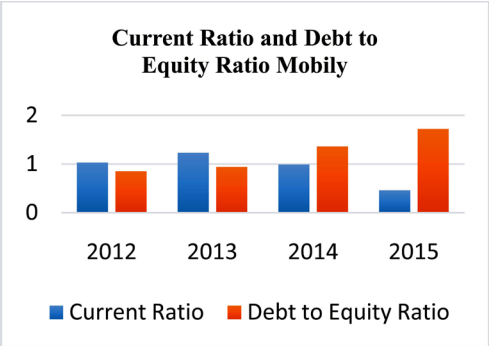

Figure 4. Current and debt to equity ratio.

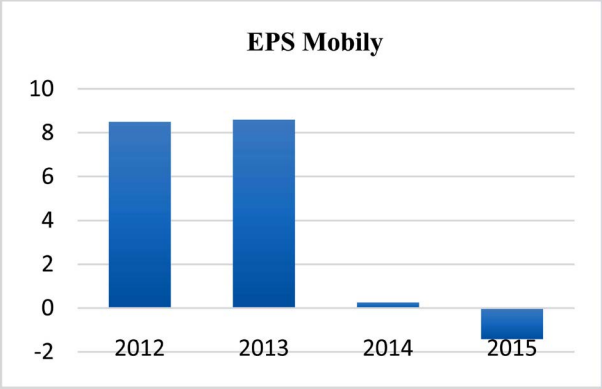

Figure 5. EPS Mobily.

increase accountability of corporations and to avoid problems before they occur. Chief executive officers and chief financial officers must be responsible and liable for any losses occurred according to false information presented to stakeholders. Delaying of authorities in KSA in taking corrective actions with accused companies and auditing offices will not help markets to regain confidence. Transparency is essential to maintain trust as essential pillar for business success. Auditors who were supposed to act as watchdogs did not bark when they are supposed to do. Auditing companies in Saudi Arabia must be suspended for number of years and jail penalty should be legalized for approving false financial statements. Banks asset evaluation departments should not be involved by any means when banks are underwriting stocks for IPOs. There must be complete overhauling of corporate governance rules in order for presenting true and representative information for the financial performance and position of companies otherwise we will witnessed more Enron's in Saudi Arabia.

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Impact of Social Media and its Influence on Purchasing Behaviour of Saudi Consumers: An Empirical Study

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Abstract: Social networks have inspired millions of users around the world. Besides, this new means of communication win consumers' trust by communicating with them at a deeper level. As local and international marketing companies have recognized social networking as a potential marketing platform and have used innovations to drive advertising campaigns and marketing approaches through social networks. One cannot stand on the lack of social media channel now that their counterparts have waves of products and services on the market. Despite the proliferation of social networks and the widespread dissemination of different communication tools, very few studies in the Arab region describe the objectives of the current study. The rationale for this article is to explore the mechanism and determinants of these media and factors that affect the purchasing behaviour of the Saudi consumer. Throughout Sample of 226 via Google forms and monkey survey (online) using close-ended questionnaire with handling particular attention to reducing non-response error was given in the study. For descriptive analysis (frequency distribution statistics), the hypothesis test Chi-square goodness of fitness test at P. Value 0.05 was applied, and the results were interpreted accordingly in the study. It is found that there is variance among the respondents in time duration spent on social media and purchasing preferences within the social media platform.

Keywords: Social Media, User Perceptions, Marketing Communication, Consumer Attitudes, Consumer Behavior, Shopper Insight, Saudi Arabia

1. Introduction

The wave of social networks has changed the way of communicating and interacting with consumers. This because social networks allow people from all over the world to interact and exchange products and brands information with each other (Mir & Zaher, 2012). In recent years, social networks such as Facebook, Twitter and Instagram have become an essential development in e-commerce. Besides, the growth of social networks is apparent and shows no sign of disconnection or relapse (Jaber & Wright, 2014).

According to Kaplan and Henlin (2010), social networking is a term that can be represented as a set of Web applications and Web 2.0 technologies that allow users to create modify and generate content. In fact, social networks have become an essential part of our daily lives (Kaplan et al., 2012). In addition, in the technology-driven world today, such as social networking sites have become a way for retailers to expand their marketing campaigns to a wide range of consumers.

Users of social networks can easily exchange information about products. At the same time, consumers can also "consult with the social community to seek advice on purchasing decisions. Through social communities, consumers can influence purchasing decisions in much more substantial populations (Liang and Turban, 2011); social trade has the potential to become a significant sales channel in the future (Pricewaterhouse Coopers, 2013). Social trade is, therefore, a phenomenon when the interaction between social networks and e-commerce is of global importance to non-market participants,

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namely markets, companies and researchers (Wang and Zhang, 2012).

On the other hand, it was noted that the number of Internet users is growing significantly more than 3 billion users estimated worldwide (Internet Statistics, 2014). Moreover, in the same time in Saudi Arabia, the Internet users have the record of the second largest region in the Middle East; it is about 66% in Saudi Arabia (Internet Statistics, 2014). Other statistics revealed by the Ministry of Communications and Information Technology in Saudi Arabia Saudi Arabia that there are higher than 7.6 million Facebook users, more than 5 million Twitter users, more than one million LinkedIn users and more than 290 million daily visits on YouTube (Http://www.mcit.gov.sa/). Saudi Arabia people spend an average of about 8 hours a day on various networking sites, and social networks have become part of everyday life for most Saudis, according to all of these statistics to the high prevalence of the internet, social media and other media in Saudi Arabia. With more and more convenient to use social networking, communication and communication methods are complementary. Communication between companies and other consumers may also be affected (Lee and Kim, 2014; Al-Qeisi, K., Dennis, C., Hegazy, A., & Abbad, M, 2015).

Although social networking in Saudi Arabia is among one of the highest numbers, use in the world, but we do not find vital research to explain the reasons for user acceptance and impact and the impact of social media in this segment. Preserving the mind that increases the use of social networks by Saudis, primarily by young people, the rationale for this article is to explore the mechanism and determinants of these media and factors that affect the purchasing behaviour of the Saudi consumer throughout.

2. Objectives of the Study

1. To understand the time duration spent on social media among the respondents 2.
2. To know the purpose involvement on of social media
3. To identify the purchasing preferences through social media among the respondents
4. To find out the types of product buying preferences through social media among the respondents
5. To explore the influences of social media campaign on consumer buying behaviour
6. To know the behaviour of consumer regarding advertisements on social media

3. Literature Review

3.1. Social Media/ Networks

The development of the Internet use has a new communications platform, known as social networks, where users post comments and blogs, create their videos and images and publish them in various social accounts. Kaplan and Henlin (2010), define social media as a “The Internet, which is based on the ideological and technological network 2.0, which allows creating and sharing content created by users. According to the Miriam Webster Dictionary (2017), social networking" forms of electronic communications (such as social networks and microblogging) Users create online forums to share information, ideas, personal messages, and other content (videos). Another definition is that social networks are a set of "creating and sharing content or engaging in social networks" (Oxford Dictionary, 2017).
Cavazza (2008) noted that social networking marketing refers to the tools and practices used to identify and analyses conversations about participation, to initiate social interactions within communities and then consumers. Social networks include many online technology tools that allow people to communicate quickly through the Internet and share information and resources (Ralph, M, Ralph, L., 2013).

Gillin (2007) revealed that social networks had become a new phenomenon, a new source of consumers and their influence and creativity; this training for consumers is to make the old pattern of marketing decline from the traditional media steadily with the behaviour of the influential

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consumer (Constantinides et al., 2008). In addition, the most critical innovation in marketing is perhaps Internet access (Bhatnagar & Ghose 2004).

3.2. Social Media Usability and Involvement

Social contacts have revolutionized the way people communicate and maintain relationships. Social networks should begin to influence what consumers buy and how to buy (Booz & Company, 2011). It was revealed that social media has indeed done a commendable job of bridging the communication gap among people. Moreover, the different social media tools help the people to interact with one another within the shortest possible time (*Alam Z M., 2017*). In addition, with the development of Internet use; buyers have changed the shopping experience in the store to experience the Internet, leading to so-called e-commerce. In other words, social networks allow participants to communicate with each other and create a society in which they can interact with each other and the exchange of ideas and knowledge. The socialization that occurs with the consumer through social networks directly through the interactions of social life among consumers, and indirectly through support for product participation (Wang et al., 2012).

3.3. Time Spent on Social Networks

The online users spent average time on networks are around 25% of the total time spent (http://infographiclist.com/2013/03/14/time-spent-statistics-infographic-2). People have been spending more time online, especially in social networking, than "off-line" activities. In fact, Facebook has overtaken Google as the most visited site of the week (Dougherty, 2010). Another fact that contributes to the increase over time is the use of mobile devices that connect users at any time anywhere (The Nielsen Company State of the Media: The Social Media Report, 2012). A recent study by Duggan and Brenner (2013) found that 89 percent of Internet users spent nearly three hours a day on social networking sites on Facebook to communicate with friends. In the same study, nearly 76% of respondents (Internet users) revealed that for information about products and services; spend about four hours on social networks.

3.4. Advertisements on Social Media

Social networking platforms such as Facebook, Twitter, Instagram, YouTube and other activities have begun to transform business activities such as marketing, advertising and promotion (Hanna, Rohm, & Crittenden, 2011). Moreover, it was indicated in the study that the most preferred medium of communication to promote the products are social media, followed by emails communication, television commercial and SMS by the consumer (*Alam Z M, 2017a*). In fact, social ads can be more effective than traditional ads. According to a survey conducted by Nielsen (2012), after watching social ads on Facebook, 15% of users share ads, 26% liked advertising, and 14% bought the product. Besides, 90% of consumers trust their peers' recommendations, compared with just 14% who rely on corporate recommendations. In this way, the online program has become a powerful tool for increasing brand awareness and corporate benefit (Bazaar Voices, 2012).

Several studies have indicated that the social impact has a significant impact on the behaviour of intent or use. According to Alkhunaizan and Love (2012), social influence has a significant impact on the intention to conduct e-commerce in Saudi Arabia.

It is interesting to note that social networking means and sources increasing consumer interest through social networking sites (Goyal, 2013). The study found that users who are members of groups on Facebook are more likely to disclose their personal information than non-members are. Chu (2011) points out that sharing and sharing with online advertising requires a higher level of personal information as users publicly disclose their links to Facebook groups and promote brands or products when passing ads to their friends. Chu (2011) also discovered that users who are members of the Facebook group maintain a more favourable attitude towards social networks and advertising. About 26% of users are likely to notice an ad posted by a user in social networks, and 17% feel more connected to the brand displayed on social networking sites. (Nielsen, 2012)

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3.5. Social Media and Purchase Intention/ Behavior

Social networks can directly affect the procurement phase, according to a survey by Booz and Company, (2011) consumers who spend at least one hour per month on social networks and who have bought at least one product online. In addition, Social commerce is a new trend in e-commerce, encouraging social interaction of consumers through social networks (Hajli 2013). Social networking provides opportunities for companies to become more attractive in the world (Chen et al. 2011b).

3.6. Social Media and Consumer Decision Making

According to the previously studied, consumers trust the Internet not only in the search for information relating to goods and services or are sold, but also to have access to social networking sites for the same purpose (Gatautis & Medziausiene, 2014). It motivates consumers to participate in the knowledge of social networks in consumer activities. Consumers have three main incentives or motivations to use the Internet as a means of communication, entertainment and social aspects (Heinonen, 2011). When making a purchasing decision, social influence plays an important role. Once a customer has identified a list of required features, he can use those products to begin searching for the right product. However, browsing, researching and buying a product on e-commerce sites is often a frustrating and time-consuming task for consumers. More than 80% of online shoppers have at some point left e-commerce sites without finding what they want (Silverman et al., 2001).

Social networking sites have an excellent reputation around the world, to realise the potential of these e-commerce technologies, and companies try to identify ways to combine the power of social networking sites with new e-commerce opportunities (Shen & Eder 2012). Facebook has enormous potential to be the most popular social networking site and more Facebook businesses and publications in marketing and business strategies. In addition, retail sales driven by social networks are the fastest growth compared to any other online counterpart. According to a report from the online retailer (2015), the top 500 retailers received $ 3.3 billion in 2014 of social purchases, an increase of 26% over the previous year. In addition, a report by Business Insider (2015) found that social networks drive retail sales faster than any other online medium. A new form of e-commerce and social commerce (Kim & Park 2013) that support social interaction and consumer input to buy and sell products and services (Shen & Eder 2009) social media affect customers before, during and after purchase (Ickler, Schülke, et al., 2009).

3.7. Social Media in Saudi Arabia

Social networks have become the preferred communication channel between companies and consumers in Saudi Arabia. Social networks in Saudi Arabia are top-rated, especially among young people (Makki & Chang, 2015), and 18-35, representing 75.7% of the total population in Saudi Arabia (Makki & Chang, 2015). The rapid growth of online shopping, some retailers that sell goods and services online and it became the primary channel to expand the market locally and internationally *(Alam Z M. and Elaasi, 2016*). Besides, the use of mobile phones among the population of Saudi Arabia is around 95% (Alsenaidy and Ahmad, 2010). 87% of children have mobile phones and more than 80% at the age of 10 (GSMA, 2016). The availability of smartphones and shared connectivity to the Internet has increased public participation in social networking sites and applications in Saudi Arabia. One of the most popular social media platforms in Saudi Arabia is Facebook, Instagram, Twitter and YouTube (Faraj, 2014). A survey conducted in 2015 revealed that average social networking users in Saudi Arabia spent more time on social networking sites than the global average of the user based on data collected from 33 countries (Globalwebindex, Saudi Arabia Market Report - Q1, 2015).

This study also showed that Facebook is the most widely used social media platform in Saudi Arabia, followed by Twitter, YouTube and Instagram (Globalwebindex, Saudi Arabia Market Report - Q1, 2015). Social networking platforms in Saudi Arabia offer a wide range of

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purposes. Connect with family, relatives and friends, connect with new friends, communicate, entertain and access information, services and marketing products (Reyaee & Ahmed, 2015). Recently, companies and businesses marketing their products and services in Saudi Arabia and Saudi Arabia (Faraj, 2014) are increasingly using social networking platforms. A study conducted by Faraj on the involvement of food companies in Saudi Arabia with social networks shows that the main obstacle to the use of social networks in food marketing is the lack of marketing strategies for communication platforms (Faraj, 2014). It is the "door to reach the factor" through which people can communicate with people from all over the world (Social Media in Saudi Arabia Statistics and Trends, 2016). Social networks are actively competing with traditional media as the primary source of news for millions of Arabs (Arab Social Media Outlook 2014). Social networks were formerly used as a tool for social networks and entertainment, and now permeate almost every aspect of everyday life for millions of Arabs, affecting their social interaction, doing business, interacting with government, and engaging in community activities (Al Jenaibi, B.N.A. 2011).

According to the Saudi newspaper, a recent study on social networks in the Arab world has been published. In this report, Saudis are the most active users of social networks in the Arab region, with an estimated 393,000 Twitter users and 4 million users. Fatany, (2012) revealed that Saudis are among the most prolific users on Facebook and Twitter, benefiting from the independence and freedoms offered through social networks. Many Saudis around the world use social networking with joy. Also, The Committee of Technical and Communications in Saudi Arabia revealed in the study that navigation and communication with others were the main reasons for Internet use In the Kingdom, while the educational reasons ranked fifth (CITC, 2012).

3.8. The Research Rationale

Through the different studies, we found that customer satisfaction, attitude, and preferences are the essential factors to achieve business objectives. Marketers, in recent time, are trying to develop a new communication and promotional strategies to fulfil the needs of the consumers with the latest approach. Although, much research has been undertaken to determine the success and strengthen of consumers' perception and its evolving factors these days. Notwithstanding, the implementation of many of research as well as around the world and inside the region towards the consumer use perception of social media. There is still a call for to identify and measure the preferences, perceptions, attitudes of the consumers and its success factors to achieve the goals of business because of the area of consumer behaviour always changeable. In fact, there is always a need for research on attitudes' analysis of users, their preferences and using habits of social media in the literature, as it does not cover in depth. Therefore, the current study is the attempt of this direction.

4. Hypothesis

The following hypothesis Null (Ho) had been assumed for the analysis.

1. There are no significant differences in time duration spent on social media among the respondents
2. There is no difference in opinion regarding the purchasing preferences through social media among the respondents
3. There is no difference in the types of product buying preferences through social media among the respondents
4. There are no differences in opinion about the changes of attitude regarding the brand image through social media
5. There are no differences in opinion among the respondents about the advertisement on social media

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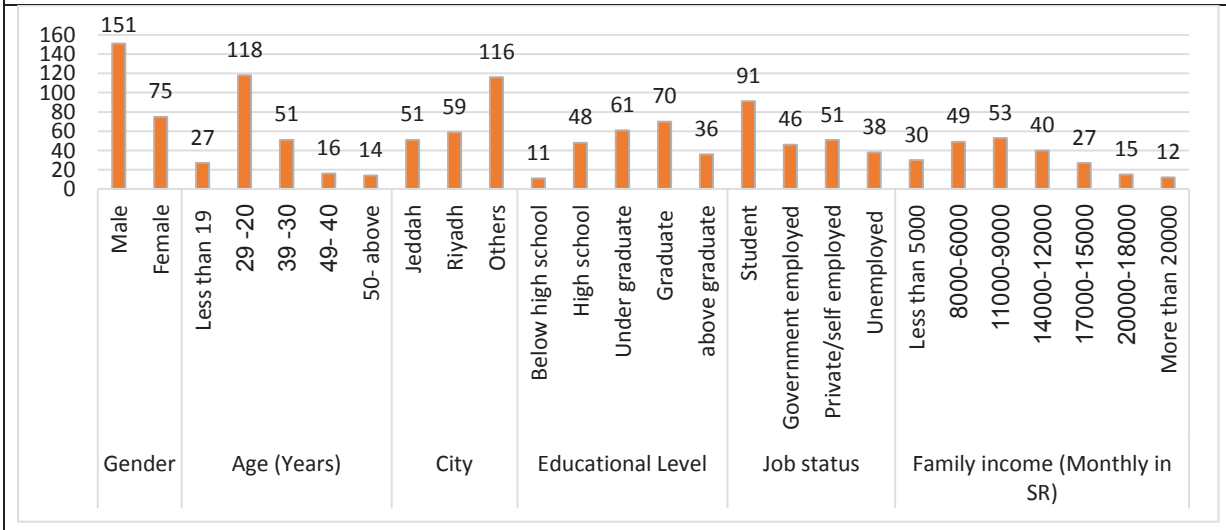
5. Research Methodology

The examination of this study intends to identify the ideas, preferences, perceptions of Saudi clients towards social media. The study community consists of users of social networks in Saudi Arabia. Moreover, to answer the research, question a primary data collection was used addressing the specific issues to consumers about their use of social networks and how these media influence decision-making processes specifically. Since access to the internet is a necessary condition for social media use and keeping internet popularity in mind, online surveys have been adopted to obtain the data. An appropriate sample survey has been gathered from 226 users and structured (close-ended questionnaire) through Google Forms, Monkey Survey. The link was sent through email, WhatsApp, Facebook and some other social networking sites for the purpose. After data collection, it was edited, coded and recorded and result findings were described accordingly. Besides, special precautions were taken to reduce the rate of non-response error. For the analysis a descriptive statistics (frequency distribution) and for hypothesis testing, chi-square goodness of fitness test at 95% of a certain level (P. Value 0.05) were applied.

6. Findings and Discussion

Figure 1: Respondents Demographic Information



Demographic factors such as gender, age, city, educational level, job Status and their monthly income can be seen in Figure 1. The majority of respondents of the study belongs to male 151 (67%) and female 75 (33%). Most of the respondents reported they belong to in the range of 20 to 39 (75%) age group and the rest of them were followed by less than 29 (12%), 40-49 (7%) and above 40 (6%) of the sample of the study. Moreover, from the table it can also be seen that most of the participants belong to the different 22 cities of KSA (51%), capital city Riyadh (26%) and the rest were from Jeddah industrial city that is 23% of the sample surveyed. Each of the city, compared with other cities in the region, have a good representation on the business side. Educational level of respondents was most of them graduate 31% followed by undergraduate 27%, the high school passed 21%, above graduate 16% and very few had below high school qualification that was only 5%. Regarding the job status of the interviewees it can also be seen in the table that majority 40% were student followed by private/ self-employed 23%, the government employed 20%, and the rest were unemployed 17% of the respondents. Furthermore, the table shows that the income levels of the participants, more than 60 percent of the participants belong to the monthly family income range of less than 14,000/- SR group. Less than 40 percent of the

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respondents belong to the monthly SAR 14,000 or more of their monthly family income. This result indicates that the majority of the population belongs to the middle-income class of the society (*Alam Z. M, 2017*).

Figure 2: Respondents Time Duration Spent on Social Media

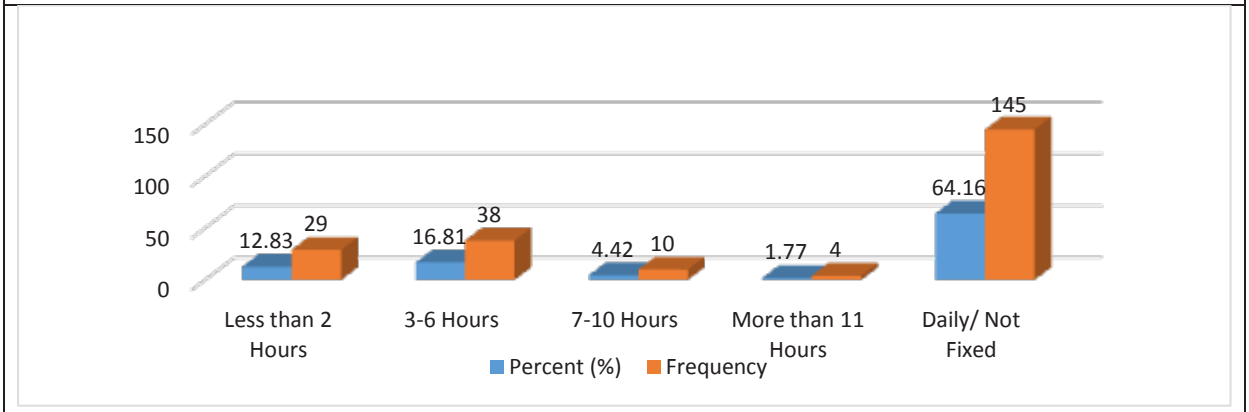

Table 1: Respondents Time Duration Spent on Social Media

	Observed	*Expected*	*Difference*	*Difference Sq.*	*Diff. Sq. / Exp Fr.*
Less than 2 Hours	29	45.2	-16.20	262.44	5.81
3-6 Hours	38	45.2	-7.20	51.84	1.15
7-10 Hours	10	45.2	-35.20	1239.04	27.41
More than 11 Hours	4	45.2	-41.20	1697.44	37.55
Daily/ Not Fixed	145	45.2	99.80	9960.04	220.35
The Chi^2 value is 292.274.					292.274

Figure.2 provides the information regarding the preferences in times duration spent on social media. It reveals that majority of respondents about 64.16% of the sample spending their time usually daily and it is not fixed how much they are involved in the social media use. Followed by 3-6 hours (16.81%), less than 2 hours (12. 83%), 7-10 hours (4.42%), and more than 11 hours (1.77%). From the result, it is decided there are the message that majority of the Saudi consumers are engaged with social media and 29.61% of the surveyed population representing the group of one to six hours involved with social media overall. It means almost one-fourth of their daily times they are engaged with social media. Therefore, it can be stated that for the marketer this medium of communication can be useful and productive tools for the communication to consumers. Ho: 1; the calculated value of the Chi^2 goodness of fit test is 292.274, and The P-Value is < 0.001. The result is significant at p=≤0.05 (See Table: 1). Therefore the null hypothesis (1) There are no significant differences in time duration spent on social media among the respondents is rejected an alternative hypothesis; There is a significant difference in time duration spent on social media among the respondents will be accepted.

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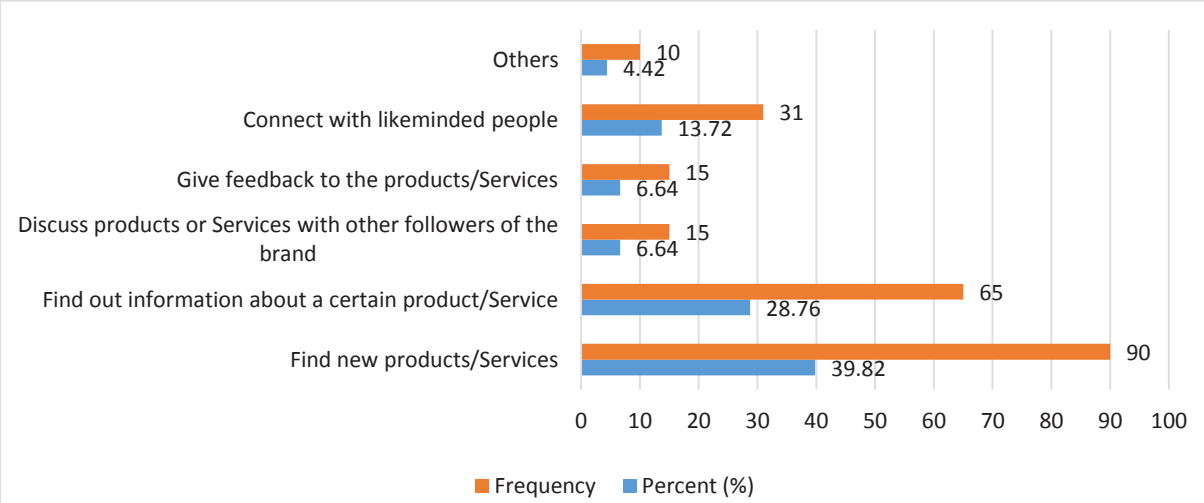
Figure 3: Purpose of Involvement on Social Media



Regarding the purpose of involvement on social media, it is revealed that high percentage (39.82%) of the respondents expressed that find the new products/ services information was the principal purpose of involvement with the social media as a consumer perspective. Followed by finding out the information about a specific products/ services (28.76%), connect with like-minded people (13.72%), give feedback about the product/ services and discuss products or services with other followers for the same interest (6.64% each). Moreover, other purposes were (4.42%) of the total surveyed population (See the figure 3). In another view, it can be stated that about around 82% of the respondents indicated that they are anyhow involved with shopping and consuming elements. That is a good indicator for the marketer to communicate regarding their products/ services with the consumer will be active as majority showed their interest in involvement with consumption related.

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Figure 4: Product Purchasing Preferences through Social Media

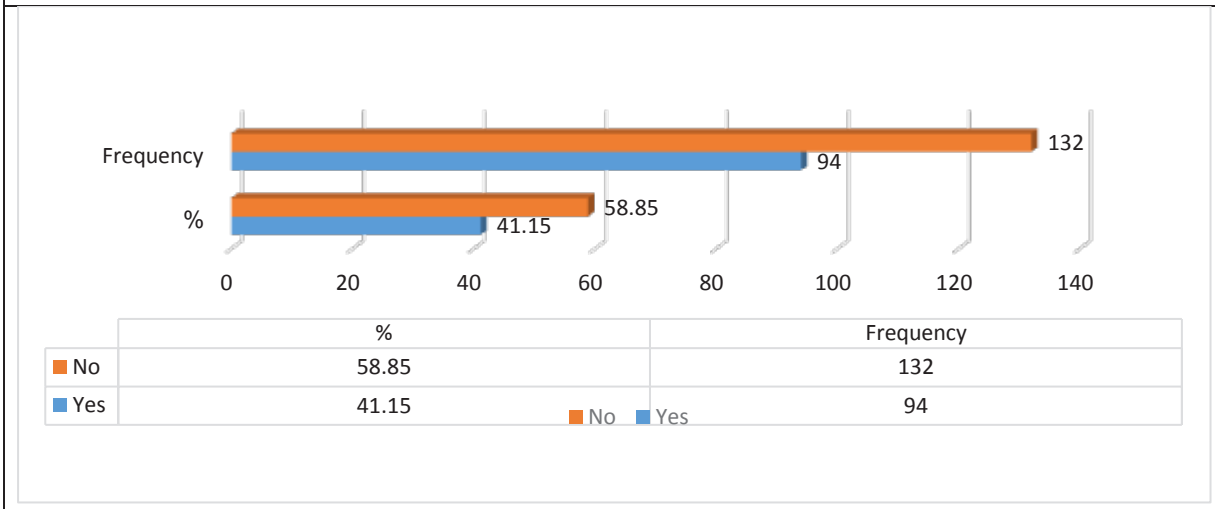

Table 2: Product Purchasing Preferences through Social Media

	Observed	*Expected*	*Difference*	*Difference Sq.*	*Diff. Sq. / Exp Fr.*
Yes	94	113	-19.00	361.00	3.19
No	132	113	19.00	361.00	3.19
The Chi^2 value is 6.389					6.389

When respondents were asked regarding the product purchasing preferences through social media, the majority (58.85%) of them agreed that they prefer the purchasing products or services through social media followed by 41.15% declined that they will not prefer to buy product or services through social media (Figure 4). The ratio of positive feedback is almost equal as compared to the not preferable one. So it is the vital point for the marketer that they can provide the better services to make the existing customer loyal and they can lure the customers through using cyber bait and some other incentives to the customer who is still not interested to prefer social media as a purchasing/ buying spot for the goods and services. Ho (2): There is no difference in opinion regarding the purchasing preferences through social media among the respondents, for this a statistical Chi^2 goodness of fit test calculated the value of is 6.389, The P-Value is 0.011. Therefore, the result is significant at p=≤0.05 (See Table:2). Therefore, the null hypothesis is rejected and alternative hypothesis; There is the difference in opinion regarding the purchasing preferences through social media among the respondents will be accepted.

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Figure 5: Respondents Product Buying Preferences on Social Media

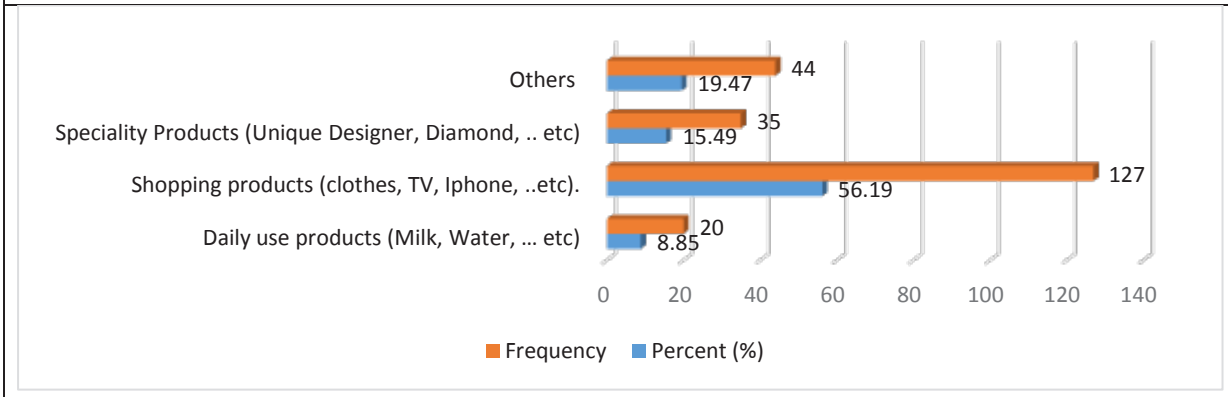

Table 3: Respondents Product Buying Preferences on Social Media

	Observed	*Expected*	*Difference*	*Difference Sq.*	*Diff. Sq. / Exp Fr.*
A	20	56.5	-36.50	1332.25	23.58
B	127	56.5	70.50	4970.25	87.97
C	35	56.5	-21.50	462.25	8.18
D	44	56.5	-12.50	156.25	2.77
The Chi^2 value is 122.496					122.496

A. Daily use Products, B. Shopping Products, C. Specialty Products, D. Others.

From the figure 5. it is perceived that majority (56.19%) showed their preferences on buying the shopping products such a cloths, phones, T.V., etc., followed by other products about 19.47%, speciality products like unique, designer items, other product, speciality products (15.49%). Moreover, 8.85% respondents expressed their feelings that they also buy daily use product like convenience product that can be used very fast. Therefore it is an excellent indication that marketers who sell shopping product such a cloths, phones, T.V., etc. having genuine chance to sell their products or services through social media platform as these products are highly preferred among the other types of products. For speciality and daily use items, there is a need for awareness, proper comparison of products and trust building with consumers. For Ho:(3); There is no difference in the types of product buying preferences through social media among the respondents, the calculated value of the Chi^2 goodness of fit test is 122.496, and the P-Value is < 0.001 (See Table:3). Therefore, the result is significant at p=≤0.05, and hence null hypothesis is rejected, and alternative hypothesis 'there are differences in the types of product buying preferences through social media among the respondents' will be accepted.

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Figure 6: Responses to the Influences of Social Media Campaign on Consumer Buying Behavior

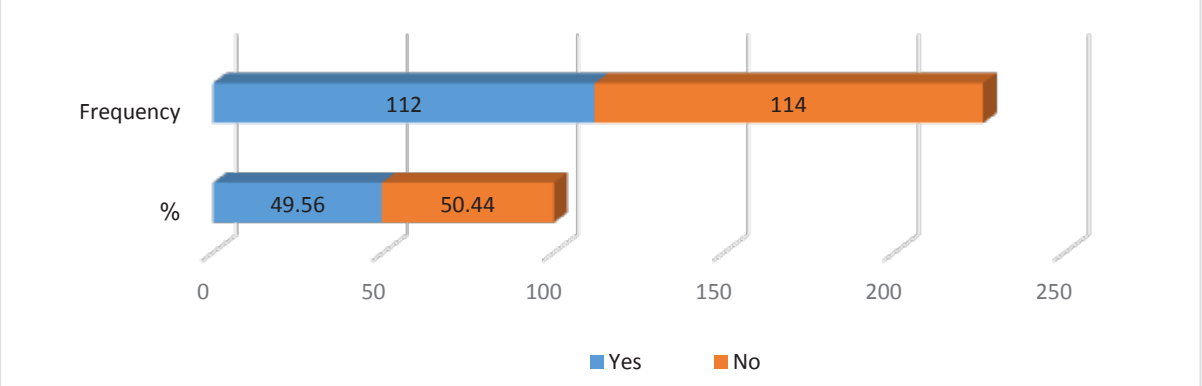

Table 4: Responses to the Influences of Social Media Campaign on Consumer Buying Behavior

	Observed	*Expected*	*Difference*	*Difference Sq.*	*Diff. Sq. / Exp Fr.*
Yes	112	113	-1.00	1.00	0.01
No	114	113	1.00	1.00	0.01
The Chi^2 value is 0.018					0.018

Figure (6) provides the information regarding the influences of the social media campaign on consumer buying behaviour. Almost equal proportion (49.56% and 50.44%) of the responses from the consumers that is around fifty percent in favour of that social media campaign has influences on consumer buying behaviour. At the same time, almost the same 50.44% has opposite opinion that the social media campaign did not influence/ change the buying behaviour of consumers. It is interesting to note that previous studies had revealed the positive impact of social media influence on purchasing habits but in the current study, it is not having a significant impact on it. Ho (4); was assumed that there are no differences in opinion about the influences of a social media campaign on consumer buying behaviour, the Chi^2 goodness of fit calculated value is 0.018 (Table.4). The P-Value is < 0.001 at 95% confident level and it is < 0.001. The result is insignificant at $p=\leq 0.05$. Therefore, the null hypothesis is accepted and it can be stated that there are no differences in opinion about the influences of social media campaign on consumer buying behaviour.

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Figure 7: Responses to the Advertisement on Social Media

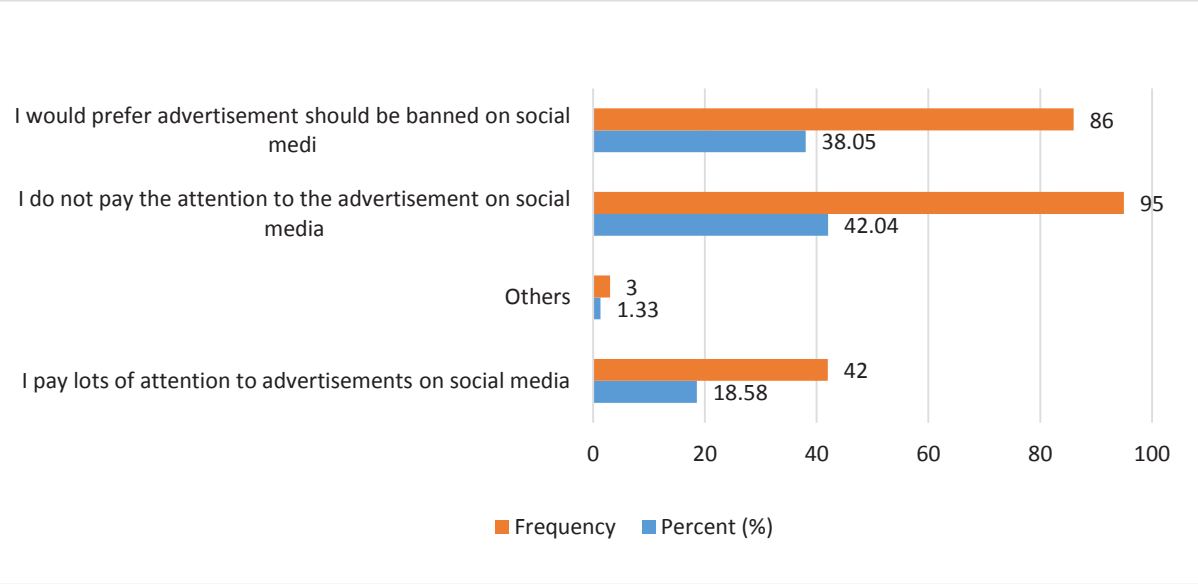

Table 5: Responses to the Advertisement on Social Media

	Observed	*Expected*	*Difference*	*Difference Sq.*	*Diff. Sq. / Exp Fr.*
A	42	56.5	-14.50	210.25	3.72
B	3	56.5	-53.50	2862.25	50.66
C	95	56.5	38.50	1482.25	26.23
D	86	56.5	29.50	870.25	15.40
The Chi^2 value is 96.018					96.018

A. I pay lots of attention to the advertisements on social media, B. Others, C. I do not pay the attention to the advertisement on social media, D. I would prefer advertisement to be banned on social media.

From the figure 7, it is investigated that majority of the consumers express the views that they do not pay attention to the advertisement on social media (42.04%), followed by the statement that they prefer advertisement should be banned on the social media (about 38.5%). Only decidedly, less than 18.58% express their views that they pay attention to the advertisement posted on social media. Here it is also inspiring to note that in other question of this research they also were not very positive about the influence of social media on the changes of purchasing habits as well as this question result also support the previous findings of this ongoing study. Therefore, it is suggested that a marketer should not bother too much on the social media as a traditional advertisement techniques/ tools. Promotions on the social media shall be interactive form and both parties involvement that means two-way promotional tools and strategies will be highly useful on the social media platform. Ho: 5; the calculated value of the Chi^2 goodness of fit test is 96.018, and the P-Value is < 0.001(See Table 5). Therefore, the result is significant at p=≤0.05. Thus, the null hypothesis is rejected. In addition, alternative hypothesis 'there are differences about the

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advertisement on social media among the social media influence on shopping habits, but in the present study, it has no effect in the same sense. Also, in this case, it is interesting to note that in this study there is also not a very positive feedback about the impact of social media advertisements on changes in buying habits, as well as the result of this question also support the findings in progress. Therefore, it is suggested that the seller not bother too much in social networks as they use techniques/tools in the traditional advertisements. The promotions in social media should be preferable in the interactive form as of both parties concerned, which means that the two-way communication tools/strategies for the products and services promotion will be handy on the social media platform. Besides, integrated interactive communication methods are suggested with the social media platforms for the communication and promotion to achieve the objectives of business efficiently.

7. Conclusion

A careful analysis of the data are mentioned to increase the knowledge of the reality that the social media has already done a commendable job is to close the communication gap between people. The different tools of social networks help people to interact with each other in the shortest possible time. The result indicates that the majority of Saudi consumers utilise social media spend time between one hour to six hours and it is about a quarter of the daily time spent by them. Therefore, we can say that marketing professionals can use these means of communication that can be a suitable and sufficient communication method with the consumers in the region. Regarding the purpose of participation in social media/networks, it is observed that approximately 82 percent of respondents are involved in the purchase and consumption of products. Moreover, it is a good indicator for the seller to call concerning business and promotions with shoppers, which will be highly efficient as majority shows their interest in involvement with consumption-related issues. Excellent time to approach the client in are the evening, at night and before bedtime are appreciated that the seller who sends their message in the afternoon compared to the hours of sleep (*Alam Z M., 2017*). Concerning preferences in buying products through social networks, the proportion of positive comments are almost equal to what is compared. Therefore, it is vital that the seller to be able to offer the current best service to loyal customers, and they can lure the customers through using cyber bait and some other incentives to them who is still not interested to prefer social media as a purchasing/ buying spot for goods and services. The seller who sells shopping products such as textiles, telephones, television, etc. have a very positive opportunity to sell their products or services through the social media platform since these products are preferred to a large extent compared to other types of product categories. Concerning speciality and daily use items, there is a need to create awareness, and it should be sufficient to make a comparison between the products and generate trust among the target consumers. It is interesting to note that previous studies have shown the positive impact to the opinion of respondents' and it will be accepted.

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THE IMPACT OF THE REVISED EXPAT LEVY ON THE SAUDIZATION RATIO

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KEYWORDS:

employment, expat levy, average rate, income, foreign workers, private firms

ABSTRACT

Saudi Arabia government introduced Saudization in its employment policies to control the high number of expatriates taking away jobs at the expense of the Saudi citizens. Most recently, the Saudi government revised the expat levy on the Saudization ratio. The new expat taxes we operational as from May 2017. These costs are largely expected to raise costs for the private sector. The impact is likely to be felt more on the labor-intensive sectors like retail and construction. Currently, the Saudi firms pay SAR200 levy per expat worker, and this figure is expected to double to SAR400. Every year to SAR800 in 2020. This paper explores literature and gathers evidence of the possible impact of the revised expat levy on the Saudization ratio.

1.0.INTRODUCTION

There is a number of reasons, both economic, social and political, which explains why the Saudi Arabian government has recently adopted the stringent approaches used to deal with the Saudi unemployment issues and labor market. When there is unemployment, it implies that there is a low level of production, low standards of living and high levels of dependency rates in the economy. Studies show that the Saudi Arabian dependency rate reaches 56 for every 100 workers, which is about 2.4 times the global average rate of dependency (Al Sheikh, 2003). Therefore, any significant reduction in the worker income, or when there is no work, the living standards of the citizens is directly impacted. The local Saudi press has in the recently reported increase in the crime rates in the country, and this is attributed to the high rates of unemployment (Al Munajjed and Sabbagh, 2011).

However, the |Saudi government faces two primary challenges in its effort to create employment and to raise the standards of living; Firstly, Saudi Arabian age structure is young, with the new number of entry workers increasing every year. This is supported by the fact that Saudi Arabia has one of the greatest birth rates globally. Secondly, Saudi Arabia receives several workers every year from foreign countries. The system does not, however match the availability of jobs with the market skills for the foreign workers. This means that the foreign workers are bringing in skills already existing in Saudi Arabia. The problem is even further propounded by the sponsorship scheme by the private firms, referred to as the *Kafeel* system

In an attempt to solve the unemployment situation in the country, the Saudi Arabian government has introduced the program and policy referred to as "Saudization." The program is directed to replace the expatriate workers gradually with the Saudi workers (Looney, 1992). The private sector is being encouraged and directed to increase the proportion of the citizens in the employment through a policy of punishments and inducements, which charges for *Iqamas* or work permits and re-entry/exit visas significantly raised. As a result of the policy, the private sector finds it very challenging and expensive to hire expatriate workers. The issuance of the foreign labor visa is also being strictly and rigorously screened.

2.0.EXPAT LEVY

The Saudi Arabia expatriate levy can have a significant impact on the private sector. From May 2017, the government started collecting a new fee on a monthly basis amounting to 100 Saudi riyals for every foreign worker dependent, with plans to increase the charge on gradual basis every year until 2020. Initially, it was not clear who will shoulder the levy, but it has come out clear that the foreign workers are the ones to pay for the charges, and not employees. It is the expats to pay for the levy as described by the executive vice president of Kuwait Financial Center, Mr. Markaz.

The firms that have employed more foreigners compared to the local Saudi citizens on their payrolls are presently spending 200 riyals on the monthly basis for every foreign worker. The charges only apply to the foreign workers, and the companies have to adhere to the specified number of foreign workers they employ to escape the monthly charge. The fee will apply to all companies, not just companies' dependent on the foreign workforce. For the expatriate workers that do not exceed the number of the Saudi workers,

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the levy will no longer be waived but will be taxed at a discounted rate as reported by PwC.

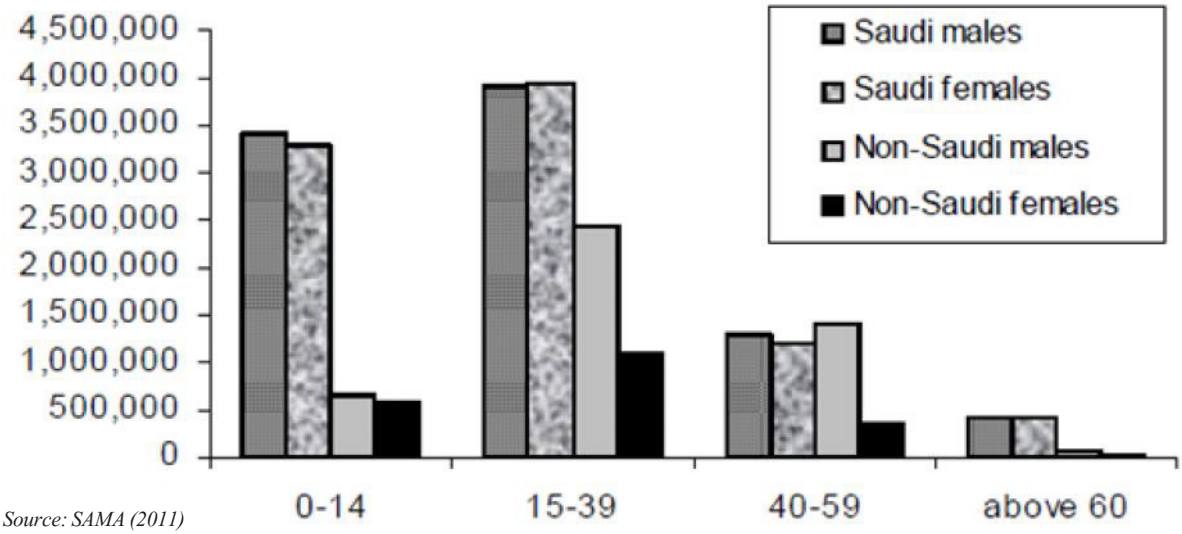
The revised Saudi Arabia expat levy could easily put pressure on businesses that possess a high number of foreign workers. This implies that the cost of doing business for such companies could definitely go up year on year alongside the increase in the levy. Again, the companies that employ more Saudi citizens to render them services will also not be exempt from the policy but will have to pay a discounted tax.

The organizations that employ a high number of the workforce from foreign countries will be impacted with the increasing levy per head. If the expats have dependents, they will not only have to pay a monthly fee but will also be required to face higher costs, with the upcoming VAT and increasing utilities and fuel coats that eat into their savings. As a result, there is a likelihood of a general decline of savings by about 6 to15 percent. These levies are not bad for the Saudi economy, provided that they don't take away the attractiveness of doing business in Saudi Arabia, especially in the private sector which significantly relies on the foreign labor. It is projected that the newly revised expat tax and dependents levy will generate for the country an income of about 65 billion Saudi riyals by the year 2020.

3.0. CHARACTERISTICS OF THE SAUDI LABOR MARKET

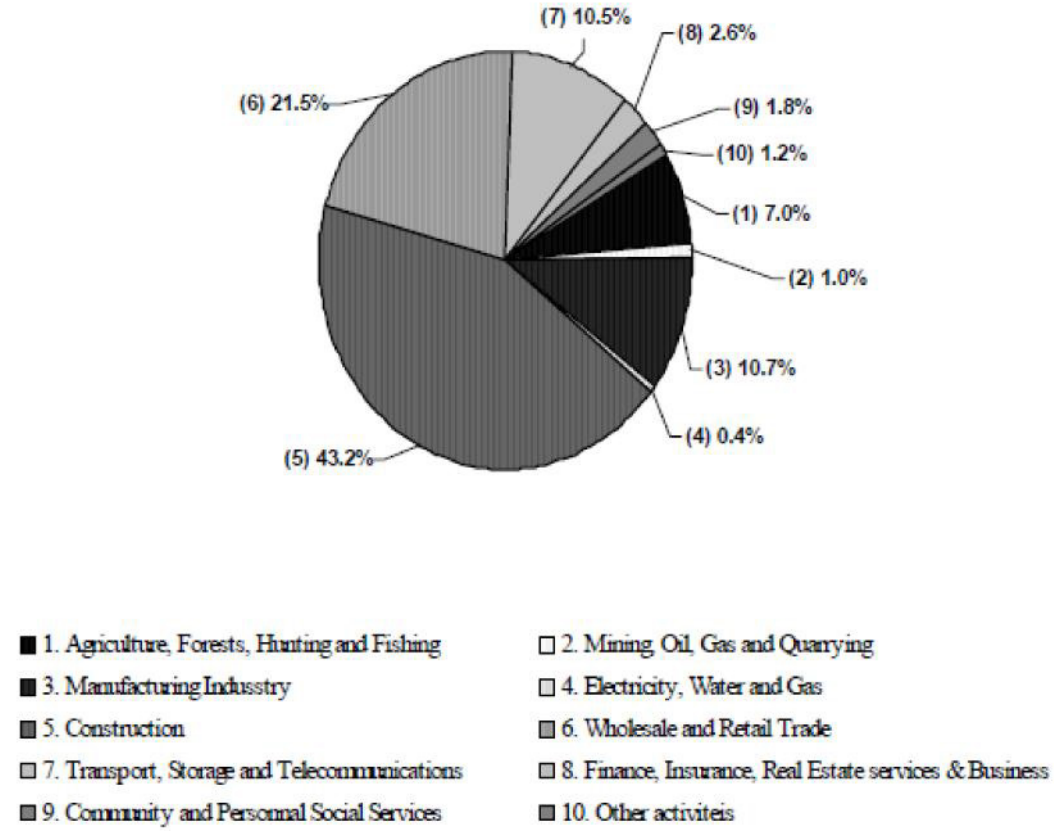
A labor market is either a formal or informal marketplace where the employees find work in exchange for payment, the employers hire the services of skilled workers and the wage rates in the market are determined by the demand and supply forces (Leahy, 2007). Again, a labor market can be either national, international or local in their scope, and constitutes smaller related and interacting labor market segmentation, geographic locations, skills, and qualifications. The labor market depends on the free exchange and flow of information between the job seekers and the employees regarding the conditions of employment, the wage rate and the location of the job. The Saudi Arabian foreign labor force and the imbalances in the youth demography are demonstrated in the figure below.

Figure 1 Saudi Arabia's population by age groups, gender, and nationality (2010)



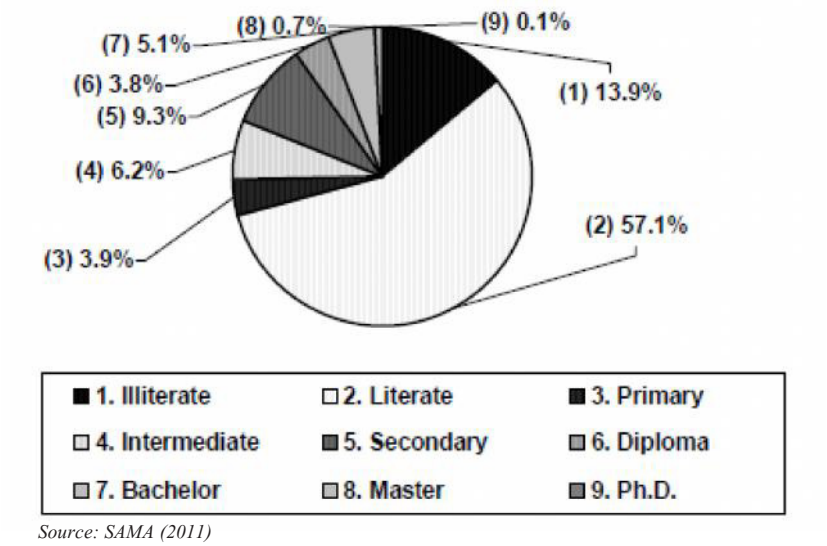
Source: SAMA (2011)

Figure 2: Distribution of Saudi Arabian workforce in the private sector in 2010



Source: SAMA (2011)

Figure 3: Saudi Arabian Workforce Breakdown in the private sector by educational level (2010)



Source: SAMA (2011)

Overall, the labor force in Saudi Arabia market is characterized by the growth of a significantly high level of youth participation, and very high rates of expatriate's employees especially in the private sector, leading to increasing the levels of depression of the average general wages, reduced productivity and high levels of unemployment which is projected in the years to come if no critical action is taken. As provided by SAMA, the |Saudi foreign labor accounts for about 90% of the total national labor force as at 2010, amounting to about 7 million. On the other hand, only 725,000 Saudi citizens are employed in the private sector (Saudi, 2012b). The pattern of employment in Saudi Arabia is completely the reversal in the public sector, with about 885,000 Saudi citizens working in the sector in the year 2010, constituting 92% of the workforce.

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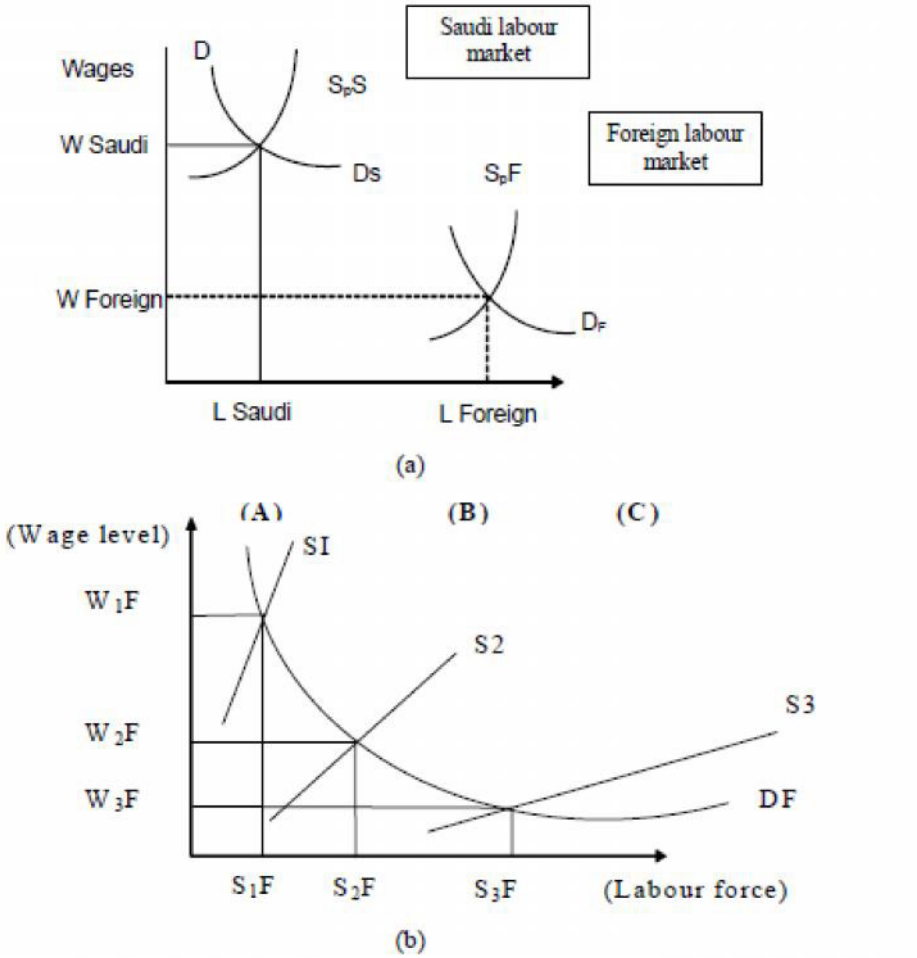
Table 1: Saudi Arabian Average wage (1994–2008)

	Saudis		*Non-Saudis*	
	Males	*Females*	*Males*	*Females*
1994	7,298	3,660	2,153	3,133
1995	7,896	3,864	2,142	3,016
1997	7,570	4,144	2,046	2,716
1998	7,473	3,812	1,934	2,740
2000	6,877	3,217	1,763	2,391
2001	6,684	3,151	1,710	2,403
2002	5,984	2,703	1,543	2,221
2008	7,650	3,100	1,650	2,480

Source: Ministry of Labor, SAMA

The subclasses of income compared to the native Saudis and aliens are broken down in terms of dual diverse labor markets (United Nations Development Programme – Regional Bureau for the Arab States, 2009) This finding was reported by a Saudi economist, and it is relevant to the bigger GCC employment market this is shown in figure 4 below.

(a) The difference of the Saudi labor market (b) the orders and deliveries for immigrant labor in Saudi Arabia by market divisions



The image 4(a) shows the idea in modes of specialized order and deliveries for Saudi and alien employment markets. In the diagram, D's and Sps mean order and deliveries of Saudi workforce, while DF and SPF mean the order and deliveries of the alien workforce (Urdal, 2006). As stated before, there is a big difference in salary levels, not only amidst Saudi natives and aliens but also amidst diverse expert groups of aliens. Thus the foreign labor demand and supply in Saudi Arabia displays a big difference on delivery compatibility, thus giving the varied salary levels of alien

workers. By delivery compatibility, we mean the receptiveness of the delivery or workforce to fluctuations in the salary level. This is shown in 4(b).

4.0.SAUDI QUOTA *NITAQAT* SYSTEM: OBJECTIVES, EXPECTATIONS AND ASSESSING THE COST

Measures by the government to reduce alien workforce and develop audition have gone both ways. It's been challenging to relay and follow up the rules that manage a number of aliens because the bringing in of the alien workforce has more support from the influential trading and commercial organizations. Cheap alien labor has made profits for these organizations. The backing of alien employees blocks market demand and supply ways thus the stagnant sectors with more than needed workforce and deliveries shortages in other sectors (Damanhouri, 2017). The institution in governance can come up with a strategy to slowly remove the support system after reimbursement of employers for costs incurred. Some of these costs can be deducted from laborers salaries in a set system. Reduction of work visas has been taken as a measure by the Saudi government in order to regulate the number of workers so as to create a demand for supply. This is the origin of the prologue of the Nitaqat system to boost causation (Saudi Gazette, 2017).

Ahead of evaluating the goals and anticipation from the quota Nitaqat structure launching, inquiry on why the Saudi Arabian private segment is hesitant in employing the Saudi citizens, but choose to employ experts has to be answered. Various people claim that the hesitation comes from the cultural attitudes of the Saudi people towards work. Reality is that because of the negative mindset of Saudis about specific types of work, a lot of experts are found there, although it is a single most country in the GCC with a lot of inhabitants that are capable of carrying out the country's growth without help from any other country (Looney, 1992; Nur, 1995). In addition, the importation of workers overseas, and at the same time offering privileges to the citizens have contributed to the negative mindset of the Saudi Arabians towards working. This has isolated Saudi Arabians from the job market.

5.0.EXPAT TAX AND ITS IMPACT ON MARKET ECONOMY

The trickiest factor that is faced by the Saudi people is the existence of a big number of expatriates who came to Saudi Arabia during the 1970s economic boom. These experts have become part of the Saudi society since some perform their duties in some Saudi offices, homes, streets, hospitals, schools, universities government sectors and various other sectors.

The work or services that are offered by these experts cannot be forgotten or taken for granted during periods of Haj as well as Umar, whereby they clean and maintain the mosques in Makkah and Madinah. On the other hand, we should congratulate the government's efforts towards deporting illegal workers in the country, which is a good step in reducing violations (Damanhouri, 2017).

Various measures have been put in place through the improvisation of technology at various passport departments. This has brought about the efficient renewal of passports and permits of the experts that come into the country. Muqeem and Abshir websites, as well as the monitoring of violators and insurance payers, is another accomplishment towards efficiency in the country's labor market. On the other hand, the newly introduced expat dependent tax has brought about some difficulties in the expat sectors which create some negativity and thus bringing about low output. A lot of expats have taken back their families, which has led to the closing down of some stores (Saudi Gazette, 2017). These new laws have made a lot of expat families to go back to their respective countries, and this has a serious effect on the market.

Humanitarian cases tend to arise in these areas since the international laborers have no knowledge of any other state which they can migrate to. This because many workers were born inside this territory. Some of the workers started employment through the connection of their guidance and had no documents to show their qualification. This factor contributed to the state to get involved and trace these culprits who defy laws of iqama and work policies and rules. This manhunt for illegal nationals has been a great achievement by the government and a great success on part of the use of technology in this technical world (Ahmad, 2017).

The government has introduced the collection of expatriate levies to the private business community. It wasn't well received by the private investors because it was costly to them but in the part of the state, it was a source of revenue (Chaudhry, 1989). Moreover, a collection of levies will bring about a rise in prices the basic needs and services. In return, this will affect low-income earners, retired and even the old ones who require different services. This has seen countries such as the Philippines and the likes of Indonesia to seize the exportation of the house helps due to exploitation and late wages. The state of Saudi is trying to solve the issue of lack of work by the nationals by replacing the foreign workers with its people. Also, it is trying to avoid loss of money through international transfers which amount a lot annually. Also to stop narcotics trafficking and money washing.

The damages caused by taxing the experts have no humanitarian impact. The enterprises affected by this imposition of taxation are the small business. This caused when the state tax the experts in a variety of fees such as working document, insurances, iqama, visa fees when entering and when living, and much more which has been added. All these taxes are paid by the private sectors. According to business studies especially economies tries to help has understood that small businesses are the backbone of any economy of a state. Therefore, causing this small business to run down means damaging the entry countries gross domestic product. In conclusion, we hope the state through its ministries, especially of development and labor, will have the second opinion and rethink before taxing the small business to avoid damaging the economy of the country. They should conduct total research before imposing taxes on its people

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Background: Here is the schedule implementation.

Employer group	2018	2019	2020
Organizations that have less or equal employees than Saudi employees	RS300 for each foreign worker per month.	RS500 for each foreign worker per month	RS700 for each foreign worker per month
Organizations that overseas employees are more than Saudi employees.	RS400 for each foreign worker per month.	RS600 for each foreign worker per month	RS800 for each foreign worker per month

Charges are part of the government's hard work. Imposition of the fees is part of the government's efforts to persuade organizations in hiring Saudi employees. A new tax by the Saudi authorities has been imposed on relatives of the expatriate employees in July, while the new Saudization rules on the employers started working on the third of September.

BAL Analysis: The Saudi Arabian employers are to plan for the rise in charges for overseas employees in the coming 3 years as well as evaluate their proportion for overseas workers to Saudi workers to commence planning for a set of Saudization rules that will affect employment, and business costs.

6.0. THE IMPACT OF EXPAT LEVY

a) Expat levy has little impact on purchasing power

The tax imposed on expats has less effect on the power of purchase. According to the local experts, the tax imposed on experts and the choice of some families to leave the Kingdom does not leave an immediate effect on the economy's purchasing power. Various private sector organizations are imposing the expense they are gaining on their employees. On the other hand, according to Hattan Saaty, the number of experts willing to leave the Kingdom due to the new tax is not much. They are also willing to weigh the expense of leaving. Hattan Saaty is a managing stakeholder at Strategic Gears which is a local consulting company that issued a report that showed the amended expat tax and the effect it has on the economy. Rarely will the expats leave right away after the new tax is put into effect, and based on the research, most of these experts have stayed in Saudi Arabia for so long that the decision to move would be a tough one. Saaty adds that quite a number of the high-performing experts may expect a rise in their salary in the years to come. A survey of 1500 male experts that have families with different jobs and different income reveals that most of these workers will consider the tax to be too high at fifteen percent of their income (Robinson, 2017).

Saudi has about 11000000 experts nationwide, and at the same time, six hundred thousand jobless Saudi Arabians. According to the researchers, this escalating number of jobless people will force the government to come up with other ways of dealing with the situation. Saaty has the belief that the tax imposed on the experts will lead expert hiring being less or unattractive since the gap between Saudi experts and the Saudi employee's wages will be high (Robinson, 2017). In the long run, the expert tax will have a positive effect on the labor market in various ways, for example, private sector business structure change that mainly depends on cheap labor, Saudization increase, which will bring about high purchasing power for the Saudi families.

Six hundred and seventy thousand to leave Saudi Arabia in three years. By the years 2020, a report by Banque Saudi Fransi claimed that approximately six hundred and seventy thousand overseas workers are to leave Saudi Arabia (Bank Saudi Fransi, 2017). The Saudi Arabian newspaper that goes by the name 'Mecca' stated that about one hundred and sixty-five thousand experts are anticipated to leave the nation each year. Additionally, it was claimed that the new tax charges that are imposed on the workers' partners would increase the next year's budget by twenty billion dollars (Saudi Gazette, 2017). Approximately, there are about 11,700,000 foreigners in Saudi, 7,400,000 are employed while the remaining 4,300,000 are the partners (companions). These sums up to 1,100,000 families. From 1st of July is when the Saudi Arabian authority began getting the fees from the expert partners during their ID card renewal (Ahmad, 2017). These partners (companions) pay about one hundred riyals every month which is about 27 dollars due to become four hundred riyals, about 107 dollars every month by the year 2020.

The Kingdom has come up with an economic plan by not depending on oil as much and expand its economy. In the 2030 vision, taxes have been imposed, for example, the value-added tax on products, raise charges, and come up with new industries as well as weapons manufacturing.

b) Expat levy to add SR60bn economic burden on Saudis

Same as any other main strategy plan, Saudization causes conflict in sectors like transport expecting a disaster. A final objective of improvement and growth is associated with some expense in short-term in-between distraction. Measurement of effects of Saudization economically is still at its young or early stage. However, two major worries exist. Foremost, various organizations may have the feeling that Saudization minimize their competitive advantages, and so they may choose to leave the Kingdom to somewhere else that is more business-friendly. Organizations in the service sectors for example; banks are where the Saudi labor has applied Saudization. According to many bankers, Saudization would cause business failure to other neighboring banking institutions, mainly the ones in Dubai. This nation's poor regulations resulted into about two thousand five hundred Saudi organizations relocating to Dubai instead of the Kingdom. Various advocates from Saudi Arabia for example, the Saudi economist Ihsan Bu-Hulaiga argues that due to the fact that only 15% of the experts are skillful the, there will be no vacuum in the domestic labor market due to amendments in the quotas. The advocate's argument claims that the Saudi Arabian local market is already filled with overseas people, of which some are not employed, no skills or cannot read or write (Kerr, 2017).

Competition with the local Saudi Arabian job hunters is what they do in order to force the wages down. The other area that Saudization will affect is in the Kingdom's FDI

sector. Overseas organizations may end up assuming Saudization does not just inconvenience, but also the agenda is not predictable, which is not a good sign for them. Worry over Saudization effect on the foreign investors led to the change in foreign investors' tax from 45% to 20% (Kerr, 2017).

c) Saudi Arabia expel Egyptian workforce

The word Saudization was created by the journalist first after the broadcast of vision twenty thirty of the state of Saudi for reforms in the country was announced on television. This word has been tormenting the laborers of Egypt descend expatriates who work within the nation. This hatred began in January sixteen when there was a dispute between the two nation's governments over land. This land was the islands of Sanafir& Tiran of the red sea. During this period (January 16) the highest court of the land of Egypt administrative, the Supreme Court, nullified the nautical boundary separation accord among the two countries. The judgment made by the Egyptian courts was the main causes to trigger saudization hardship for the nationalities of Egypt descend expats in the state of the Saudi kingdom.

The vision twenty thirty of the state of Saudi Arabia is mostly concentrated on economic development and communal guidelines. This guideline to create work for its populace in order to avoid over-dependence of international expatriates and transfer this works to its citizen in order to reduce the percentage of the unemployed in Saudi to seven percent. The judiciary judgment by the Egyptian highest court was not the only factor that triggered saudization of the expert in Saudi Arabia. This tension of enmity between these two countries since Oct year twenty sixteen ignited the labor force of Saudi by giving the jobs which were being occupied by the Egyptians experts to its locals was due to the political instability as one of another factor (Robinson, 2017).

7.0.DISCUSSION

Incentive-Based Saudization Strategies

There is a significant number of teachings to learn from for other GCC nations while trying to construct work for its citizen populace.

I. The petroleum industries find it very hard to provide enough work opportunities for its citizens and still compete effectively due to the resources strength.
II. Instead of giving out works belonging to the internationals to its nationals, the government should rather create new vacancies to its nationals in order to have a lasting answer for housing increased workforce.
III. The idea of developing new employment without expanding international express ventures is impossible, therefore foreign influence will always be a factor
IV. The newly employed personnel should be trained well for the position and can be implemented in countries rules.
V. The foreign employees send money outside the country making the survival of upper-class national needs hard.

Most Saudi new foreign experts tend to seek work employment in private industries rather than the government. This gives the opportunity to the nationals to grow economically through international trade and technological reliability.

a) The Role of Market Forces and Incentives

Saudization should concentrate more on economic factors initiatives rather than market share concentration. It should be focused on the development of environment with an increase also in international enterprises through some venture such as educational programmers. From these procedures involving supply and needs some rules must be implemented to create new work positions. These policies can be categorized in 3 wide groups which are; income and job expense, purchase of labor and investing on funds technological systems. These rules are organized focus on the economy and follow requirements such work shares which mostly influence competition and nonpetroleum increase by increasing expenses and maximizing job suppleness (Ahmad, 2017).

b) Regulations and policies affecting Wages and Costs of Employment

If payments on income for or earnings by the state sector employees is reduced, means that it will cause a shift of thought by the employees to seek alternative source which will be the private sector. Restriction on the state on employing also can bring a shift of thought by the locals to look for alternatives from the private investors. This creates a balance in the two sectors (Ahmad, 2017).

c) Skill development

The ability to get skilled labor especially by the private enterprise in Saudi helps the country increase in job vacancies. Formulating a well-organized higher education system will help the locals to develop or acquired skills and knowledge for different departments such as the technological and much more. This can even help in entrepreneur skills and also create a nation of skilled workers.

d) Investment in capital and knowledge

The use of advanced technology especially buy private investors helps the sector to develop at the same rate as the rest of their competition. In order to keep that competitiveness, a larger workforce is required therefore the creation of jobs will arise. An increased fund means an increase in industrial development thus creating more job vacancies. The state should focus more on the efficiency of the state.

e) Costs and Benefits

If Saudization is rightfully managed, the possibility of achieving vision 2030 is most likely to succeed. However, expenses incurred during activities such as education are expensive and the intervention by the government is needed.

8.0.CONCLUSION AND RECOMMENDATIONS

Some of the kingdoms in Saudi Arabia do not fully agree with Saudization or the new systems put in place for economic development towards productivity such as job expansions, competitions, and market expansion (Kerr, 2017). There should be a diversion from focusing more on petroleum production but rather also other sectors. This helps to encourage the private sector to grow and even attract more multinational investors. The state should consider the following as it awaits transformation.

- Should make working conditions for private industries attractive and conducive to work. The income difference among private and state should be lowered.
- Equality among internationals and the locals
- Promote education and other skills required for entrepreneurial skills

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- Efficiency and investing in funds/capital
- Using of price valuation rather than amount valuation economic connection.

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THE ROLE OF SOCIAL SUPPORT SYSTEMS FOR SAUDI ARABIAN STUDENTS IN THE UNITED STATES

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The aim of this study was to assess the role of social support systems for Saudi Arabian students in the United States. A survey was conducted with Saudi sojourners using the Index of Sojourner Social Support (ISSS) instrument and the Ethno-Cultural Identity Conflict Scale (ECIS) (N=210) and semi-structured interviews (N=15). Saudi students reported that when it comes to adapting to their lives in the United States, they rely on few people (M=3.07) to support them during their stays, thus indicating that they rely on minimal social support networks. This was confirmed by the ISSS data, which provides that students overwhelmingly have limited social support networks. When the ISSS scores were compared to the ECIS scores, the data show that there is a weak negative statistically significant correlation between identity conflict and social support $r_s(125) = -0.200$, $p < .05$. As social support for the Saudi sojourners increased, their intrapersonal identity conflict decreased. Interview data adds that although the majority of sojourners had small (limited) support systems, those support systems were nevertheless robust and able to assist the students with overcoming obstacles with their academics as well as assimilating, if only temporarily, into American society.

Keywords: Saudi Arabian students; intrapersonal identity conflict; social support systems; study abroad

Introduction

It is through socialization that individuals find meanings and safety in life (Erikson 1950). Personal relations and supportive networks, herein referred to "social support systems" often include one's close relationships with friends, family, and colleagues (Brewer 1999). The aim of this study is to assess the role of social support systems for Saudi Arabian students in the United States. Using a mixed method approach (survey and interviews employed), the research intends to provide clarity, compel debates, and encourage new directions in research that may further cross-cultural understandings through the advancement of the literature on how Saudi sojourners use social support systems to deal with identity conflict and other related issues. Through reviewing the existing literature on Saudi student sojourners in the United States and social support systems, the research identifies current limitations of the literature examining the overlap of these topics. Specifically, there is a dearth of literature addressing cross-cultural social support and acculturation beyond the Western contexts or relevant to the Arabian and Muslim experiences.

Saudi Student Sojourners in the United States

Kitsantas (2004) defines study abroad as "educational programs that take place outside the geographical boundaries of the country of origin" (1). As early as the twelfth century, kings and churches supported foreign students by giving financial aid or inexpensive food and lodging. Such previous practices can be considered the prototype of contemporary educational scholarships. Additionally, in exchange for aid, twelfth century students were expected to work for either the State or the Church, as is the case today with the scholarship requirements of Saudi students studying abroad.

The number of foreign students has been increasing since the twelfth century. By the year 2010, Wildavsky noted:

> …153 million students are now enrolled at universities around the world, a 53 percent jump in just nine years. With many nations unable to keep up with this growing demand, students have strong incentives to seek higher education wherever they can find it. An extra motivating factor is the perception that global aptitudes—linguistic, cultural, academic, or all three—are more and more necessary (p. 37).

Wildavsky goes on to state foreign students have seen their mobility markedly increase. By 2010, nearly 3 million students were studying outside their own countries. The largest portion of these students, twenty-two percent, studied in the United States, compared with the United Kingdom and Australia, which played host respectively to 12 percent and 11 percent. Among graduate students, the percentage is even higher; approximately two-thirds of foreign graduate students study in the United States. As Wildavsky quoted Daniel Fallon, an emeritus professor at the University of Maryland at College Park, "today, going from nation to nation with great ease, is certainly unprecedented" (p. 17). Saudi student sojourners in the United States, in particular, reached 45,232 in 2011 (Maati, 2011).

There are many motivations for the Saudi students who leave their homes and families, friends, and country, in order go to the United States to study and engage in intercultural exchange. Shaw (2009) produced the only study, an unpublished dissertation, which deals with the motivations of Saudi students. The results of his qualitative study of 25 undergraduate Saudi students in the United States showed that 31% came to the States to receive their undergraduate degrees; 25% to receive their graduate degrees; 13% to learn about American culture; 6% to become educated and skilled in in-demand disciplines and areas of occupation to improve their home country; 6% to achieve a higher standard of living; 6% to gain proficiency in English, and 3% for different reasons such as to help their families, to show Americans what Saudis are like, to make new friends, and to become independent.

Saudi student sojourners, however, are only one subset of all of the international students within the United States. Two studies, one by Carlson, Burn, Useem, and Yachimowicz (1990) and the other by Spaulding and Flack (1976), consider the motivations of student sojourners in general. These studies found that international student sojourners were motivated to study in the United States in order to receive schooling and training not available in their home countries, to satisfy their desire for foreign cross-cultural experiences, to experience new cultures, to advance their careers with prestigious degrees, and to learn the language of the host country. A few studies in Arabic (Al-Hariri, 1948; Al-Hariri, 1949; Hijazy, 1983; Al-Hariri, 2000; Maati, 2011) have documented the history of Saudi sojourners specifically who study abroad, but

there are none in English. Therefore, the historical information in this study derives from Arabic sources.

Saudi scholarship programs began in 1927, before the unification of the Kingdom of Saudi Arabia by its leader King Abdul-Aziz Al-Saud (Maati, 2011). After the unification, 14 Saudi students were sent by the government to Egypt to educate and qualify them to fill the country's need for teachers and other professionals. The success of that scholarship program encouraged the government to establish a school in Mecca, in 1936, to prepare the Saudi students who wanted to study abroad. As a result, Saudi scholarship programs then supported study in Egypt and other Arabic countries until the government permitted young scholars to travel outside of the Arab Middle East (Al-Hariri, 2000). Half of the scholarship resources were then divided to accommodate study opportunities in Europe and the United States. The government's first mission in 1947, after the unification, was composed of two students who studied in Switzerland. One studied law and the other studied political science. In the same year, one Saudi student received a scholarship to study engineering in Istanbul. Following that, many more scholarship opportunities allowed students to go to Europe and the United States, especially after the explosion of oil sales around 1974 and increased resources in Saudi Arabia (Al-Hariri, 2000).

The idea of scholarships and sending students abroad to study became increasingly important to the Saudi government. The government began to appreciate the national benefits that could gained by sending students to other countries, specifically the United States, to have exchanging experiences, gain information about other cultures, and develop cultural and intellectual communication among diverse peoples. In order to achieve those goals with the United States, formal and positive relations between Saudi Arabia and the United States of America had to be improved. The relationship between the United States and Saudi Arabia was initiated first at the commercial level, then evolved to an agreement signed between the two countries in 1946 to include the exchange of cultural and professional training and hosting of students (Hijazy, 1983).

The first official educational Saudi scholarship to the United States began in 1947 with Saudi Arabia sending thirty Saudi students who transferred from the American University of Beirut to Texas State University (Maati, 2011). In 1951, Saudi Arabia opened its first Cultural Mission to the United States to look after the welfare of the group of Saudi students (Maati, 2011). In 1956, the number of Saudi students increased to forty-eight (Maati, 2011). Once the number increased dramatically, the Saudi government relocated its Cultural Mission to Houston, Texas (Maati, 2011). The name of the agency was changed to the Saudi Educational Office to the USA (Maati, 2011). The number of Saudi students continued to grow until, in 1981, it reached a total of 13,000 students (Maati, 2011). That was prior to the establishment of the current and only existing scholarship program in Saudi Arabia–the King Abdullah Scholarship Program, which was established in 2005.

The Saudi scholarship programs continued until the terrorist attacks of September 11, 2001 on New York, Washington D.C., and Pennsylvania, which had serious repercussions for the safety of the Saudi student sojourners in the United States. Fear of individual-driven reprisals was a source of major concern. For four years, most of those students left the United States and went back either to their home country or to other countries to complete their studies (Maati, 2011). For those four years, until the establishment of the King Abdullah Scholarship Program (KASP), the prevailing political atmosphere at the time was not conducive for Saudis to

study in the United States. After the visit of King Abdullah Al-Saud to the United States, when he was still Crown Prince, the cultural exchange relationship between Saudi Arabia and the United States gradually returned to normal. In 2005, both countries released public statements agreeing to facilitate the study of Saudi students in the United States (Maati, 2011). Both countries noted that such an endeavor could engender positive gains for both nations. On the Saudi side, royal approval was issued to send Saudi students to pursue their studies in the United States. U.S. officials in the United States Department of State, security agencies, and the U.S. Immigration Service, renewed their efforts to attract and encourage Saudi students to study at American universities. Subsequently, King Abdullah announced the establishment of the King Abdullah Scholarship Program (KASP) on May 22, 2005. The inaugural KASP had 5000 Saudi students. By 2011, there were 45,232 students in the program (Maati, 2011).

Altorki (1977) asserts that social relations within Saudi society are strictly structured in the areas of hospitality, generosity, and sensitivity in dealing with each other. Saudi social relations are based on an "elaborate system of reciprocal right-duty relationships" (Altorki, 1977, p. 281). For example, an individual in Saudi Arabia is expected to accept an invitation to an event from a friend, and if he fails to attend, that seemingly innocuous act (to an American) may end the friendship between the two if an apology is given but then not accepted. Social relations in Saudi Arabia include a consideration of superiority in relationships. According to Lipsky et al., such relationships are "not hierarchical but remain on a [two-step] level" (p. 299). That is, unlike in the United States where, for very specific historical reasons stemming from the consequences of slavery and race-based disenfranchisement, people are considered to be equal, that is not the case in Saudi Arabia. In Saudi society, there is a real sense of superiority resulting from a recognition of the various types of social roles individuals and groups take on fulfill.

Social Support Systems

Sojourners can face stress and emotional issues resulting from culture shock and the acculturation process. One strategy for facing this stress and the resulting emotional issues is to seek support from those within sojourners' social networks (Cohen and Wills, 1985; Snyder, 2001; Geeraert and Demoulin, 2013). Cross-cultural and acculturation literature highlight the importance of social support networks for sojourners as a tool to effectively manage their emotions and be able to adjust and adapt to their host cultures (Sandhu & Asrabadi, 1994; Furnham & Alibhai, 1985; Yang & Clum, 1995; Vega & Rumbaut, 1991; Adelman, 1988).

According to Heaney and Israel (2008), there are four types of social support: 1) emotional support, 2) instrumental support, 3) appraisal support, and 4) informational support. Emotional support refers to the amount of love, empathy, and caring received by the sojourners in their host culture setting. Instrumental support involves the provision of essential tangible goods or services to the sojourners in their host culture environment. Appraisal support refers to productive feedback that supports sojourners' self-evaluations. Informational support comes from advice and suggestions provided to sojourners and the members of the host country and community.

A quantitative study by Hendrickson, Rosen, & Aune (2011) of 86 international students from Hawaii University was conducted to examine the relationship between student sojourners' friendship networks and satisfaction, contentment, homesickness, and feelings of social connectedness. The study found that the larger a sojourners' friendship network

is, the more satisfied they are in their host culture. Thus, if we assume that a sojourners' friendship network can act as social support for sojourners, then we can argue that it is expected that sojourners who have strong social support networks are more adjusted to their host cultures and have greater interculturally-developed identities.

Another quantitative study by Stuart and Ward (2011) examined the influence of family cohesion on identity conflict within the host culture using a sample of 262 first-generation immigrant South Asian youth living in New Zealand. The study found that family cohesion significantly affected the level of identity conflict experienced by immigrant youth. The findings indicated that the better the relationship between those immigrants and their families, the less identity conflict they felt. Assuming that families can act as one of the most important sources of social support to Saudi student sojourners, it is fair to assume that the more social support Saudi sojourners have, the less identity conflict they face.

Social support proves to be particularly effective for sojourners and immigrant populations (Cho & Haslam, 2010; Vega, Kolody, Valle, & Weir, 1991; Ataca & Berry, 2002), in the educational context (Geens & Vandenbroeck, 2013; Pomaki, DeLongis, Frey, Short, & Woehrle, 2010) as related to identity conflict (Berry, Phinney, Sam, & Vedder, 2006). However, no study has been found that investigates the relationship between social support and identity conflict within educational situations of Saudi sojourners. This study seeks to fill that gap by investigating the relationship between social support and identity conflict with the Saudi student sojourner population in the United States. Li and Gasser (2005) suggest that more research is needed to investigate the relationship between social support and identity conflict in sojourners. Lin (2008) emphasizes the importance of studying other sojourners' groups in relation to identity conflict.

The Present Study

This research uses a mixed methods approach (c.f., Creswell et al. 2006; Gorard and Taylor 2004). In this study, quantitative methods are used to find the relationship between the two variables (see RQ1 below). The qualitative method was used to enrich the quantitative data through examining the words and perceptions of the participants in interviews (see RQ2 below). As cultural anthropologist Clifford Geertz (1973) states in *The Interpretation of Cultures,* a qualitative method can provide a "thick description" of social phenomena. Both the quantitative and qualitative phases have a different design, sample, and data analysis.

> RQ1: What is the relationship between intrapersonal identity conflict and social support systems for the Saudi students in the United States?

> RQ2: What is the nature and extent of social support for the Saudi students in the United States?

This research uses a quantitative design to measure participants' identity conflict, social support system, and the relationship between. Specifically, the Index of Sojourner Social Support scale (Ong and Ward 2005) was used to assess the social support networks of Saudi students in the United States and the Ethno-Cultural Identity Conflict Scale (Leong and Ward 2000) was used to provide the data needed to assess the quantitative relationship between intrapersonal identity conflict and social support systems for Saudi students in the United States. The researcher expects to find Saudi sojourners' social support networks in the United States significantly and positively affects the minimization of intrapersonal identity conflicts. The Statistical Package for the Social Sciences (SPSS) was used to provide the descriptive statistics (range and mean) for the survey data. RQ1 was addressed

using the Spearman's rank-order correlation test between identity conflict and the social support scores. According to Healey (2008), the Spearman's rank-order correlation is a statistical calculation that describes the nature of a relationship between two variables and determines whether one variable is a predictor of another variable.

Next, the researcher uses a qualitative design to provide robustness to the findings relating to social support in RQ1. The extent of social network support was a dominant theme in the research interviews and is highlighted in this paper.

Social Support is a variable defined by Albrecht & Adelman (1987) as "verbal and nonverbal communication between recipients and providers …[that] reduces uncertainty about the situation, the self, the other, or the relationship, and functions to enhance a perception of personal control in one's life experience" (p. 19). This independent variable was developed using the scale developed by Ong & Ward (2005) to measure the social support of sojourners by examining behaviors that make their stay in their host culture(s)1 more pleasant. In order to assess social support networks for sojourners in an acculturation context, Ong and Ward (2005) developed the Index of Sojourner Social Support (ISSS) composed of 18 statements for participants to rate their responses on certain behaviors based on a five-point Likert-type scale (*No one would do this/ Someone would do this/ A few would do this/ Several would do this/ Many would do this*). The ISSS has socio-emotional support and instrumental support as subscales. In order to test the validity and reliability of the ISSS, Ong and Ward (2005) conducted a preliminary study with results showing strong validity and reliability. They reported a 0.92 score for the socio-emotional subscale's Cronbach Alpha and a Cronbach Alpha of 0.91 for the instrument support subscale. Use of the ISSS helped in understanding the coping issues of the Saudi students and may lead to better understanding the causes of identity conflicts that they face.

The Ethno-Cultural Identity Conflict Scale (EICS) is designed to measure sojourners' intrapersonal identity conflicts (Leong and Ward 2000). It consists of twenty statements for which participants rate their agreement on a five-point Likert scale *(strongly disagree/ disagree somewhat/ neither agree or disagree/agree/ strongly agree)*. Within this research, the EICS is used to determine if social support minimizes intrapersonal identity conflict. This research assesses the relationship between social support and intrapersonal identity conflict, which occurs when an individual experiences an internal struggle in dealing with the different aspects of his or her identity, often engendering tension, anxiety, and/or depression (Leong and Ward 2000).

Interviews. The interview instrument was developed by the research (see Methods section) and analyzed based on the following categories: perception of the United States before leaving Saudi Arabia, study experience, living experience, personal strengths and primary motivators, social support networks/ processes, understanding of the United States and its people after spending time in the host culture, and cross sexual relationships. Social support networks and processes, as the focus of this article, was analyzed using notions highlighting aspects of support from professors, religion, family, and other Saudi Arabian international students.

Method

The first research question asks "What is the relationship between intrapersonal identity conflict and social support systems for the Saudi students in the United States?" This question was addressed using the Spearman's rank-order correlation test between identity conflict and the social support scores. According to Healey (2008), the

Spearman's rank-order correlation is a statistical calculation that describes the nature of a relationship between two variables and determines whether one variable is a predictor of another variable.

Interviews were used in this research to provide additional meaning to the quantitative approach used with the survey analysis. According to Bretaux (1981), fifteen is the smallest acceptable sample for qualitative research. However, Creswell (2006) claims that phenomenological design researchers usually "interview from five to 25 individuals who have all experienced the phenomenon" (p. 61). Because this is a mixed method design that involves both qualitative and quantitative phases, a sample of seven to nine Saudi sojourners, who met the inclusion criteria, was chosen in addition to the key informant. This sample size was based on the recommendation by Lee, Woo, and Mackenzie (2002) that mixed methods research requires fewer participants in order to acquire more robust and elucidating data. The data collection method for the qualitative phase was a semi-structured tape-recorded interview. In a qualitative study, the researcher is the primary instrument for collecting data (Creswell, 2006; Marshall & Rossman, 1999). Interviews are one of the most popular tools in collecting data for qualitative research (Kvale & Brinkmann, 2008). Furthermore, interviews are one of the most appropriate methods in collecting complex social interaction and human behaviors data (Miller and Crabtree, 2004). Miller and Crabtree (2004) describe interviews as "a dance of intimacy and distancing that creates a dramatic space where the interview partners disclose their inner thoughts and feelings, and the interviewer knowingly hears and facilitates the story and recognizes, repairs, and clarifies any apparent communication missteps" (p. 196). Kvale (1996) states that the purpose of selecting the interview format is to "obtain a qualitative description of the life world of the subjects with respect to their interpretation of meaning" (p. 124). By using semi-structured interviews, participants had the opportunity to generate new ideas about the topic through a process of self-reflection.

The interview questions were developed after receiving and analyzing the quantitative data because the purpose of the interview was to generate more in-depth data based on the participants' answers to the quantitative questionnaires. The interview questions were based on two core topics: 1) the participants' hidden social, educational, and cultural difficulties in their host culture(s), and 2) the varied experiences of the participants in dealing with identity conflicts, which arose during their acculturation in the United States. Each participant shared thoughts and experiences about those two main topics.

Open-ended questions were asked throughout the interviews. According to Daymon and Holloway (2002), open-ended questions can be used to engage participants fully and naturally in conversation with the researcher. Berg and Lune (2011) support that claim by stating that open-ended questions can guide the interview to reveal experiences without forcing a participant into one direction.

According to Creswell (2007), data analysis in qualitative research relies on data management. Following each interview, the data was reviewed and transcribed in order to evaluate the efficacy of the interview questions. Each transcribed interview was entered into the computer using Microsoft Word software. Using this computer software helped with the data management phase of analysis (Creswell, 2007).

This study used Moustakas' (1994) approach to phenomenological data analysis (revised from the Van Kaam method). According to Moustakas (1994), there are seven steps in analyzing phenomenological data: 1) horizontalization, 2) reduction, 3) clustering, 4) validation, 5) individual texture description,

6) individual structural description, and 7) individual textural-structural description.

For horizontalization the transcribed data was read several times until it became familiar. For the first reading, a comprehensive understanding of the participants' responses was sought. Next the transcribed data was read for the second time using note taking along with memos of short phrases, ideas, or key concepts that could offer

Results

The quantitative research question asked, "What is the nature and extent of social support for the Saudi students in the United States?" The Index of Sojourner Social Support's means and range scores (ISSS) were computed (see Table 1). The purpose of using this instrument was to examine behaviors that make Saudi students' stays in the United States more pleasant. The average level of social support received by the respondents was 55.26 points (55.26 ÷ 18 = 3.07 score). Such a score indicates that the students rely on few people to support them during their stay and thus have minimal support networks. The range of the ISSS scores was 26 to 87 points (1.44 – 4.83 scores), indicating that the sample ranged from relying on "someone," when they were seeking social support, to relying on "many." The results show that out of the 18 items in the ISSS, "visit you to see how you are doing" was uncovered to represent the lack of social support received by the students, followed by "reassure you that you are loved, supported, and cared for". Other social support behavior they commented on was "Explain things to make your situation clearer and easier to understand," followed by "tell you what can and cannot done in United States". Table 1 reflects the frequencies, means, medians, modes, and standard deviations for each item on the ISSS.

The quantitative research question asked the following: "What is the relationship between intrapersonal identity conflict and social support systems for the Saudi students in the United States?" As with the fourth research question, a Spearman's rank-order correlation was run to assess the relationship between social support (independent variable) and identity conflict (dependent variable). There was a weak negative correlation between identity conflict and social support, $rs(125) = -0.200$, $p < .05$. Table 2 presents the Spearman's correlation test between EICS and ISSS.

Finally, the interview data reveals that the support services that the Saudi students received from their professors, families, and through their faith, sufficiently insulated them from having any acute mental health issues related to the potentially traumatic experience of being a foreigner in another land. The student sojourners may have had relatively few individuals in their social support networks in the United States, but those individuals were sufficient sources of support nonetheless. One of the participants declined to pursue professional counseling to discuss academic or personal issues. This lack of interest in seeking professional help is consistent with the literature about cultural norms regarding support systems among international students. Overall, professional counseling services are not accepted as much in Middle Eastern cultures as they are in Western cultures. This phenomenon is likely because counseling as practiced in the West tends to employ a client and individual-centered approach for problem solving than that which exists in Middle Eastern cultures where there is an emphasis on communal problem solving. Furthermore, in the Middle East, there is an expectation that people are supposed to turn to their families, ethno-religious social resources and friends when they need help instead of utilizing professional (mental health or social work) services. Many in the Middle East consider asking for help outside the family to be a cultural affront and therefore, an offense worthy of social stigma.

Table 1. ISSS: Frequencies, Means, Medians, Modes, and Standard Deviations

No.	Survey item	n	M	Median	Mode	SD
1	Listen and talk with you whenever you feel lonely or depressed.	144	3.01	3	3	1.05
2	Give you tangible assistance in dealing with any communication or language problems that you might face.	144	3.24	3	4	1.1
3	Explain things to make your situation clearer and easier to understand.	144	3.44	4	4	1.13
4	Spend some quiet time with you whenever you do not feel like going out.	144	3.02	3	3	1.17
5	Explain and help you understand the local culture and language.	142	3.22	3	3	1.11
6	Accompany you somewhere even if he/she doesn't have to.	144	2.94	3	3	1.06
7	Share your good times and bad times.	144	2.97	3	2	1.03
8	Help you deal with some local institutions' official rules and regulations.	144	3.08	3	3	1.03
9	Accompany you to do things whenever you need someone for company.	144	2.95	3	3	1
10	Provide necessary information to help orient you to your new surroundings.	141	3.18	3	3	1.08
11	Comfort you when you feel homesick.	143	2.99	3	3	1.23
12	Help you interpret things that you don't really understand.	141	3.22	3	3	1.14
13	Tell you what can and cannot done in United States	143	3.34	3	3	1.14
14	Visit you to see how you are doing.	142	2.73	3	3	1.12
15	Tell you about available choices and options.	143	3.04	3	3	1.09
16	Spend time chatting with you whenever you are bored.	143	3.01	3	3	1.17
17	Reassure you that you are loved, supported and cared for.	143	2.9	3	2	1.14
18	Show you how to do something that you didn't know how to do.	144	3.2	3	3	1

Table 2. Correlations between EICS and ISSS[b]

			EICS	ISSS
Spearman's rho	EICS	Correlation coefficient	1.000	-.200*
		Sig. (2-tailed)	.	.024
	ISSS	Correlation coefficient	-.200*	1.000
		Sig. (2-tailed)	.024	.

*. Correlation is significant at the 0.05 level (2-tailed).

b. Listwise N = 127

Although the students did not report establishing any warm relations with their professors, they did, however, report that their professors cared about them and encouraged them to ask for additional support if needed. The students also reported that these non-familial relationships with the peers and friends complemented their educational endeavors and ensured that they were insulated from culture shock. By engaging in these intercultural exchanges, the students learned how to effectively communicate with people from differing cultural, philosophical, and ethno-religious backgrounds, thus increasing their tolerance for others. The students learned from these cultural differences and tried to positively express themselves in new and sometimes tradition-bending ways, which served to further transform their individual identities. The students overcame, with varying degrees of success, culture shock by setting goals, reading books, engaging in productive tasks and increasing their interactions with the locals as already mentioned. Most of the participants tried to be themselves while also learning about American culture. They increased their interactions with locals and tried to communicate with their professors and peers on a regular basis. For example, Participant 2 articulated the following:

> The good thing about the American people that they will break the ice for you. For example, the first day that I came to Florida I found many neighbors welcoming me and greeting me which made feel accepted by them and they want to know more about me. Other thing is when I interact with the professors in my university, most of them accepted me as an international student and they are very understanding people and they don't judged me even if I did some mistakes because they knew that this is not my original culture and they knew that English is not my first language and that made feel more comfortable.

Consequently, some students started to feel strange about their previous, as well as new cultural and religious identities. Their experiences led them to points where they were no longer "Other," yet they were still different. They seemed to no longer be sojourners simply in another country but also among dichotomous cultural realms. In keeping with such monumental changes, some students – those who did not change as much as others –had mixed opinions about students who had undergone considerable changes. Although two of the participants reported that they are still afraid of what their cultural transitions will bring when they return to Saudi Arabia, they noted nevertheless being willing to effect positive change in their country.

Discussion and Conclusion

The data show that the Saudi students have low to moderate levels of intrapersonal identity conflict (M= 2.37). Further, results indicate that the students are "moderately competent" (M=3.55) when it comes to adapting to their lives in the United States. Furthermore, the findings show that the students rely on few people (M =3.07) to support them during their stays, thus indicating that they minimal social support networks.

The results also show that out of the 18 items in the ISSS, students overwhelming had limited social support networks. The evidence for this was the frequency with which the items "visit you to see how you are doing," followed by "reassure you that you are loved, supported, and cared for" were chosen. However, among those who had greater support networks and social support experiences, students indicated that supportive individuals were able to "Explain things to make your situation clearer and easier to understand,"

following by "tell you what you can and cannot do in the United States."

Similar findings were evident when examining the association of ECIS scores and ISSS scores. The data show that there is a weak negative statistically significant correlation between identity conflict and social support, $rs(125) = -0.200$, $p < .05$. As social support for the Saudi sojourners increased, their intrapersonal identity conflict decreased.

Although the majority of sojourners had small (limited) support systems, those support systems were nevertheless robust and able to assist the students with overcoming obstacles with their academics as well as assimilating, if only temporarily, into American society. Despite the fact that non-Arab, non-Muslim and Arab and Muslim social dynamics can be strained, which the literature points out, the student sojourners were nevertheless psychologically protected by their attachment and close-knit family-based upbringing. This essentially served as their shields from being psychologically damaged and having their academic goals and objectives derailed by psychosocial issues. Culture shock and feeling a sense of "Otherness" per Edward Said (1977) did, at times, negatively affect student sojourners, but social supports helped them to persevere. While this does not contradict the literature, it is not exactly in sync with it since the literature regarding academic community members serving as social supports is not as robust as the literature regarding traditional (Western) support figures such as therapists, counselors, etc.

Students were pleasantly surprised to find that, while they had limited social support systems/networks, they were, nonetheless, strong and able to help them remain focused about the tasks before them. The data thus proved that it is not necessarily the number of social supports that is important but rather, their nature and the depth of relationships forged with others. In this sense, the relationships forged with American students and professors proved to be especially noteworthy and poignant with respect to the deeper context of American-Saudi relations. Rather than there being a socio-political and cultural disconnect, there was a meeting of minds, a unity based on the universality of education and intellectual curiosity – a thirst for knowledge. Lastly, by being exposed to American culture, students were also able to live in a society (and educational, smaller communities) in which male-female relations are more relaxed and not as dictated by tradition or custom as is the case in Islam and particularly in Saudi Arabia.

The employed mixed methods methodology also served to demonstrate the importance of not only gathering qualitative and therefore "thick description" (Geertz, 1973) data, but also relying upon quantitative instruments and analysis to create more robust – reliable – results. The results can be especially useful with respect to educating American mental health practitioners and school administrators about creating social support programs and networks that are based on multicultural and faith-based means of overcoming personal struggles. Doing so would be consistent with the study respondents' musings on the differences in mental health issues and treatment in the West compared to the Middle East, and specifically in a societal framework that revolves around problem-solving through faith and family.

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Determinants of auditor choice in emerging markets: evidence from Saudi Arabia

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Keywords
Audit market. Auditor choice, Emerging market, Audit committee.

Abstract

Purpose: *This study aims to analyze the choice of auditor in Saudi Arabian firms. The study investigates the main audit characteristics that influence firms'decision to go for either Big Four or a local audit firm.*

Design/methodology/approach*: the design and research method are empirical using a questionnaire survey to collect data on the determinants of the choice of auditors. The study adopted Oxera (2006) questionnaire. A representative sample of 124 firms out of a total of 183 listed firms in Saudi stock market have been selected. The questionnaire was distributed to members of audit committee to ensure reliable responses regarding the selection process.*

Data analysis*: data collected were analyzed using both descriptive and inferential statistics-Logistic Regression Analysis method.*

Findings*: only four variables were proved significant in the selection decision; namely; auditor fees, audit firm reputation with investors, geographical proximity and long-term relationship with current auditor.*

Research limitations/implications*: difficulty to generalize the findings of the study due to the uniqueness of the Saudi economic, political, educational and culture environment.*

Practical implications*: the increased competition in the audit market in Saudi Arabia called for the necessity to understand what influences the selection decision. Most researches were conducted in developed countries and little in emerging markets; so, this study will help auditor identify their competitive advantage in Saudi Arabian market.*

Originality/value: *this study contributes to better understanding of the firms' auditor choice and will stimulate further research in the same vein to investigate other factors on the side of the firm characteristics that affect the auditor selection decision. As well as more comparative analysis with other emerging markets in the Middle East.*

1. Introduction

The choice of a firm's auditor is considered one of the most important decisions taken by any firm. This is due to the vital benefits resulting from having the financial statements audited by a reputable auditor. First, it reduces information risk; as argued by the agency theory; firms with higher agency costs are motivated to choose a high-quality auditor to strengthen their corporate governance and thus lessen potential agency conflicts (Francis & Wilson, 1988; Mansi et al., 2004; knechel et al., 2008; Matonti et al., 2016) specially in complex organizations where management interests could differ from shareholder interests (Ekumankama & Uche, 2009). It has been documented by Farooq and Kacemi (2011) that stock price performance improved in the MENA region because of choosing one of the big-four auditors. Second, an audit might result in improving internal processes operational efficiency and effectiveness since the auditor must assess the client's internal control reliability, moreover, it helps firms better comply with legal and regulatory constraints (Wallace, 1981).

Olowooker (2016) mentioned that there is a market share gap between the Big Four and smaller firms in Nigeria, as 90 percent of listed companies are audited by the Big Four; while the 15 national firms audit the remaining 10 percent. In Saudi Arabia, as reported by the Saudi Ministry of

Commerce and Investment (2018) there is 176 auditing firm. A large number that shows a severe competition in Saudi audit market, that triggered the need to investigate the market share of the Big Four as compared to the Non- Big Four auditors in Saudi market and the factors behind the firm selection of its auditor to help auditors rely on their competitive advantages.

In addition, most of the research investigating this area has been conducted in developed countries as US and other developed economies such as UK (Beattie & Fernley, 1995), Australia (Craswell, 1988), Finland (Knechel, et al., 2008), and Italy (Matonti, et al., 2016), and Few research were conducted to investigate the factors affecting the firm selection of auditor in emerging markets; such as in Greece (Citron & Manalis, 2001), in Turkey (Aksu, et al., 2007), in MENA Region (Farooq & Tabine, 2015) and in Nigeria (Tommasetti, 2016). Beattie and Fernley (1995) suggest that auditor choice is motivated by three possible sources – audit environment, audit firm characteristics, and client characteristics. Revier and Schroé (2010) also concluded that three groups of variables can explain the auditor choice - the audit firm variables, the institutional variables and the firm variables. The objective of this study is to examine the determinants of external auditor choice in Saudi listed firms with a focus on only some audit firm characteristics. This paper is organized into six parts. Other than this Introduction, the second part is the Literature Review, followed by the Methodology, the fourth part is The Analysis and Results, part five is the Discussion and Conclusion, and finally the Research Limitations and Direction for further Research.

2. Literature Review

The agency problem and the need for quality audit

It has been recognised that firms acquire financial statement audit even when it is not mandatory because of its economic value (Sundem, et al., 1996). Watts and Zimmerman (1987) presented evidence that auditing has been developed to reduce agency costs and conflicts of interest among parties to the firm and not because of governmental requirement. According to DeAnglo (1981) firms must deal with a changing amount of agency costs, which vary over time and place and create an incentive for managers to find ways to lessen these changing agency costs by hiring a high-quality auditor to ensure the appropriateness and adequacy of his provided service. Other studies similarly supported this view about the ability of reputable auditor to signal outside investors that a firm is governed properly and has less agency problems (Datar et al., 1991; DeFond, 1992; Simney & Tanewski, 2000; Fan & Wong, 2005; Cheng & Leung, 2011; Farooq & Tabine, 2015). Nichols and Smith (1983) provided evidence that the stock market reacts more favourably when a company switches to a large auditor rather than to a small auditor. Broye and Weill (2008) suggested that the likelihood of having a Big Four auditor increases when the firm is listed. The study of Moizer (1997) investigating auditor reputation, revealed that company managers perceive a Big Four auditor as different from others as they are expected to provide higher quality services as compared to Non-Big Four auditors. Consistently, most researches define Big Four auditors as high-quality auditors (Simunic and Stein, 1987; Revier and Schroé, 2010; Olowookere & Inneh, 2016). Thus, in the literature, audit selection is based on a distinction between Big Four auditors and Non-Big Four auditors.

According to Farooq and Tabine (2015) the importance of reputable auditors increases many folds in emerging stock markets, where agency problems rise and information disclosure decreases. In the same vein, Leuz, et al. (2003) documented on the increased agency problem in emerging markets which necessitate the use of superior reputable auditors to give credibility to information disclosed by firms. Nevertheless, still the decision to have an auditor and the decision to switch auditors are considered complex decisions (Knechel, 2002).

Therefore, this study is conducted in Saudi Arabia, which is an emerging economy, and collected data from only listed firms; regarding the determinants of their choice of auditor; as listed firms face more agency problem due to the separation between the management and the external stockholders.

Factors affecting firms' selection decision

Niemi and Sundgren (2008) investigated the Finnnish auditor choice environment. Also, Knechel el, at. (2008) analysed the auditor choices for small and mid-sized Finnish firms. They proved that the need for a higher quality auditor is driven first by complexity, then, by the use of debt and the need of equity and debt financing. Revier and Schroé (2010) used data from 12 European countries including the Czech Republic, Estonia, Hungary, Latvia, Poland and Slovakia, to test the impact of the country a company is based in, next to the impact of internal firm characteristics and debt on the auditor choice. They proved the positive influence the internal complexity has on the auditor choice.

Wang (2013) argued that there could be a lot of factors that influence companies' auditor choice such as audit fees; auditor's reputation; industry specialization of an auditor, audit opinion, geography proximity, size of an audit firm, listed companies' own characteristics, political and legal factors. The paper provided evidence on Chinese listed companies' preference in choosing external auditors with a consideration to the Chinese special political influence on state-owned Chinese listed firms.

Choi et al. (2012) find that about 80 percent of firms choose the auditor located in the same area and more reputable. Another study provided evidence from U.S. companies that firms with independent audit committees are more likely to hire industrial specialists (Abbott and Parker, 2000). In the same vein, Craswell et al. (1995) proved that in addition to size and reputation of the auditor, a premium is given to industry specialization, indicating that industrial-related knowledge is also an important factor considered by client firm. Data from U.K. showed that changing auditor can be strongly encouraged by fees reduction, also audit fees proved to be an important factor in selecting a new auditor (Beattie and Feamly, 1995, 1998) Thornton and Moore (1993) also investigated how audit fees influence the audit choice. On the other hand, Gatumia (2012) concluded in his study conducted in Kenya that audit fees do not affect the choice of external auditor. Matonti et al. (2016) investigated auditor choice in Italian non-listed firms. The results showed that organizational complexity including firm size, investment in inventories, subsidiary status and complexity are main drivers of auditor choice. Evangelia (2013) used regression model to investigate internally-driven and external influencers of audit choice in 22 European countries. The level of internal complexity in a company had negative association with the selection of a Big Four auditor, while higher leverage increases the probability of engaging with a Big Four auditor.

Olowookere and Inneh (2016) investigated the determinants on the side of the auditor characteristics affecting manufacturing firms' choice in Nigeria. The study tested the effect of eight independent variables (technical accounting skill, sector-specific expertise, international coverage, management preference of specific auditor, long-term relationship with current auditor, reputation of audit firm with investors, reputation of audit firm with corporate broker, reputation of audit firm with other external advisers) on the choice of hiring a Big Four or a none-Big Four auditor. The results supported only international coverage and long-term relationship with current auditors. Based on the preceding researches the following hypotheses have been developed to be tested in this study:

H1: Firm choice of external auditor is affected by audit firm characteristics.

3. Methodology

The data for this study was collected based on both primary and secondary sources. The secondary data was collected from the firms' published financial statements, while the primary data was collected using a well-structured questionnaire. The questionnaire on the determinants of the choice of auditor used by Oxera (2006) has been adopted for the study. Listed firms in the Saudi Stock Exchange Market totalled 177 firm as published in Argaam website. A representative sample of 124 firm has been chosen from all industries as shown in Table (1). The questionnaire was

distributed to a member in the audit committee to ensure reliable responses from a knowledgeable member involved in the auditor selection process.

Data were collected between October 2017 to February 2018. Both descriptive statistics and inferential statistics were used to analyse collected data. Logistic Regression method was used to analyse the data since the dependent variable is qualitative in nature (Gujarati & Porter, 2009).

Variables and Measurement

3.1.1 Dependant Variable

The dependent variable is the firm choice of the auditor which is classified into either Big Hour or Non-Big Four. A dummy variable will take the value of (1) when respondent is using Big Four and (0) if otherwise.

3.1.2 Independent Variables

The dependent variable; audit firm characteristics; is measured by eight variables as suggested by the literature which are listed below:

Audit firm fees (X_1)
Audit firm reputation with investors (X_2)
Audit firm reputation with corporate broker (X_3)
Audit firm reputation with external advisor (X_4)
Industrial specialization (X_5)
Geographic proximity (X_6)
Management preference for specific auditor (X_7)
Long-term relationship with current auditor ($X_{8)}$
Each variable is assigned (1) if the respondent opinion is it does affect his choice and (0) if otherwise.

4. Data analysis and results

Analysis was conducted with the help of SPSS 23. First frequency test has been conducted and the results showed that 46.8% of respondent choose one of the Big Four and 53.2% chose other local auditor. 52.4% perceived audit fees as important factor in the auditor choice, 50% considered audit firm reputation with investors as important factor; audit firm reputation with corporate broker collected 54%, 49.2 selected audit firm reputation with external advisor; industry specialization collected 48.4%, geographic proximity 48.4%; management preference for specific auditor 44.4%; and finally long-term relationship with current auditor 49.2%.

Industry	Count	survey sample	% Sample
Banks	12	8	6.45%
Diversified financials	4	2	1.61%
insurance	33	24	19.35%
telecommunication services	4	3	2.42%
utilities	2	1	0.81%
REITS	5	4	3.23%
Real estate management & development	10	7	5.65%
retailing	6	4	3.23%
food & staples	4	3	2.42%
food & beverages	12	8	6.45%
health care equipment & SVC	6	4	3.23%
pharma biotech & life	1	1	0.81%
energy	4	3	2.42%
materials	42	30	24.19%

capital goods	12	8	6.45%
commercials & professional SVC	2	1	0.81%
transportation	5	4	3.23%
consumer Durables & apparel	5	4	3.23%
consumer services	6	4	3.23%
media	2	1	0.81%
	177	124	100%

Table 1: Sample selection

Then by conducting the logistic regression test variables X_1; X_2; X_6; X_8 where accepted to have an effect on the firm choice of auditor selection as shown in table (2).

Auditor_choice		B Coef.	S.E.	Wald	df	Sig.		Exp(B)
Step 1[a]	X1	.836	.435	3.693	1	.050	Accept	2.307
	X2	.991	.445	4.947	1	.026	Accept	2.694
	X3	.406	.448	.820	1	.365	Refused	1.500
	X4	-.091	.439	.043	1	.836	Refused	.913
	X5	.131	.440	.088	1	.767	Refused	1.139
	X6	.870	.445	3.815	1	.050	Accept	2.386
	X7	.503	.443	1.290	1	.256	refused	1.653
	X8	1.156	.428	7.306	1	.007	Accept	3.176
	Constant	-2.240	.552	16.461	1	.000	Accept	.106

Table 2 : Logistic Regression Result Predicting External Auditor Choice in Saudi listed firms

Number of obs = 124 p-value less than 0.05

Cox & Snell R Square = .253 , Nagelkerke R Square= .338

LR chi2(8) = 36.185 sig. = 0.00 Log likelihood = 135.199 .

The results can be summarized in the table above as follows:

Y = (.836) * X1 + (.991) * X2 +(.406) * X3 +(-.091) * X4 +(.131) * X5 +(.870) * X6 + (.503) * X7 + (1.156) * X8 -2.24

Wald = (3.693) X1 , (4.947) X2 ,(0.82) X3 , (0.043) X4 ,(0.088)X5 ,(3.815) X6 , (1.29) X7 , (7.306) X8 , (16.461)constant

It is clear that the estimated logistic model is consistent with economic logic; the logic of the estimated parameters in terms of parameter reference, the increase in the independent variable by plus and decrease by minus of coefficient. The coefficient of determination (R square) indicates that considering all the variables, it explained just 25.3% of the determinant of external auditor choice in Saudi listed firms. So the second metric was chosen. This is as a result of four significance of other eight variables. This presents the result of logistic regression. It also confirms that the estimated model represents the data as a complete representation and supports the latent intrinsic value of a model according to the Hosmer-Lemeshow test, which is based on the Kai-square test and shows that the observed (original) frequencies and expected (estimated) frequencies of the dependent variable were exactly identical, The square is small and equal (0.000) and the value is (0.000) The chi-square value which shows that overall model fit is significant less 1% level. Equally, the correct classification of the sample was categorized into the two classification groups (0, 1) by 100%; the sample observations were categorized in full without any error rate. This affected the value, morale and accuracy of the Wald test for the significance of the parameters.

5. Discussion and conclusions

The market share of the Big Four proved to be less then the other national auditors in Saudi Arabia. A finding that contradicts with the literature regarding the high agency cost in listed firms in

emerging markets which is supposed to increase the need of firms to hire reputable, high quality auditors, as suggested by Leuz, et al. (2003) and Farooq and Tabine (2015). The findings of the logistic regression analysis showed that only four out of the eight variables were significant namely; auditor fees, reputation with investors, audit firm geographical proximity, and long-term relationship with current auditor. This finding agrees with the results of Olowookere and Inneh (2016) in Nigeria, who found international coverage and long-term relationship significant, and with Thornton and Moore (1993) regarding the audit fees. But contradicts with Gatumia (2012), in kenya, regarding the audit fees having no effect on the firm choice.

It can be concluded that the study of the firm choice of the auditor still needs more investigation to find an acceptable justification to a firm choice to one Big Four or a domestic audit firm.

6. Research limitations and direction for further research

One limitation of the paper is that results cannot be generalized to other emerging economies given the uniqueness of the Saudi economic, political, educational, religious and cultural environment.

Further investigation of the effect of firms' characteristics and degree of complexity of operation on the choice of a Big Four auditor is required since analysing the side of the auditor characteristics solely is not enough to explain the firms' selection process. Moreover, comparative studies are to be conducted in the middle east to reach points of similarities between such emerging markets as well as documenting any differences to better understand the factors behind the firms' choice and to investigate the importance of quality audit in the middle east to encourage foreign investment in the middle east by increasing trust and lowering agency costs.

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How Internet-of-Things (IoT) Making the University Campuses Smart?

QA Higher Education (QAHE) Perspective.

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***Abstract*—**This paper proposes a model to develop a university smart campus enabled through Internet-of- Thins (IoT) technology. The infusion of IoT in education embraces the internet-based communication between controllers, sensors and the physical objects. This landscape of modern technology has changed the universities education on a massive scale. Various objects are integrated with sensors, wearable technologies are collecting data with augmented reality and intra-communication is taking place through cloud computing. This IoT paradigm defines the diverse range of parameters for universities identifying opportunities to make them smart urging new interaction between objects and people. This research focuses to make smart rooms, smart parking as well as delivering smart education to students.

***Index Terms*—**Internet, Higher, Education, Smart, Campus, University.

I. Related Work

The computing world is rapidly developing the new technology during the last decade and internet of things is one of those disruptive innovations that would change the world from simple objects activities to interconnected activities making the complex infrastructure. The concept of IoT has encompassed various areas of life such as agriculture, healthcare, transportation, cities and businesses. It is envisaged that modern institutions would face major implications and an impact due to the replete development of this technology. To produce and develop classy environment within the university the campuses require to embed IoT technology which could be securely utilised e-campus activities during this digital era. Modern universities are spread over a large area and it is very difficult to manage, track and control everything happens within its campus [2]. There is a need of adopting and utilising the contemporary developed technology IoT to make e-campus for academics as well as students. The high enabled e-campus would bring many changes for students ranging from advantages two interconnectivity using smart objects.

A recent communication infrastructure of IoT has envisaged the future where everyday life will be based on intra communication of transceivers, microcontrollers, digitally communicating via stacks of suitable protocols. This infrastructure would enable the communication of one user to another and would stand as the focal point of e-campus structure. Several devices would be connected with each other exchange and transform the data and by working in this way variety of devices and gadgets such as digital displays, smart watches, audio recorder and camera would be able to communicate with each other. To provide dynamic services do teachers and learner's the concept of IoT interconnectivity would nurture and improve the communication via generated and gathered data by IoT devices. This development in technology enabled through IoT methodologies would coin smart campus within the network area.

The pervasive interaction between environments, people and objects are enabled through the technological revolution of Internet-of-Things (IoT). The embedded sensors and actuators gather the data and transmit it to relevant specialized applications to get it processed and make it actionable. The contemporary industry has acknowledged the importance of IoT as a potential ingredient of bringing valuable change in business and industrial processes [3]. This advent has also led the physical environments to become more interconnected to form smarter surroundings. Every aspect of our lives is changed in regards to the economy, accuracy, efficiency, and sustainability. Several industries such as smart cities, smart homes creation, environment monitoring, management of energy, education, traffic management, airport traffic control management, healthcare systems and weather forecast systems have already leveraged IoT in it. Educational institutions are trying to promote sustainability by leveraging the data and streamlining their day-to-day processes.

A number of universities have already established the use of wearable devices and smart objects within their classrooms. The enormous amount of data is produced inexpensively via enabling technologies of sensors, chips, and actuators [11]. The effect of IoT in contemporary universities is focused on this research and this is classed in two sections. Section one discusses the education business model with respect to higher education whereas section two explains the practical notion of IoT in teaching and learning enhancements, students healthcare management, classroom management techniques, campus security and attendance monitoring system. Many of the things encompassing us assemble data about us without our acknowledging it: things installed into objects, worn on our bodies, controlled by sensors, produced for knowledge, and made for information gathering limit and correspondence [5]. Every one of these things conveys through the cloud, decide, and share data. This is the Internet of Things. Given the fast improvement of the IoT, it is critical that we perceive its key qualities and plan for its inescapable effects in advanced education. The way that advanced education underpins teachers with the IoT in learning conditions will altogether influence how we as a general public capacity, impart, team up, and move into a universe of expanding interconnectedness.

Envision a situation where a learner enters a classroom and an IoT device he holds consequently enlists his participation. When they are situated, in light of their action in the class, a customized message is pushed to their email or shrewd device to incite them energetically for that day shape a gathering for that day's exercises, post to a dialog board, and transfer a task.

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They can open a program and keep an eye on the measurements for a craftsmanship show they posted in an assigned territory on campus to perceive what number of individuals has filtered the QR code to communicate with the piece [12]. Barely any instructive foundations effectively join innovation into adapting, in particular, connect and associate with each other. Also, fewer educators share information, with the exception of research ventures. Huge appropriation of innovation in instruction is required with the goal that the energy of IoT can be acknowledged and learning can turn out to be more true and important through engagement past the classroom. Instructive locales and organizations can never again depend exclusively on their center abilities and educator learning. Rather, they should grasp, not restrict the devices that students bring into the classroom and enable learners to utilize them as learning apparatuses to catch knowledge speedier and quicken learning. The multiplication of cell phones will likewise empower instructive organizations to gather information to decipher a student's practices and exercises. Utilized keenly, such information will bring about customized learning focused to singular needs, learning styles, and yearnings.

II. Higher Education And Internet-Of-Things (IoT)

The disruptive influence of the replete development of technology has changed the paradigm of higher educational institutions from knowledge-transfer semantic to self-directed and active collaborative model. This influence has made universities to think their existing models of teaching and learning and adapts modern techniques. Teacher’s provision of personalized contents, improved student outcomes, lectures contents creations and students engaged in learning are few certain aspects; those could be seen influenced by IoT [10]. The innovation in education is driven by several strategies, tools, and technologies of visualization, social media, internet, learning, digital strategies and consumer adaptations. Education is supported by internet in diverse ways considering IoT is a subdivision of this technology. The solutions provided by IoT enable both universities and higher education institutions to collect mass data from wearable devices, sensors, and actuators to perform meaningful actions [8]. These technologies of embedded sensors and QR codes enable students to explore their environment more efficiently.

Learners can access the contents and material at any time and from anywhere. Lecturers can use the smartphones and wearable devices to enhance teaching and learning, student engagement and student satisfaction. An intelligent environment equipped with software and hardware modules is classified as a smart classroom. Face recognition algorithms, sensors, cameras, projectors are few examples of IoT environment in the classroom. These modules determine and monitor the diverse range of parameters such as student’s achievement and performance, concentration, and their physical environment. The potential impact of IoT on higher education has been acknowledged by various higher education and industry experts in regards to the issues related to data ownership, privacy, and security. One of the major benefits of IoT in education is the unique and personalised interaction with learners [4]. Learners could send alerts to their administrators when they are struggling academically come across learning issues. It would help learners to get recommendations on academic topics as well as resolving other issues.

The IoT presence cannot be neglected in the universities as this is already witnessed in the form of temperature controlled devices, light power, security cameras and access to a building. The teaching and learning could be improved in the classrooms with the use of smart objects [3]. The role of IoT encompasses energy savings, student’s health and safety monitoring, optimization of campus and classroom environments as well as enabling the remote presence of students. The embedded IoT in the campuses has coined a new paradigm of connected campuses proving students the opportunity of enhanced and improved teaching and learning. Everything gets connected in IoT and facilitates administrators for campus management. The current application of IoT in universities is delivering smart education to the new generation. Students become co-creators of knowledge when IoT is incorporated in education. It also replaces data-driven decision-making with the ad-hoc decision-making process. One size fits all model of static instructions in the classrooms is replaced via replicable, scalable and recordable instructions and customized crowed-sourced curriculum. Valuable features are integrated with the adoption of IoT in contemporary education models.

III. Secure Campus and Classroom Access Control

The University of Wiscons in Madison developed an IoT Lab that backings the college mission. Learners can team up with workforce and industry individuals in the lab as they create inventive utilizations for the IoT. Given the potential advantages, of which these illustrations speak to a hint of a greater challenge, it won't be some time before campus assets are called to help imaginative employments of the IoT in learning situations. Instructors must comprehend the suggestions, difficulties, and impediments of the advancements associated with the IoT so we can better help the personnel, staff, and learners will's identity utilizing it and enable them to understand the "specialty of the conceivable"[12].

From the university building to the college, teachers must build up a solid information base about how to use the IoT to upgrade the nature of training and plan learners to be dynamic supporters of, and recipients of, this instructive joining. For instance, devices interfacing safely to information, substance, and learning frameworks can empower and enhance learning administrations that progressively adjust to students' needs as they develop and instructors' needs as they refine their educational module. An instructive situation unequivocally centered on supporting learning with the IoT could be amazingly valuable; it would be known as the Educators' and Learners' Internet of Things, or ELIoT. As the IoT alternatives develop, so will the ELIoT choices. The ELIoT will give students and staff access to various wellsprings of learning and showing information in a way that enhances instructing, the educational modules, and learning [7].

Access to laboratories, classrooms and other places in the universities are few niche challenges in the recent era and these could be managed through integrating latest technologies in it and to make it the secure and safe place for students. To improve university security, Near Field Communication (NFC) and Radio-frequency Identification (RFID) are two IoT enablers which could form IoT infrastructure to simplify access control [6]. NFC is used to create a classroom control which collected student’s attendance through connected sensors and results displayed on both the university TV panels and the web-based application. It is also proposed that RFID tags could be used for monitoring the student’s attendance and with the use of defence technology, their locations could be tracked within the campus [8]. An evolutionary access control system based on IoT architecture and NFC tags; is implemented by several universities in its campus which has transformed the traditional campus to a smart campus.

The universities have designed a smart “app” for its students, which could assist them to know which desks are available in the library and they can reserve them. Using the app, students could not only just mark their attendance but also register for certain rooms and auditoriums in the university. This integrated messaging system has slashed the IT budget of universities enormously and now students are sent notifications through “app” instead of traditional method of emails [4]. Cisco Physical Access Control technology is implemented by one of the colleges in west midlands having campuses in different location to control access. The main campus includes 400 doors and this single “app” has simplified their management process. The foot traffic in the communal areas, offices, and classrooms is also monitored and notifications sent to the building management system []. After the implementation of IoT infrastructure, it is found out that 95% of students have agreed that the new system has provided safer and secure environment.

Constructing smart campus based on the IOT and cloud computing technology is an inevitable trend. But there are many issues have to be perfect. One of the questions is that the top-level design is not perfect. The

designer ignores to dig deeply the value of information resources, so that the resources are difficult to be shared. Moreover, the solution of education cloud is not perfect, and schools attach more importance to office management than teaching and research. Anyway smart campus is the higher stage. We should pay more attention on design in this stage. The other problem is the data standard. At present, there are many manufactures of RFID label and sensor, the standards are various and not compatible caused by this phenomenon. Cloud computing technology is difficult to get a complete unified control and effective management, so we should create a set of standards for data format and make the sensory data be shared and managed easily. In the future, smart campus needs the big breakthrough on information collection, chip research and programmed algorithm.

Universities and higher education institutions are under-expanded strain to guarantee their campuses are safe. A surge in university crises in the course of the most recent quite a long while, alongside the developing feelings of trepidation over tormenting and viciousness, mean it's more essential than any other time in recent memory to guard learners [1]. The IoT's capacity to track items, learners and staff, and to interface devices crosswise over campus (es) conveys another level of safety to establishments. A GPS-empowered transport framework implies that transport courses can be followed, with the goal that guardians and directors can know where a given transport is at any given time. Notwithstanding influencing the university to travel safer for learners (and significantly less unpleasant for guardians), learners can be informed when the transport is close to their pickup area; not anymore sitting tight outside for a late transport.

ID cards and wristbands enable instructive associations to store the last-known area of a learner or guest, guaranteeing the correct individuals are getting to the correct ranges on campus. They additionally empower cashless instalments at the university cafeteria or campus store, which makes a more streamlined exchange and can possibly debilitate tormenting and robbery [5]. At last, the connected campuses correspondences enable staff to respond all the more rapidly in a crisis circumstance. By associating tablets, cell phones, and two-way radios, staff can right away talk, message or send an email to some other device in the system. For instance, a security watch who spots a battle can tell instructors and overseers quickly, with one straightforward activity. Presently, help can come immediately, and a heightening of savagery can be kept away from. The IoT stands to significantly change the way foundations work, ensuring profitable resources and upgrading learner learning at each level. Notwithstanding the prompt advantages laid out above, instructive establishments can bridle long haul an incentive from these advancements by breaking down the subsequent information to better arrangement asset portion, educational module and safety techniques in the years to come.

IV. CONCLUSION

The overall research educate about shaping smart classrooms and campuses using Internet of Things (IoT) applications. The IoT paradigm is divided into several sections which have determined the sustainable impact on campuses and classrooms. The higher educational institutions have massively been changed since Internet of Things (IoT) applications allow various objects to communicate with each other. The objects range from controllers to sensors and connectivity among them to provide a central paradigm of communication. Different educational parameters could be measured using big data, wearable technologies, augmented reality and cloud computing techniques in this platform. These technologies have created a new link between the educational environments and the students to provide useful information. The application of IoT in education is classed into the following aspects of class room access control, improving teaching and learning, monitoring student's healthcare, real time eco-system and energy management.

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A DYNAMIC MODEL FOR MUSLIM PILGRIMS MOVEMENT

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ASTRACT:

This paper presents a model for simulating Muslim pilgrims movement during Hajj (Pilgrimage to Makkah) using the system dynamics modeling approach. Its objective is to provide better understanding of the pilgrim's movement system. The model also can serve as a planning and analysis tool for studying related issues such as traffic bottle necks, and effect of various transportation modes and traffic regulations and policies on pilgrims flow. In addition, it can facilitate investigating alternative infrastructure design (e.g. roads, parks), or expansion projects.

INTRODUCTION:

Muslims from all over the world come every year to the holy land of Makkah for the purpose of fulfilling Hajj or Pilgrimage, the fifth pillar of Islam.Table1shows the number of pilgrims who performed Hajj from outside Saudi Arabia for the last ten years. Hajjis an Islamic duty that is required of every adult and able Muslim at least once in a lifetime. It consists of a series of rituals (tasks) that are time and place dependent in accordance with specific guiding rules. Table 2 gives a summary of the Hajj activities, while figure1 shows the accompanied directions of the movements and times. The arrival of pilgrims to Makkah starts as early as two months before the Hajj month, which is the12th month of the Islamic lunar calendar year 'Hijra'. However all pilgrims would have to assemble in Makkah on the seventh day of the Hajj month. The actual Hajjis performed during the period from the 8^{th} to the 13^{th} of the month.

This yearly gathering of more than a million Muslims (from outside and within) in a confide land and moving almost at the same time between the fixed designated locations (Mashaers) of Makkah, Muna, Muzdalefa, and Arafat (figure2 shows a map of these Mashaers) makes Hajj a unique and challenging event with a host of equally challenging activities.In particular, the problem of pilgrim's movement between the holy Mashaersis one of immense magnitude and concern to the planners and managers of the Hajj activities for it has a direct bearing on the comfort and satisfaction of the pilgrims.

This paper presents a model for simulating pilgrim's movement during Hajj using the systems dynamics modelling approach with an objective to provide better understanding of the pilgrim's movement system. The model also can serve as a planning and analysis tool for studying related issues such as traffic bottlenecks, and effect of various transportation modes and traffic regulations and policies on pilgrims flow. In addition, it can facilitate investigating alternative infrastructure design (e.g. roads, parks), or expansion projects.

SYSTEM DYNAMICS:

System dynamics models are constructed from levels, rates, decision functions, and connecting channels. Levels describe system states at any time and it represents entities that move through the system. Rates determine how the system levels changes. Thus, levels would influence rates just as rates would influence levels.

Decision functions work to regulate the relationship between the system levels and its flow rate. It depicts the policy by which rates are controlled in response to system conditions. Connection channels serve as

the media that transfer or carry systementities and feedback information between levels, rates and decision functions [1].

PILGRIMS FLOW DURING HAJJ:

Pilgrims are considered to assemble in Makkah by the seventh day of the Hajj month. Accordingly, the model being presented next depicts the pilgrim's movement starting from the eighth day (midnight). Figure 1 shows the general movement of pilgrim's between the Mashaers and its time limits as prescribed in the Islamic accords [2]. As shown, pilgrims in Makkah either go directly to Arafat on the 8^{th} and 9^{th} or go to Muna on the 8^{th} and then to Arafat on the 9th. The ninth day of the Hajj month is the most important day where all pilgrims have to assemble in Arafat and no one should leave before sunset. Hajj would not be valid unless the pilgrims spend at least a fraction of both day and night in Arafat on the 9th. This time spent in Arafat is known as the 'standing' or 'wogof'.

After sunset, pilgrims move and in mass from Arafat to Muzdalefa.Such mass movement known as (Nafra) which concludes the standing day in Arafat is considered to be the most difficult task of pilgrimage where traffic jams and bottlenecks occur. A more detailed model pertaining to this part is presented later. Pilgrims reaching Muzdalefa spend a period of time that varies from three to nine hours. From Muzdalefa, a portion of pilgrims Leaves to Makkah to visit the grand Mosque (Al-Haram) for conducting 'Tawaf' and then returning to Muna for a three to four days' stay. While the other portion of pilgrims may choose to go directly to Muna from Muzdalefa and then go to Makkah for 'Tawaf' during their stay in Muna.

The final stage of pilgrimage is the return of pilgrims toMakkah after spending the prescribed time in Munawhich takes place between noon of the 12^{th} day, but before sunset. Those not able to exit from Muna during that period are required to stay until the next day where they may leave after sunrise.

A GENERAL MODEL FOR PILGRIMS MOVEMENT FLOW:

A simulation model was constructed to represent pilgrim's movement flow between the Mashars for the period from the 8^{th} to the 14^{th} of the Hajj month. Figure 3 shows the basic structure of the model and pilgrims flow. As shown, the four levels represents pilgrim's population in Makkah(PIMK), Muna (PIMN), Muzdalefa (PIMZ), and Arafat (PIAR). Pilgrims movement between these levels is regulated through the seven flow rates as follows:

Makkah to Arafat rate (MKTAR); Makkah to Muna rate (MKTMN); Muna to Arafat rate (MNTAR); Arafat to Muzdalefa rate (ARTMZ); Muzdalefa to Makkah rate (MZTMK); Muzdalefa to Muna rate (MZTMN); and Muna to Makkah rate (MNTMK).

Figure 4 shows the model assumptions for permissible times of pilgrim's movements in accordance with Hajj accords [2]. In the model flow rates are determined according to causal dynamic movement relationships when movement is permitted, otherwise flow rate where set equal to zero. Figure 5 shows causal feedback loops that depict the conceptual dynamic movement of pilgrims. In the diagram, a polarity sign of the relationship between variables is indicated as either positive (+) or negative (-).

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Positive relationship indicates a direct proportional effect where a change in the first variable changes the second variable in the same direction.

A negative relationship indicates an inversely proportional effect where a change in the first variable changes the other variable in an opposite direction. For example, the relationship between the number of vehicles on a road and traffic congestion is positive, which means thathe more are cars on the road, the higher the degree of traffic congestion will be and vice versa.However, the relationship between speed of movement and travel time is negative which means that an increase in speed reduces travel time and vice versa.

Also, figure 5 shows partitioning pilgrim's movement into pedestrian and motorized. The model being presented further deals with motorized pilgrim's movement.The causal feedback concepts (fig.5) coupled with the basic model structure (fig.3) and with due attention to movement time constraints (fig.4) were all combined in a mathematical model. This was then written in DYNAMO [3], a computer simulation language. A preview of the general model behavior is shown in figures 6, 7, And8.

Furthermore, it is noted earlier that the pilgrims movement from Aafat to Muzdalefa or (Nafra) is the most critical segment of Hajj since almost all pilgrims who have gathered in Arafat on the 9th day would attempt to leave to Muzdalefaat sun set. Accordingly, a more elaborate model is developed for vehicles flow between Arafat to Muzdalefa or (Nafra).

'NAFRA' – ARAFAT TO MUZDALEFA VEHICLES FLOW MODEL:

Figure 9 shows a flow diagram for the 'Nafra' or vehicles movement between Arafat and Muzdalefa. In this model, vehicles on the road between the two Mashars are depicted by a level (POR)Vehicles flow is regulated using a traffic stream function [4] as follows:

$g = u k$

Where:

g= mean rate of flow (Veh/hr)

u= mean speed (Km/hr)

k= mean density (veh/Km)

Furthermore, an algorithmic model developed by Greenberg (5) is selected to describe the traffic flows is considered to be most suitable for congested flow as is the case for Nafra. It proposes the follow in g speed function:

$$u = u_M \ln k_j/k$$

Where:

U M=speed at which the flow rate is maximum;

kj=jam density at which all vehicles are stopped.

Furthermore, it is noted that this model is less satisfactory at low values of density (as k $\rightarrow$ 0).

Thus, the following model proposed by Underwood [6] is applied when traffic density falls below a designated value:

U= UfEXP(-k/kM)

Where:

Uf= free speed at which free flow conditions exist;

kM= density at which the flow rate is maximum.

The flow diagram shown in figure 9 is then translated into the computer simulation code DAYNAMO.The model was tested through several simulation runs using plausible sets of initial system value and parameters. Table 2 shows a set of the values for the last run.

Model behavior is then observed and scrutinized with reference to available historical and expected system behavior. Several model variables behavior were plotted and shown in figures10 and11, while table 3 shows their corresponding values. As indicated, fig.10 shows the number of vehicles (POR) on the road between Arafat (M1) to Muzdalefa(M2), in addition to the flow rates in and out of the road, (R1, R2resp.) with respect to time. Also shown are the vehicles population in Arafat and Muzdalefa (w.r.t.) time. Figure11shows the dynamic changes of the traffic density (DEN) mean speed (SPEED), and mean travel time delay (TDEL). From the figures it can be noticed that it took about nine hours form most vehicles to move from Arafat to Muzdalefa.

The mean movement speed is slowest between the 2nd and 6th hour from the Nafra starting time, while the traffic density is at its highest at that same interval.

MODEL UTILITY AND FURTHER RESEARCH:

Thusfar, a model for pilgrims and vehicles movement has been presented. The model behavior conforms to expected system flow behavior patterns. It is also important to indicate that the model purpose is to provide better understanding of the Hajj pilgrims and vehicles movement behavior and to serve as a prototype experimental tool for analysis and design of more effective systems.

In particular, the model should prove useful in studying the following:

1. Traffic flow, bottlenecks, and alternative solutions
2. Effect of various transportation modes (e.g. Small vs. Large cars).
3. Effect of various traffic regulations
4. Infrastructure design of roads, parking, etc.

In addition, several extensions of the model are suggested as follows:

1. Inclusion of pedestrian movement dynamics;

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2. Detailed description of flowrates for reciprocal movement between Makkah and Muna;

3. Expansion of the model boundary to include external movement to and out of Mashaers (i.e. pilgrims coming to Makkah before the7th day of Hajj month and leaving after the14th).

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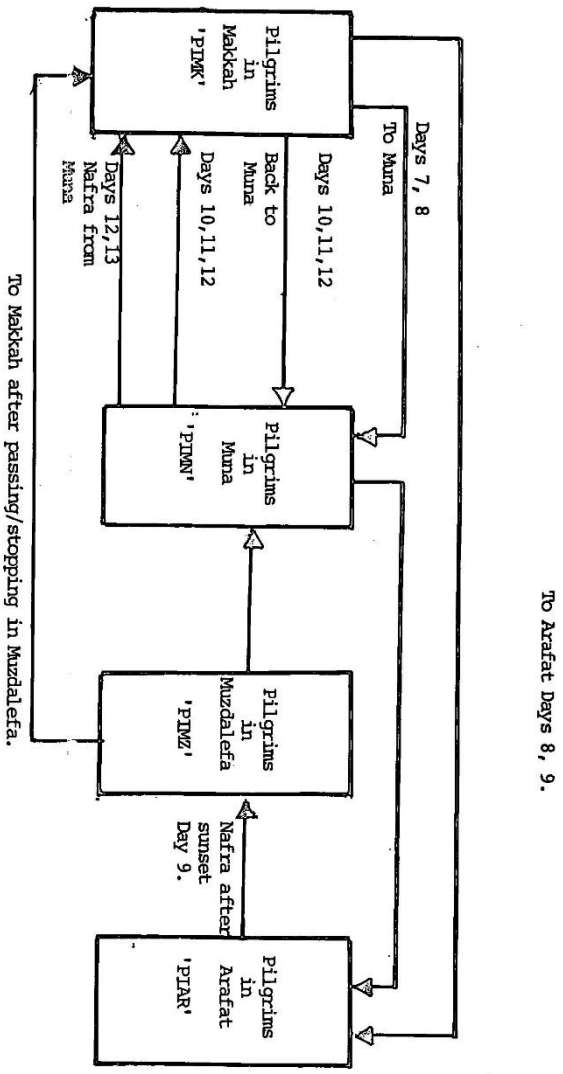

Fig. 1 - General Movement of Pilgrims.

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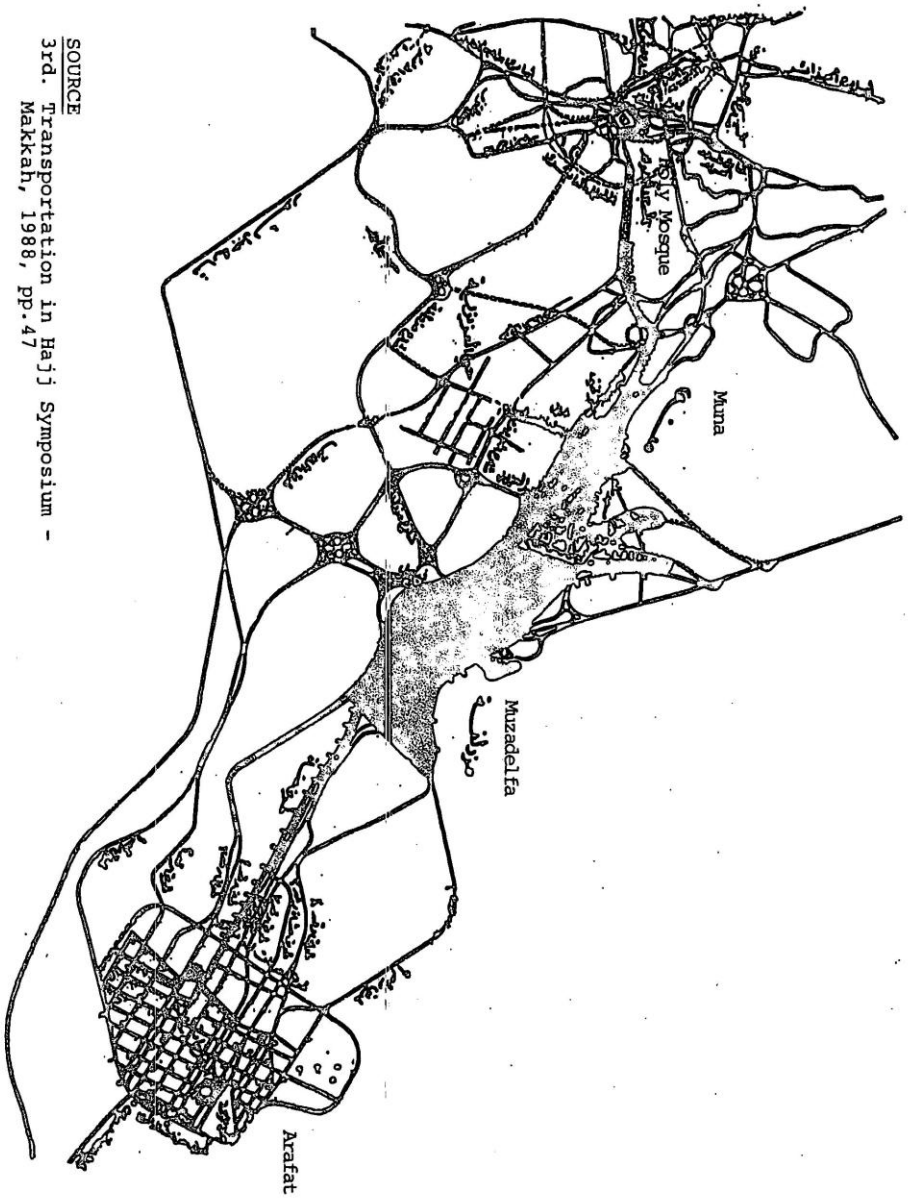

SOURCE
3rd. Transportation in Hajj Symposium - Makkah, 1988, pp.47

Figure 2 - Map of Mashars.

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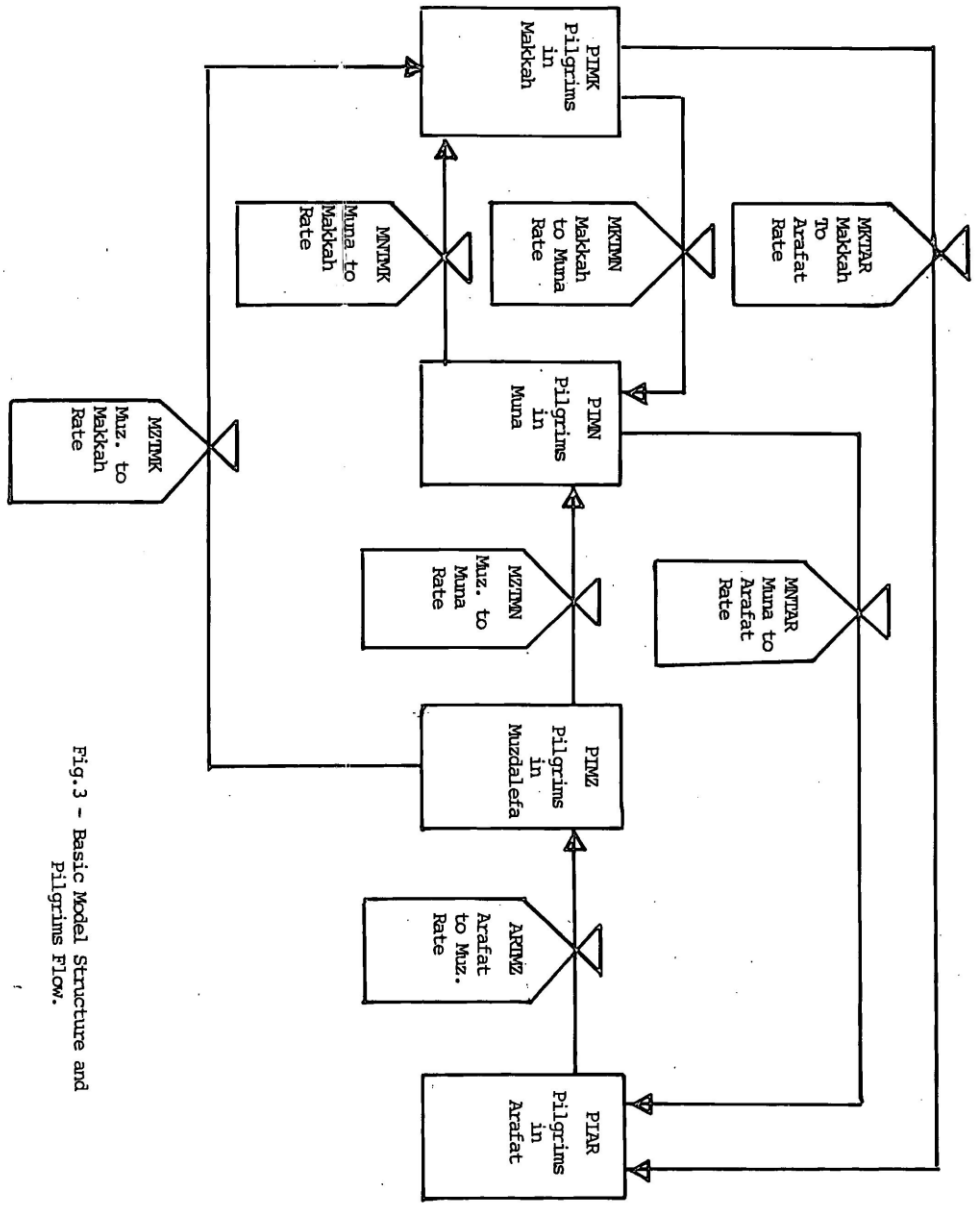

Fig.3 - Basic Model Structure and Pilgrims Flow.

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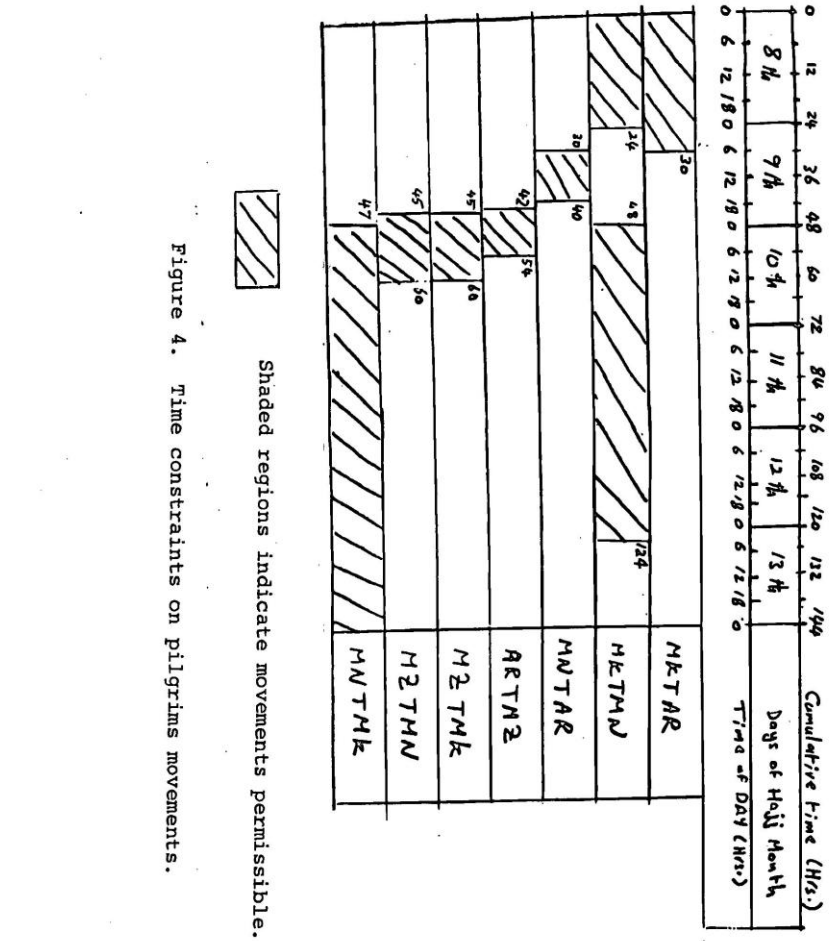

Figure 4. Time constraints on pilgrims movements.

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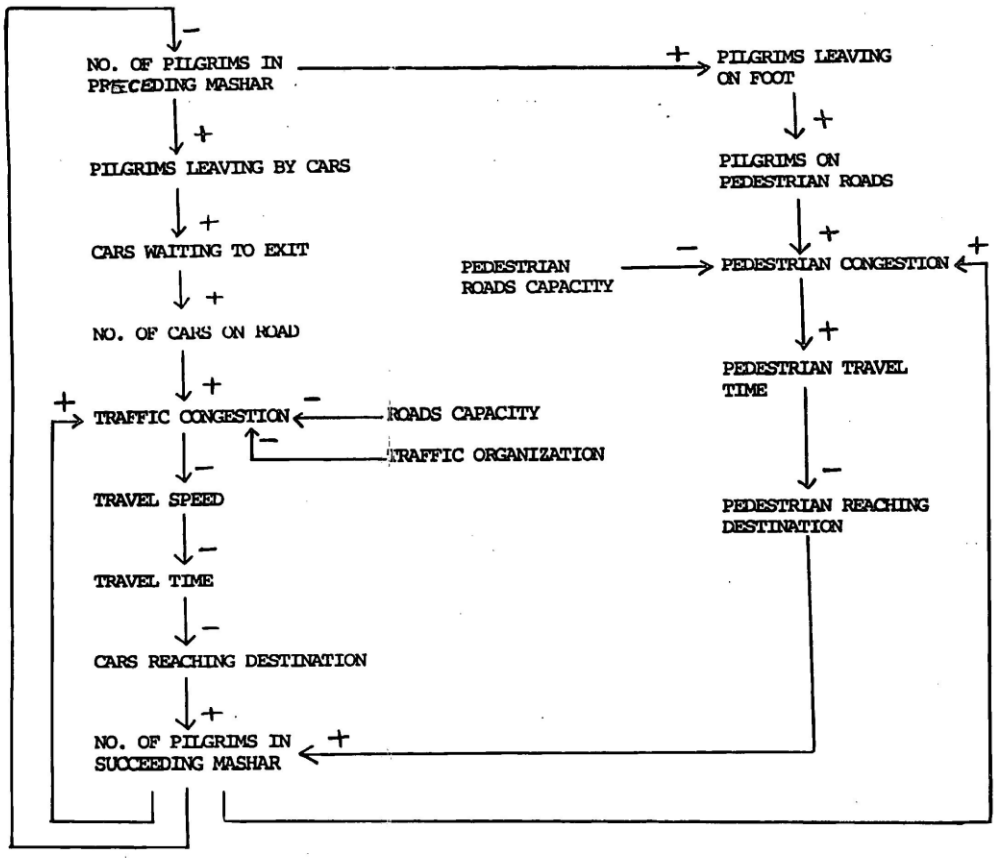
FIGURE 5. GENERAL MODEL'S

CAUSAL FEEDBACK LOOPS FOR TWO SUCCESSIVE MASHARS



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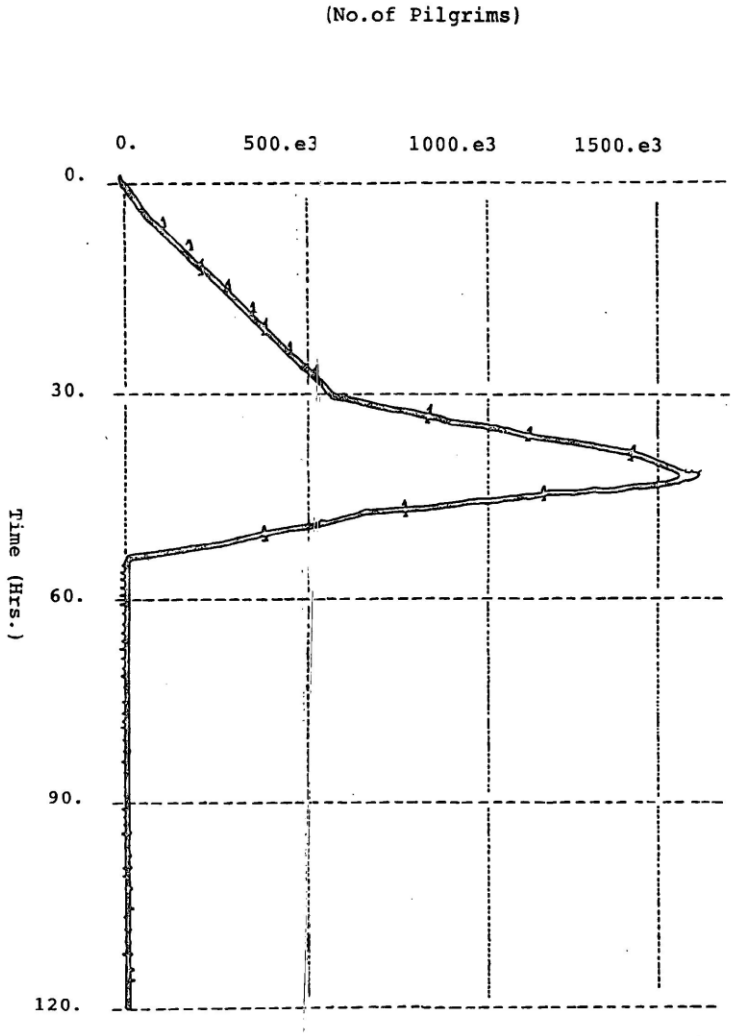

Fig.6 - No. of Pilgrims in Arafat.

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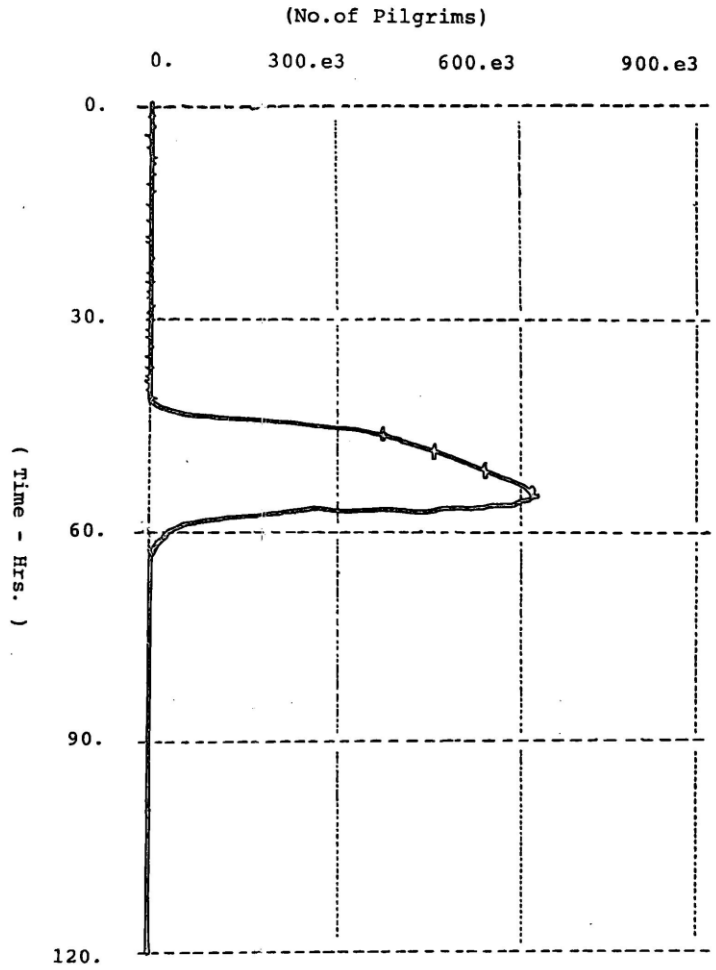

Fig.7 - No. of Pilgrims in Muzdalefa.

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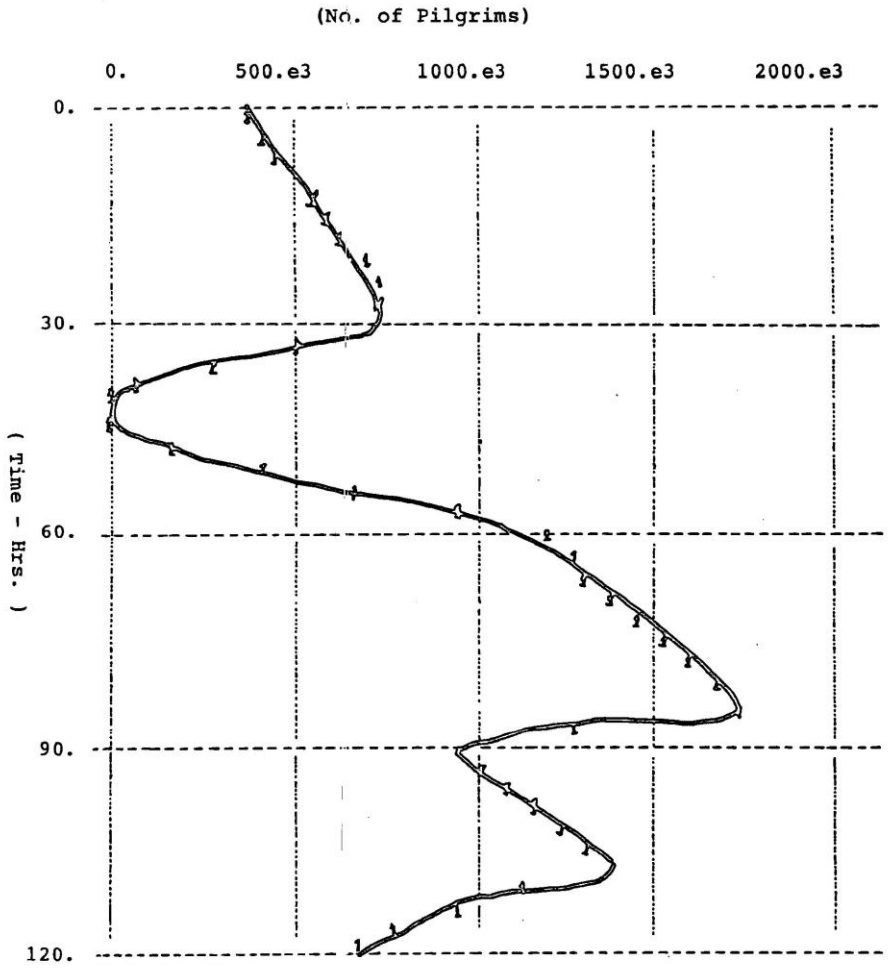

Fig.8 - No. of Pilgrims in Muna.

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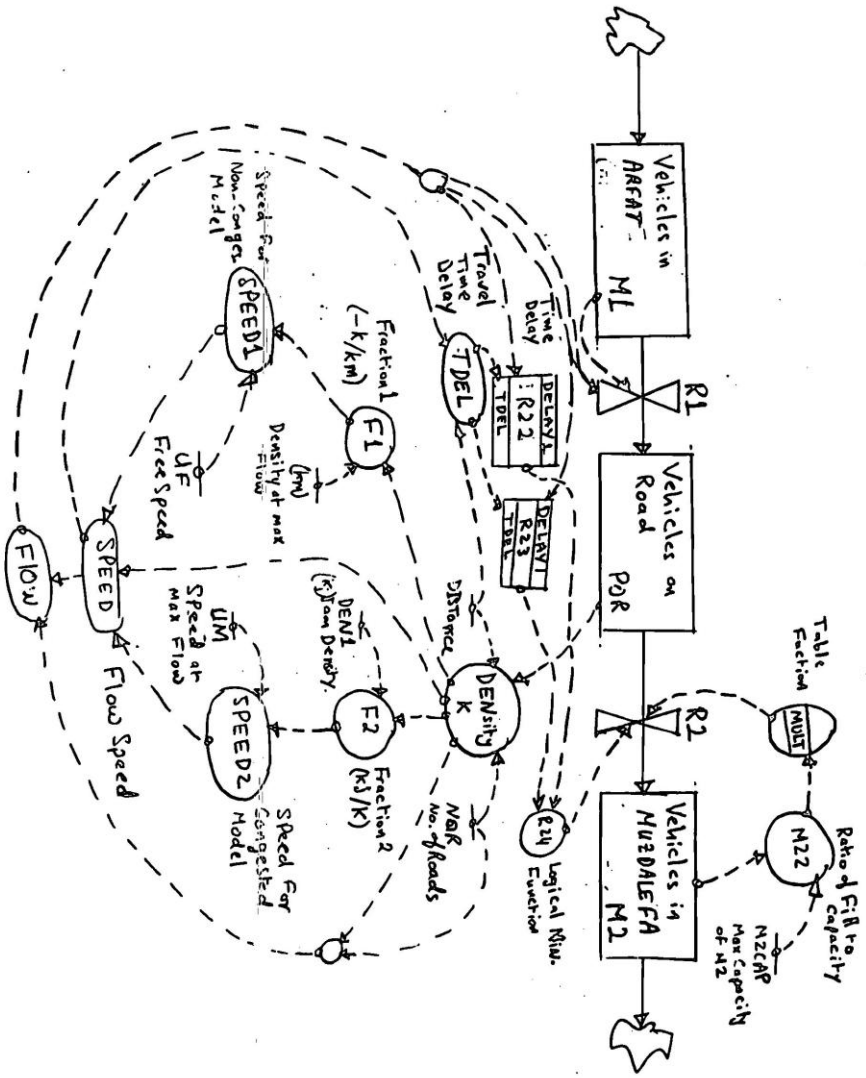

Figure 9. Flow Diagram for Nafra (Arafat to Muzdalefa) Model.

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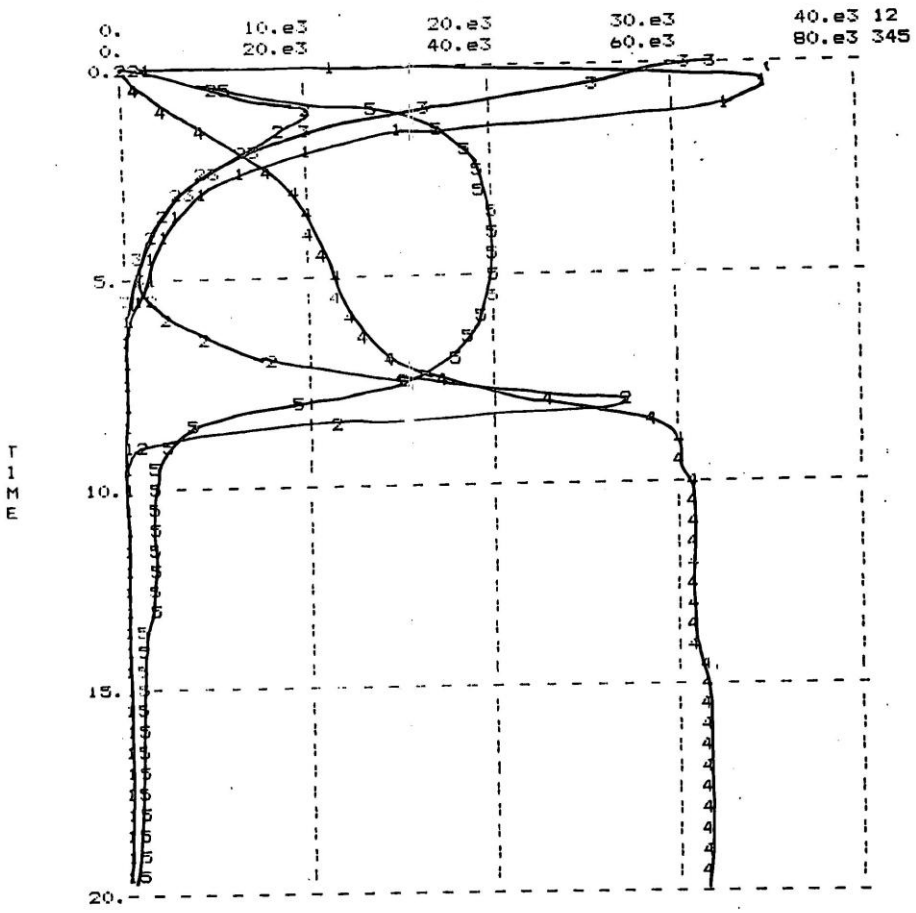

Fig.10 – Nafra Model Behaviour (Rates in and out of road, veh. in M1, M2, Road).

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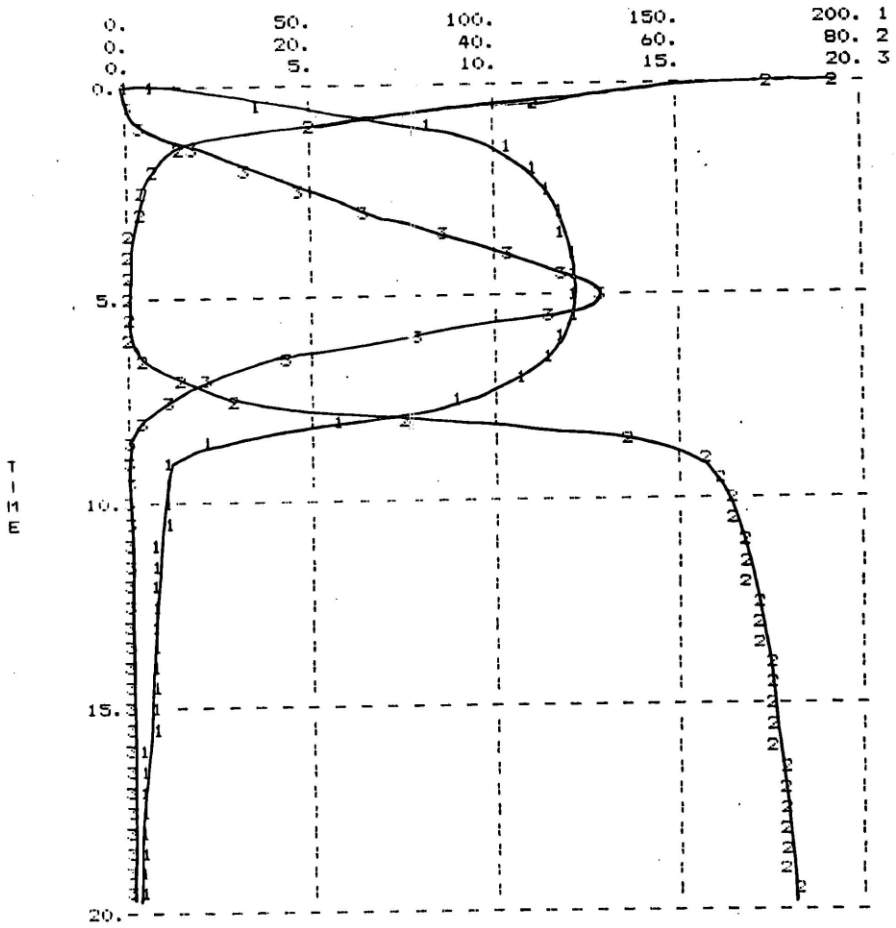

Fig.11 - Nafra Model Behaviour (Density,Speed, Time delay)

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TABLE1-NO.OFPILGRIMSFROMOUTOFKINGDOM DURINGPASTYEARS

Years	No of Pilgrims
2007	2,454,325
2008	2,408,849
2009	2,313,278
2010	2,789,399
2011	2,927,717
2012	3,161,573
2013	1,980,249
2014	2,085,238
2015	1,952,817
2016	1,862,909

SOURCE

General Authority of Statistics,Kingdom of Saudi Arabia, Hajj Statistics 1437H (2016).

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TABLE2-SUMMARYOFHAJJACTIVITIES

Activity	Dayofthe HajjMonth
PilgrimsassembleinMakkah.	7th
PilgrimsmovetoeitherArafatorMuna.Those goingtoMunawouldgotoArafatonthemorning ofthe9th day.	8th&9th.
Atsunset,pilgrimsstartmovingtoMuzdalefa. Somestayforfewhours,whileothersspendthenight.	9thSunset
PilgrimsgofromMuzdalefatoeitherMunaorto Makkah.	9th&lOth.
Pilgrimswhohavegonetomakkahmustthengo toMunafor3daysstay.ThosegonetoMunamustgotoMakkah andthenreturntoMuna Fortheremainingof3days.	lOth-12th.
PilgrimsconcludetheirHajjbyreturningto Makkaheitheronthe12th daybutbeforesun-set,otherwisetheymayleavetoMakkahonthe 13thaftersunrise.	12th&13th

TABLE3 –NAFRAMODEL'SPARAMETERSVALUES

VALUE	DESCRIPTION	PARAMETER
22Roads	No.ofRoads	NOR DIST
15KM	Distancebetween ArafatandMuzdalefa	UM KM
40KM/Hr.	Speedatmax.Flow	UF
62.5Veh/Km	Densityat max.flow	DENI
80KM/Hr.	Freespeed	M2CAP
125Veh/Km	Jam density(kj)	
65,000Veh.	CapacityofMuzdalefa	

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

A SYSTEM APPROACH TO NATURAL RESOURCES UTILIZATION

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ABSTRACT

Natural resources are substances deposited by nature within a defined geographical region and used by man. They have a major economic significance in any national economy. However, their economic contribution is only a function of how they are fitted in a multi sector economy. A system approach to natural resources utilization is defined as one which treats resources as a sector in a system of many sectors such as technology, production facilities (e.g. transportation network), manufacturing, trade, and others. Some of the dynamic interactions between the resources, technology, and transportation sectors are discussed. Then, a structure of a system dynamics model is presented including its basic objectives and features. Finally, two examples of feedback loops are presented, followed by general recommendations for further investigation and research.

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INTRODUCTION

Resources can be defined as the function which a substance performs or participate in to reach a goal or purpose (Cody *et al.,* 1980). Oil was not a resource to early man, for he had no use for it; but in today's society, oil serves as an important resource because it fulfills various important functions as energy or lubricant for machinery and as raw material for man-made products. In each case, it serves a functional purpose. If the day comes when other substances can achieve these goals more efficiently, and oil no longer performs a function, oil will cease to be a resource. Thus, resources are the creation of nature and man. Natural substances exists on earth but only when man finds a function which they can serve or a need which they fulfill that they become resources.

Natural, or basic resources may be grouped into two categories

Fund or exhaustible resources, for which nature has set an outer limit on the amount available: and Flow or renewable resources, for which usually there is a continuing supply in nature.

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Natural Resources: The role that natural resources play in the economy of a country is very much dependent on the country's structure. Natural resources alone cannot bring prosperity unless coupled with national strategy that mobilize all available resources (natural and human) to provide the social and physical infrastructure needed for industrial and other development. However, natural resources provide many opportunities for the achievement of development goals. Fund resources of high market value such as minerals, coal, petroleum and natural gas can be exported in exchange for capital which can be used to gain access to technology, to develop basic physical infrastructures, and to finance other development projects (Dorner *et al.,* 1980). Furthermore, development of the basic resources in itself induce many changes in the infrastructure and institutional facilities of the country. For example, transportation, and communication networks are usually needed to provide for the movement of material and the transfer of information. Other benefits include the contribution to the gross domestic product and to government revenues through direct government ownership or taxation which allows for the financing of public projects (Badiru and Adedeji, 2018). Another function that basic resources may play in a national economy is that of extending primary metal or resources processing downstream based on domestic resource production, thus providing added value income. Flow or renewable resources provide another source

of national income and means for domestic development. Land, inland water bodies, and oceans are rich yet largely abused or neglected resources. Land that is developed and utilized can play a significant role in the achievement of national objectives. Resources which are tied to the land include crops production, livestock grazing, and forests. Basic products from land (food, wood, etc.) can provide for local consumption and in many cases for export. With adequate preparation and proper use of technology, land productivity can increase significantly. Food processing, and wood products and by products industries offer many economic added value possibilities (Dustin Chambers and Jang-Ting Guo, 2009). Water is another source of valuable resources. Besides the obvious human needs for water, many other functions are served by water. Such uses include industrial, municipal, recreation, irrigation, and energy production. Thus, it is evident that natural resources is an integral part in a system of multi sectors and any plans for their utilization should treat them as such. Some of the sectors in national economies which can be identified as closely tied with the resources sector include the countries technological and physical infrastructure bases. The importance of these two sectors in a system of national economy and their interaction with the resources base is briefly discussed next.

Technological Systems: A technological system refer to the network of possible interactions among basic research, applied science, engineering, production of goods and services, and other sectors of knowledge, skill, and society. Technology play an important role in any national resource utilization development plans. The specific technological patterns selected for use in agriculture, industry and mining for example are among the essential factors in balancing the relative contribution of these sectors and in deciding upon national utilization plans and strategies. For example in countries of limited agriculture lands, technologies of reclamation, cultivation, irrigation, and settlement can help to expand arable lands and assure more productive use of agricultural resources. Other technologies can be stimulated by demands from small industries, farmers, and handicrafts workers. Such simple technologies especially those which rely on renewable resources offer many opportunities for better utilization of indigenous raw material (Prasenjit Mondal and Ajay Dalai, 2017). For many decades, industry and modern agriculture have become more and more dependent on exhaustible resources. Dependable estimates of basic resources supplies in the physical sense and extent of their economic availability are critical to resource policy planning. Technology contribution is vital for resolving the issues of resource utilization and associated factors such as conservation, distribution, and pricing. Technology is represented in production by the choice and design of the process and hence the equipment, the specification of raw material inputs, and the quality of the product. It exists in the skill of workers, the capacity of management, the planning and control of operations, and in the economic aspects substitutability among the factors of production. In a modern society where prices, wages, raw material, energy, competition, consumer preferences, and market shares are continuously changing, national management cannot afford to neglect the influence of its technological systems in maintaining successful operations.

Physical Infrastructure: Similarly, the physical infrastructure base plays a major role in the utilization of natural resources. Facilities of production, transportation, and storage are considered as components of the physical infrastructure that a nation may possess. Of all the various infrastructure facilities, transportation plays a dominant role in promoting economic utilization of indigenous raw material. Its importance has long been recognized and is reflected in the development programs of most countries. An expanded national transport system can trigger a process of self-sustained growth. The development of a transport network links different regional markets of an economy and leads to better allocation of resources through a more rational distribution of material. In the short run, reduced transport cost resulting from system expansion create demands for both regional products and resources too. In the long run, new investments are encouraged in different locations particularly in backward areas, partly because idle resources are redirected into new enterprises. Increasing the speed and scope of the transport network also has beneficial effect on factor mobility, allowing material resources to be transferred more readily to places where they can be employed most productively. Other sectors that interact directly with the natural sector include for example labor, manufacturing, and trade. The complexity of their interactions as illustrated for the technology and transportation sectors requires the resolution to a systematic modeling procedure to provide a comprehensive coverage of the issues involved in natural resources utilization schemes. One approach that is particularly suited for modeling such complex issues is system dynamics.

Systems Dynamics: Generally, system dynamicsrefer to modeling of the feedback loop structure of complex systems. Itis a methodology that integrates complex components through a structured mathematical modeling procedure. Its main objective as an analytical tool is to understand the system behavior and the interactions between its components in order to examine and design various modes of strategic policies and trends. Jay W. Forester, provides some of the system dynamics features and principles are as follows (Forester, 1961):

Features and Objectives: A mathematical model of a system dynamics should aid in understanding that system. It should be useful guide to judgement and initiatives decision to help establish desired policies. Further, using a model implies that we have some knowledge about the detailed characteristics of the system. These known facts interact to influence the way in which the system will evolve with time. However, our intuitive ability to visualize the interaction of the parts is less reliable than our knowledge of the parts individually. Thus by constructing a model and observing the interplay of the factors within it we can reach a better understanding of the system with which we are dealing. Hence, a useful model of a real system should be able to represent the nature of the system and demonstrate how changes in policies, structure, or external events influence the system behavior.

Principles of the approach: The structure of a system dynamics model is seen as having four significant hierarchies: closed system boundary, feedback loops, levels and rates, and policy substructure. System dynamics deals with closed systems for which the behavior modes of interest are generated within the boundaries of a defined system. Components of the system are grouped into sets of feedback loops which interact to produce the system behavior. Loops are composed of two classes of variables: levels and rates. Levels define the state of the system, while rates change the values of these levels. The rate variables represent the rules or policies whereby the state of the system changes.

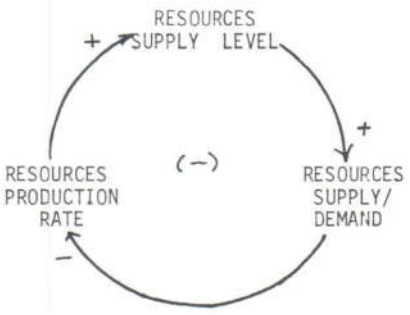

Figure 1. Example of a Negative Feedback Loop

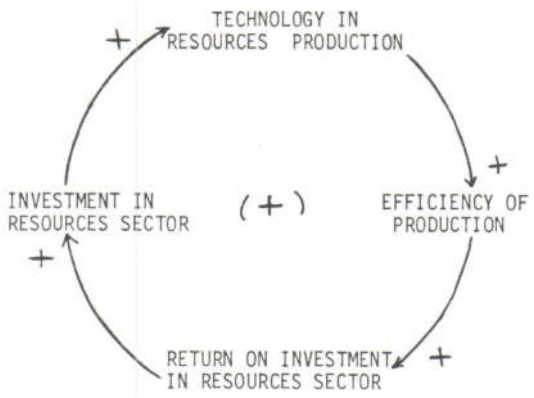

Figure 2. Example of a Positive Feedback Loop

Therefore, the appropriateness of a system dynamics approach for modeling natural resources utilization comes from the correlation between the modeling objectives and the principles of the approach. The common features are delineated as follows: A mathematical model is valuable because it can be manipulated more easily than descriptive models. Its logical structure is more explicit, thus it can be more readily used to trace assumptions to their resulting consequences. A dynamic model represent situations that change with time. It deals with time-varying interactions. A transient behavior describes those changes where the character of the system changes with time. A system that exhibits growth would show transient behavior since transient responses are one-time phenomena as compared to the repetitive pattern of a steady- state behavior. A closed model is one that internally generates the values of variables through time by the interaction of the variables one on other. Information feedback systems are essentially closed systems and they are self-regulating. However, exogenous inputs are included as independently generated variables and serves as excitation of the internal system responses. In obtaining explicit mathematical solutions, linear models are much simpler than nonlinear. However, such explicit solutions are generally unable to deal effectively with highly complex nonlinear socio-economic systems. Simulation methods that gives only a particular solution to a specified set circumstances can deal as readily with nonlinear as with linear systems. Thus, system dynamics provide a framework of philosophy and procedures that is particularly suited for studying the utilization of natural resources.

Basic Causal Feedback Loops: Causal feedback provides the basic structure of system dynamics models. A causal feedback loop consists of two or more variables. The relationship between a causal feedback loop variables can be either positive or negative. A positive variable relationship means that a change in one variable causes the other variable to change in the same direction. A negative relationship means that the affected variable reacts in a direction opposite of the initiating variable action. A set of interrelated variables forming a closed path represent a causal feedback loop. Such loops can also be designated as either positive or negative. In a positive feedback loop, if any variable changes, then the loop causes that variable to change further in the same direction. In other words, positive feedback loops generates self-reinforcing changes. However, if a variable in a negative feedback loop is changed, then the loop causes that variable to- adjust in the opposite direction. Thus, negative feedback loops produce self-regulating changes.

Examples of Feedback Loops: In modeling the utilization of natural resources system, several feedback loops can be constructed.Figure1showsan example of a negative feedback loop. The loop shows that resources production rate and supply levels are positively related. However, resources supply/demand variable is positively influenced by the resources supply level and negatively influence the resources production rate. The loop is self-regulating since a change in any of its variables in a given direction would causes it to change again in an opposite direction. An example of a positive feedback loop is shown in Figure 2. Since the loop is positive, a change in one of its variables would results in a similar change of all of the other variables in the loop.

Recommendations for further research: A system dynamics model can be constructed to simulate the working of a specific national system that integrates the sectors of resources, technology, infrastructure facilities, trade, manufacturing and other economic sectors. Reda (1985 & 1986) presents a prototype simulation model which can be employed to guide the development of a resources based national model. Such system model would address resources utilization concerns and questions such as exportation versus indigenous manufacturing or processing, and the selection of which manufacturing or down-stream processing industries.

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ORIGINAL ARTICLE

Decision support system for selecting optimal construction bid price

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Value Engineering (VE);
Cost saving;
Optimization decision making

Abstract Most important construction problems facing building operations are how to choose a contractor specialized in implementing major projects. In addition to that the increasing costs of raw materials, work force leading to the rise of construction costs. Therefore in this paper hierarchy method has been studied and it has been identified for organizations allowing them to minimize common risks of the decision-making process and management. Construction contractor can be prequalification using Analytical Hierarchy Process (AHP) as powerful management technique. Prequalification contractor aims at eliminating in competent contractors in the bidding process. This kind of prequalification helps both of the public and private project owners to successful achieve for required project tasks. The project will be completed with is estimated cost and time because of the contractor's skill, capability and efficiency. Case study gathers a number of contractor's or companies data. After studying Analytical Hierarchy Process (AHP) of a set of criteria, table of contractor's technical evaluation was concluded all experience, financial situation and the contractor's classification in the Union of Contractors. In addition labor's progress, availability equipment for contractor is applied using Value Engineering (VE) to raise the performance level and reducing costs. Hence, value engineering will be demonstrated, where its goal is to raise the performance level and functionality with the ability to reduce costs. The case study of this paper is a construction project of a hospital, administration building, and staff housing building. It was applied the Analytical Hierarchy Process (AHP) and was extracted contractor's evaluation table of a set of criteria (the previous experience, financial situation and the contractor's classification in the Union of Contractors. Also labor's progress, available equipment for the contractor and the contractor applying Value Engineering). The previous data are gathered through the contractor's proposal, while (VE) is applied as process steps on a construction project case study.

1. Introduction

The decision-aiding method was developed by **Saaty** and named (AHP) Analytical Hierarchy Process, which aims to

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quantify relative priorities for more alternatives on a scale, depends on decision-maker judgment and stresses alternatives comparison for decision-making process [1]. This paper main objective is to apply AHP in construction project management. Value Engineering (VE) will be also clarified as it is necessary that the contractor or the company to apply it at the same time and its objective to maximize performance and function with most minimum possible cost.

2. Paper objective

A paper main objective is using features of AHP application integrated with and Value Engineering (VE) in construction management. These techniques are used to choose the best contractor to reach the maximum profit and maximum value with corresponding minimum price.

3. Paper scope

The used data for this paper has been gathered through detailed literature review from many studies all over the world. A case study has been studied carefully on an integrated housing project and comparing between the number of companies participating in the tender for constructing of a set of buildings in a project for the Department of Housing and Utilities. An evaluative technical model will be concluded for contractors and explains its elements. Also an evaluative financial model will be set to select best contractor to implement any process. And then apply value engineering to raise the level of performance and functionality with the ability to reduce costs.

4. Analytic Hierarchy Process (AHP)

AHP is defined as a set for defined mathematical consistent matrices structure with their associated right weights, [1,2]. AHP technique compares alternatives and criteria with respect to mode of pair wise. It switches individual preferences inside ratio scale weights which can merge them as each alternative linear additive weight. The alternatives are ranked by resultant to assist decision maker [3]. However, it had been pointed out the weakness of the Analytic Hierarchy Process for assessing various criteria relative importance. [4] Proposed modified AHP by changing human judgment and incomplete information then provided an example to discuss AHP viability in evaluating construction technology. Observation priorities on each level for Fig. 1, the main goal all alternatives are add up to (1.000).

Table 1 Scale of pair-wise comparison.

Rating	Preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

5. Steps for applying analytical hierarchy process

It is mathematical technique which can do factors ranking of tangible against each other's and consists of quantitative and qualitative approaches, [5]. [1,6,7,8] developed AHP main steps as: (1) determine problem goal, (2) do hierarchy structure, (3) get pair-wise comparison matrices by measurement of relative scale as shown in Table 1 (4) use number of n (n − 1)/judgments which required for developing matrices as in step 3, (5) Reciprocals are assigned in each pair-wise comparison, (6) hierarchical synthesis is used to weight its lower level, (7) make pair-wise comparisons then consistency is determined by λmax, CI = (λmax − n)/(n − 1), where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI as in Table 2. CR is ok in case of does not exceed 0.10, and (8) Steps 3–6 are repeated in all hierarchy levels.

6. Value Engineering (VE)

Value Engineering (VE) was coined at 1947 and within construction was pioneered in the 1960s. It focus on effectiveness through objectives, goals, needs and requirement then defining features of quality to get acceptable product. Value Engineering is a kind for balancing between cost, quality and function

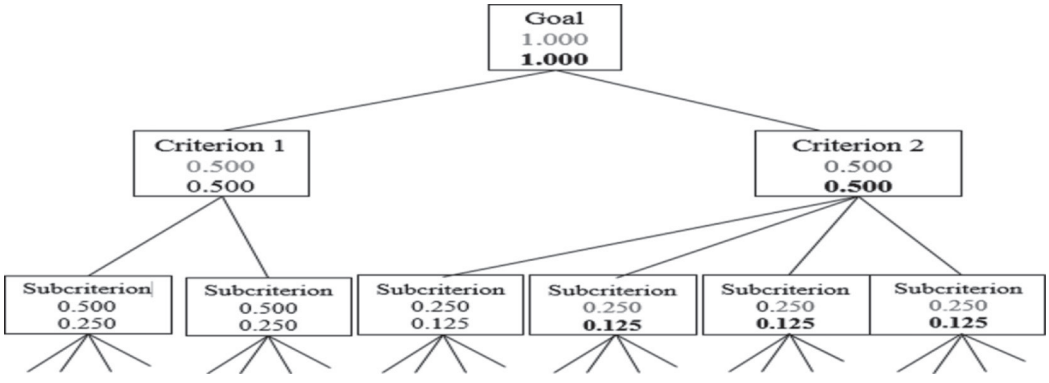

Fig. 1 Analytic Hierarchy Process (AHP) with Global/Local Default Priorities.

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Table 2 Average random consistency (RI).

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.91	1.12	1.24	1.32	1.41	1.45	1.49

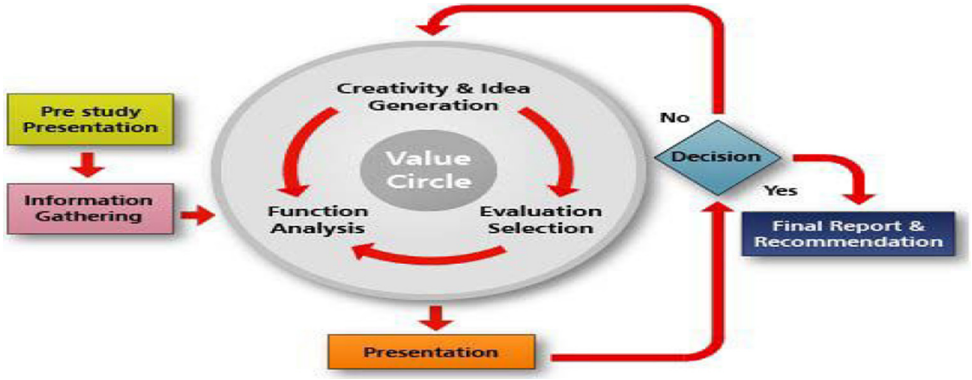

Fig. 2 Value Engineering Circle [9].

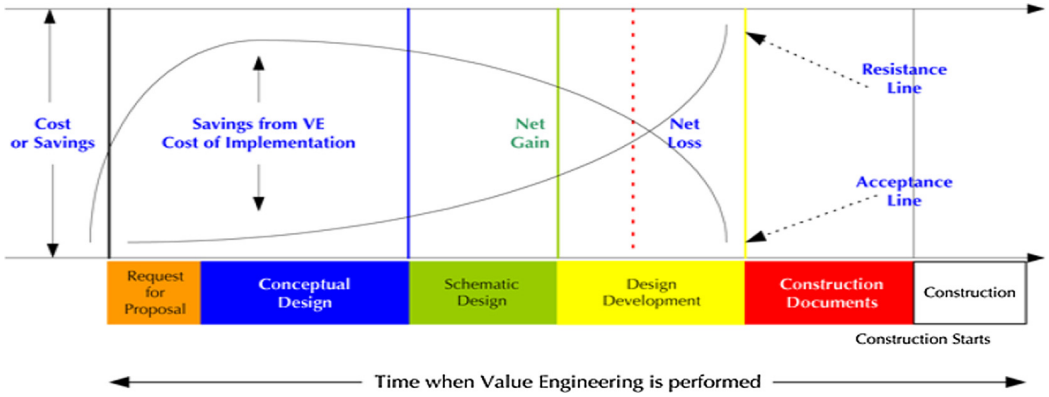

Fig. 3 Potential Saving from VE Applications.

for construction project or certain design to improve design function with reducing project cost as shown in Fig. 2, [9].

When Value Engineering (VE) is reducing direct cost or total life cycle cost, [10]. It can be used through project design cycle. Also it may be applied in more items during project life and helps for getting project direction depending upon its information. It is important to perform VE throughout the entire design process to give successful analysis. The savings of VE is greater than earlier process begins is applied. After VE is performed, two things increase: (1) investment changes, and (2) resistance change, [11] see Fig. 3.

7. Value engineering job plan

It is a recognized tools systematic application and techniques to categorize project functions for creating, selecting, and developing alternative approaches for effectively cost with improving performance [12]. It was applied job plan of value engineering to assist the study team for identifying key t functions in order to create new resulting improvements [13]. It consists of seven phases as shown in Fig. 4: (1) Information Phase; (2) Function Phase; (3) Creative Phase; (4) Evaluation Phase; (5) Development Phase; (6) Presentation Phase and (7) Implementation Phase.

8. Application case study

A simplified project; an Integrated Housing Project as an example of the contractor prequalification will be done to understand the purposes. The factors for prequalification are: financial stability, experience, labor resources, quality performance, equipment, resources and current workload [14–16]. Table 3 presents the project contractors A, B, C, D and E that the owner wishes to test and prequalify them. By AHP software Expert Choice procedure decision makers had to indicate priority for every decision alternative as shown in Table 3. Synthesizing matrix of pair-wise comparison as in Table 4. Calculate criterion priority vector same as experience 0.463

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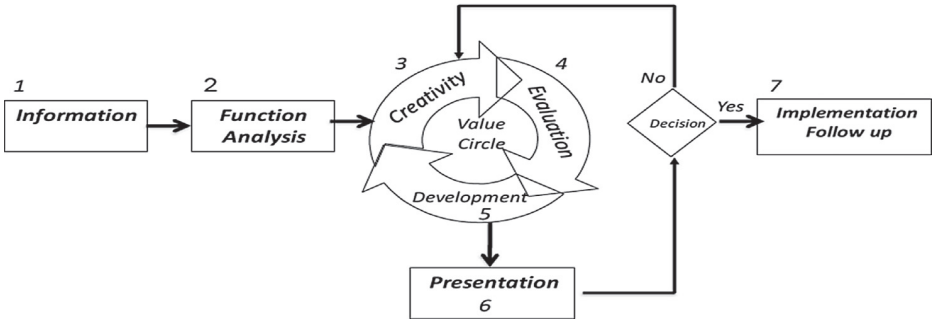

Fig. 4 Seven Phases of VE Job Plan.

Table 3 Evolution of contractors.

Contractor	A	B	C	D	E
Experience	29 year No similar project	27 year Four similar project	23 year One similar project	17 year Three similar project	16 year Two similar project
Contractor classification in EFCBC	Second	Second	Third	Second	Second
Financial stability	6 M assets 1.5 M Liabilities	13 M assets 5 M Liabilities	3 M assets 1 M Liabilities	14 M assets 6 M Liabilities	7 M assets No liability
Quality performance	Good organization C.M. personnel Good One project terminated Average quality	Good organization Good reputation Many certificates Cost raised in some projects	Average organization C. M. personnel Two delayed projects Safety program	Good organization C.M. team Government award Good reputation	Good organization C.M. personnel Good reputation Many certificates
Manpower resource	15 laborers 26 by subcontract	20 laborers 10 by subcontract	25 laborers 10 by subcontract	25 laborers Good skilled labors	30 laborers 2 special skilled labors
Equipment resource	1 mixer machine 1 excavator 10 others	3 mixer machine 1 excavator 20 others	2 mixer machine 1 excavator 18 others	2 mixer machine 1 excavator 16 others	2 mixer machine 1 excavator 15 others
Current work load	2 small projects started 3 projects ending (2 small + medium)	2 big projects ending 1 medium project	2 projects ending (1 big + 1 medium)	1 medium project started 2 projects ending (1 big + 1 medium)	1 big project ending projects in mid (1 medium +1 small)
Time schedule	Good	Excellent	Excellent	Very good	Excellent
Work without down payment	No	No	No	Yes	Yes
Method of statement.	Good	Excellent	Excellent	Very good	Excellent
Applied VE	Good	Excellent	Excellent	Very good	Excellent

Table 4 Experience pair wise comparison.

Experience	A	B	C	D	E
A	01	02	06	07	08
B	1/2	01	07	05	05
C	1/6	1/7	01	04	03
D	1/7	1/5	1/4	01	02
E	1/8	1/5	1/3	1/2	01
Total	1.935	3.543	14.583	17.500	19.000

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Table 5 Experience synthesized matrix.

Experience	A	B	C	D	E	Priority vector
A	0.517	0.565	0.411	0.400	0.421	0.463
B	0.258	0.282	0.480	0.286	0.263	0.314
C	0.086	0.040	0.069	0.229	0.158	0.116
D	0.074	0.056	0.017	0.057	0.105	0.062
E	0.065	0.056	0.023	0.029	0.053	0.045

Table 6 Determine the eigen value.

Experience	A	B	C	D	E	Sum	Weighted Sum
A	0.463	0.628	0.698	0.434	0.360	2.582	5.580
B	0.231	0.314	0.814	0.310	0.225	1.894	6.035
C	0.077	0.045	0.116	0.248	0.135	0.621	5.342
D	0.066	0.063	0.029	0.062	0.090	0.310	5.002
E	0.058	0.063	0.039	0.031	0.045	0.235	5.228
λ max							5.4374
$C_1 = \lambda \max - n/(n-1) = 0.10936$							
CR = C1/R1 = 0.097638961 < 0.1 OK							

Table 7 Pair wise comparison for criteria.

	Exp	EFCBC	FS	QP	MP R	ER	CWL	TS	WWDP	MOS	VE
Exp	1	2	2	3	9	6	5	1/2	1/4	1/2	1/2
EFCBC	1/2	1	2	3	6	8	5	3	2	2	1/2
FS	1/2	1/2	1	3	4	7	5	3	5	2	1/2
QP	1/3	1/3	1/3	1	5	4	4	1/2	2	3	1/2
MPR	1/9	1/6	1/4	1/5	1	1/2	1/5	2	4	1/2	1/2
ER	1/6	1/8	1/7	1/4	2	1	6	7	3	1/4	1/2
CWL	1/5	1/5	1/5	1/4	5	1/6	1	5	5	1/3	1/2
TS	2	1/3	1/3	2	1/2	1/7	1/5	1	3	1/2	1/2
WWDP	4	1/2	1/5	1/2	1/4	1/3	1/5	1/3	1	3	1/2
MOS	2	1/2	1/2	1/3	2	4	3	2	1/3	1	1/2
VE	2	2	2	2	2	2	2	2	2	2	1
Total	12.81	7.66	8.96	15.53	36.75	33.14	31.60	26.33	27.58	15.08	6.00

Table 8 Synthesized matrix for criteria.

	Exp	EFCBC	FS	QP	MPR	ER	CW L	TS	WWDP	MOS	VE	Priority vector
Exp	0.078	0.261	0.223	0.193	0.245	0.181	0.158	0.019	0.009	0.033	0.083	0.127
EFCBC	0.039	0.131	0.223	0.193	0.163	0.241	0.158	0.114	0.073	0.133	0.083	0.133
FS	0.039	0.065	0.112	0.193	0.109	0.211	0.158	0.114	0.181	0.133	0.083	0.120
QP	0.026	0.044	0.037	0.064	0.136	0.121	0.127	0.019	0.073	0.199	0.083	0.077
MPR	0.078	0.261	0.223	0.193	0.245	0.181	0.158	0.019	0.009	0.033	0.083	0.034
ER	0.009	0.022	0.028	0.013	0.027	0.015	0.006	0.076	0.145	0.033	0.083	0.066
CWL	0.013	0.016	0.016	0.016	0.054	0.030	0.190	0.266	0.109	0.017	0.083	0.059
TS	0.016	0.026	0.022	0.016	0.136	0.005	0.032	0.190	0.181	0.022	0.083	0.052
WWDP	0.156	0.044	0.037	0.129	0.014	0.004	0.006	0.038	0.109	0.033	0.083	0.064
MOS	0.312	0.065	0.022	0.032	0.007	0.010	0.006	0.013	0.036	0.199	0.083	0.066
VE	0.156	0.065	0.056	0.021	0.054	0.121	0.095	0.076	0.012	0.066	0.083	0.112

Note: EXP is Experience, EFCBC is Contractors classification, FS is Financial Stability, QP is Quality Performance, MPR is Manpower Resource, ER is Equipment Resource, CWL is Current Work Load, TS is Time Schedule, WWODP is Work without Down Payment, MOS is Method Of Statement and VE is Value Engineering.

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Table 9 Priority matrix for contractor prequalification.

	A	B	C	D	E	Priority vector	A	B	C	D	E
Exp	0.463	0.314	0.116	0.062	0.045	0.127	0.059	0.040	0.015	0.008	0.006
EFCBC	0.141	0.314	0.116	0.062	0.045	0.133	0.019	0.042	0.016	0.008	0.006
FS	0.419	0.292	0.052	0.134	0.103	0.120	0.050	0.035	0.006	0.016	0.012
QP	0.086	0.322	0.034	0.480	0.078	0.077	0.007	0.025	0.003	0.037	0.006
MPR	0.419	0.292	0.052	0.134	0.103	0.034	0.014	0.010	0.002	0.005	0.004
ER	0.040	0.080	0.146	0.377	0.357	0.066	0.003	0.005	0.010	0.025	0.024
CWL	0.040	0.080	0.146	0.377	0.357	0.059	0.002	0.005	0.009	0.022	0.021
TS	0.040	0.505	0.238	0.083	0.134	0.052	0.002	0.026	0.012	0.004	0.007
WWDP	0.463	0.314	0.116	0.062	0.045	0.127	0.059	0.040	0.015	0.008	0.006
MOS	0.141	0.314	0.116	0.062	0.045	0.133	0.019	0.042	0.016	0.008	0.006
VE	0.419	0.292	0.052	0.134	0.103	0.120	0.050	0.035	0.006	0.016	0.012
Total	0.086	0.322	0.034	0.480	0.078	0.077	0.007	0.025	0.003	0.037	0.006

or 0.314 or 0.116 or 0.062 or 0.045 [17], then calculating the consistency ratio, and calculating λmax, calculate CI consistency index. Select suitable random consistency ratio from Table 2. Check matrix of pair-wise consistency comparison to get if it consistent or not, [18].

Synthesizing matrix of pair-wise comparison is calculated by dividing matrix each element by its total column (see Table 5).

Estimating of consistency ratio CR = 0.463 * (1,1/2,1/6, 1/7,1/8) + 0.314 * (2,1,1/7,1/5,1/5) + 0.116 * (6,7,1,1/4,1/3) + 0.062 * (7,5,4,1,1/2) + 0.045 * (8,5,3,2,1) = (2.582, 1.894, 0.621, 0.310 and 0.235). Dividing weighted sum matrices all elements by their vector element of respective priority, it will be: (5.580, 6.035, 5.342, 5.002, and 5.228), then the average of these values to obtain λmax = (5.580 + 6.035 + 5.342 + 5.002 + 5.228)/5 = 5.4374. Then C1 = (λ max − n)/(n − 1) = 0.10936.

Select suitable random consistency ratio value RI using Table 2, it can be find RI = 1.12 and can calculate consistency ratio CR as shown Table 6. If it is less than 0.1 means judgments are acceptable, [19]. As same priority vectors and pair-wise comparison matrices for remaining criteria Table 7 shows all details (see Table 8).

Expert Choice software is used to combine criterion priorities and each decision alternative relative priorities to each criterion to can develop decision alternative overall priority ranking at priority matrix as in Table 9. Calculations for finding contractors overall priority as: (1) Contractor An overall priority = 0.463 (0.127) + 0.141 (0.133) + 0.419 (0.120) + 0.086 (0.077) + 0.419 (0.034) + 0.040 (0.066) + 0.040 (0.059) + 0.040 (0.052) + 0.035 (0.064) + 0.400 (0.066) + 0.035 (0.112) = 0.188. (2) Contractor B overall priority = 0.314 (0.127) + 0.314 (0.133) + 0.292 (0.120) + 0.322 (0.077) + 0.292 (0.034) + 0.080 (0.066) + 0.080 (0.059) + 0.505 (0.052) + 0.376 (0.064) + 0.303 (0.066) + 0.376 (0.112) = 0.273. (3) Contractor C overall priority = 0.116 (0.127) + 0.116 (0.133) + 0.052 (0.120) + 0.034 (0.077) + 0.052 (0.034) + 0.146 (0.066) + 0.146 (0.059) + 0.238 (0.052) + 0.286 (0.064) + 0.189 (0.066) + 0.286 (0.112) = 0.134. (4) Contractor D overall priority = 0.062 (0.127) + 0.062 (0.133) + 0.134 (0.120) + 0.480 (0.077) + 0.134 (0.034) + 0.377(0.066) + 0.377 (0.059) + 0.083 (0.052)

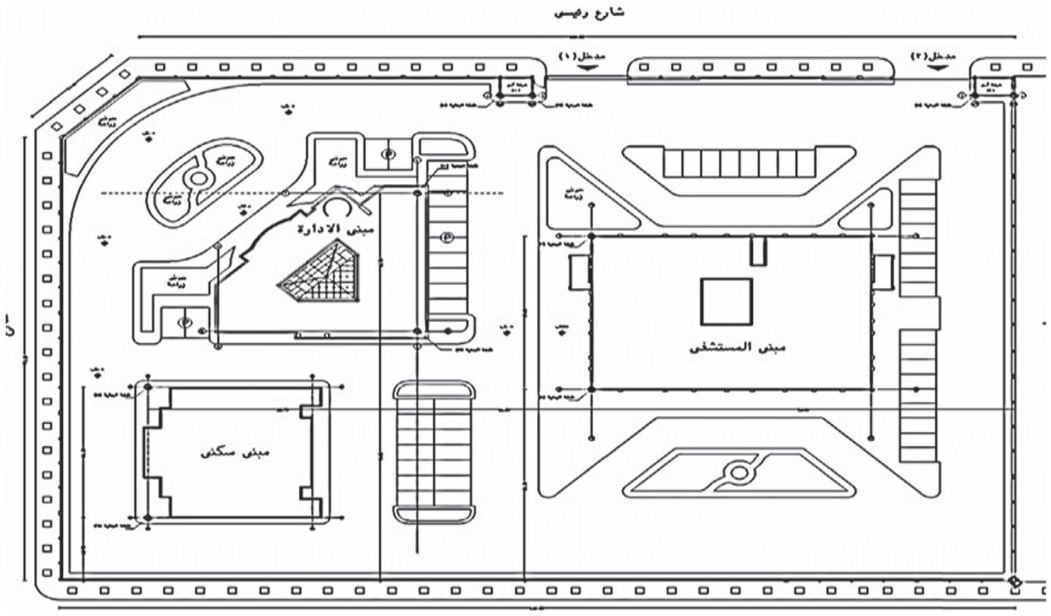

Fig. 5 A compound containing Hospital, Staff Housing and Administration Building Project.

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+ 0.112 (0.064) + 0.055 (0.066) + 0.112 (0.112) = 0.148. (5) Contractor E overall priority = 0.045 (0.127) + 0.045 (0.133) + 0.103 (0.120) + 0.078 (0.077) + 0.103 (0.034) + 0.357(0.066) + 0.357 (0.059) + 0.134 (0.052) + 0.190 (0.064) + 0.053 (0.066) + 0.190 (0.112) = 0.122.

For prequalification all contractors will be ranked due to their overall priorities: (1) D, (2) C, (3) B, (4) A, and (5) E, that indicate contractor D is best qualified one. From the previous case of study it will be concluded an evaluative technical model of contractors and explains the order of the elements that must be taken into account in the assessment of the contractors and the financial evaluative model.

Value Engineering is applicable to systems, equipment, facilities, and procedures. The following are some of the fields in which VE has been applied: (1) Construction, (2) Water system, (3) Design or equipment modifications, (4) Equipment and logistics support, (5) Facilities and hardware, (6) Manufacturing processes, (7) Materiel handling and transportation, (8) Publications, manuals, procedures, and Papers, (9) Salvage, rejected, or excess material. (10) Site preparation and adaptation, (11) Software architecture development, (12) Technical and logistics data, (13) Testing, test equipment, and procedures, and (14) Tooling Training [9].

From the previous case study it is concluded an evaluative technical model of contractors and explains the order of the elements that must be taken into account in the assessment of the contractors and the financial evaluative model. In this project as shown in Fig. 5; technical and financial evaluative models are applied, in order to choose right contractor to construct the project. Table 10 illustrates contractors' participation in the proposed tender for the implementation of this process.

Table 11 shows that the third contractor is best contractor for the implementation of the previous operation technically. Then the evaluative financial model is applied, which depends on the price submitted by each contractor. The hospital consists of a basement, ground and first floor also it contains three entrances, clinics, rest places, patients' rooms, labs, x-ray and pharmacy. The foundation type is isolated reinforced footings types & the slabs type is solid. The Staff Housing consists of five floors with five flats in each. The type of foundation is raft foundation & the slabs type is solid. The Administration building consists of ground, first and second floor. It contains reception, manager's offices, financial sector offices, conference room, training room and stores. The foundation type is isolated reinforced footings types &the slabs type is solid. The estimated cost was developed by VE team by reviewing the bill of quantity for all the project and estimate the cost for each item, and project cost is: (1) Hospital is 6,957,780 EGP, (2) Administration building is 3,342,800 EGP, (3) Staff Housing is 4,613,405 EGP and (4) Total is 14,913,985 EGP.

Table 11 Evaluative technical model for contractors.

	Contractor A	Contractor B	Contractor C
Experience	8	7	8
Contractor classification in EFCBC	8	6	8
Financial stability	7	4	10
Quality performance	8	8	8
Manpower resource	7	8	9
Equipment resource	7	8	9
Current work load	9	8	7
Time schedule	6	10	8
Work without down payment	10	10	8
Method of statement	6	10	8
Applied VE	6	10	8
Total	82	89	91

Table 10 Evolution of contractors.

	Contractor A	Contractor C	Contractor D
Experience	29 year No similar project	23 year One similar project	17 year Three similar project
Contractor classification in EFCBC	Second	Third	Second
Financial stability	6 M assets 1.5 M liabilities	3 M assets 1 M liabilities	14 M assets 6 M liabilities
Quality performance	Good organization C.M. personnel Good One project terminated Average quality	Average organization C.M. personnel Two delayed projects Safety program	Good organization C.M. team Government award Good reputation
Manpower resource	15 laborers 26 by subcontract	25 laborers 10 by subcontract	25 laborers Good skilled labors
Equipment resource	1 mixer machine 1 excavator 10 others	2 mixer machine 1 excavator 18 others	2 mixer machine 1 excavator 16 others
Current work load	2 small projects started 3 projects ending (2 small + 1 medium)	2 projects ending (1 big + 1 medium)	1 medium project started 2 projects ending (1 big + 1 medium)
Time schedule	Good	Excellent	Very good
Work without down payment	No	No	Yes
Method of statement.	Good	Excellent	Very good
Applied VE	Good	Excellent	Very good

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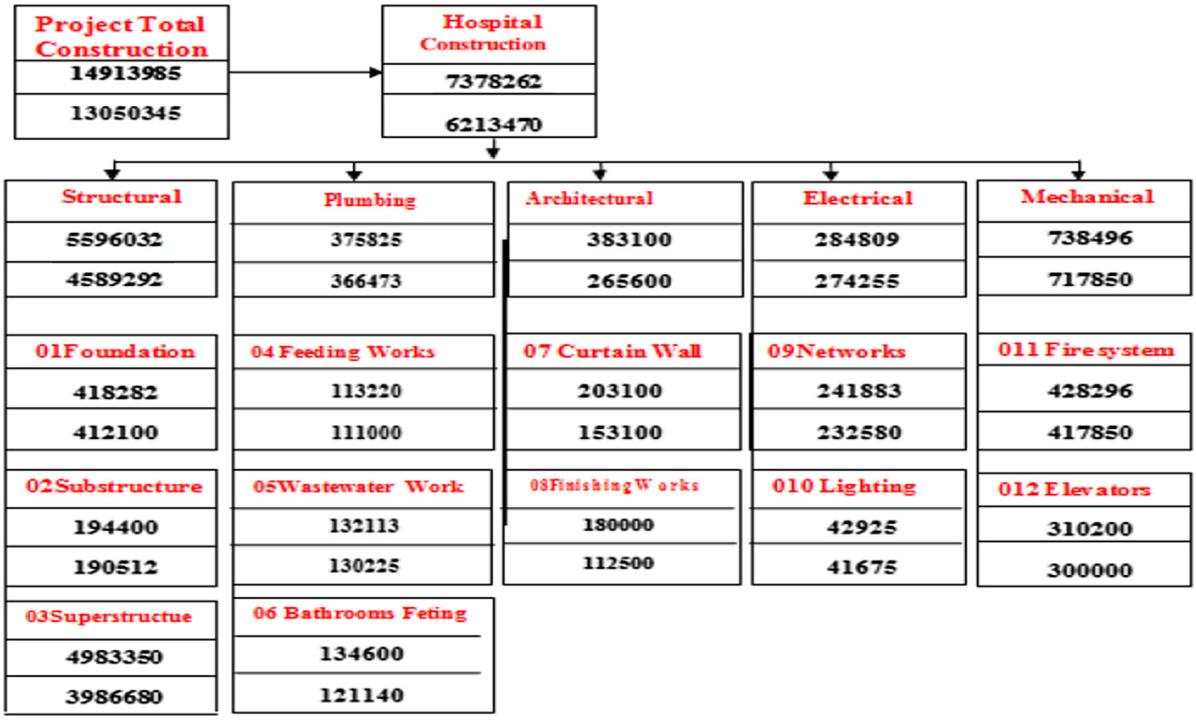

Fig. 6 Cost worth Model of the Hospital.

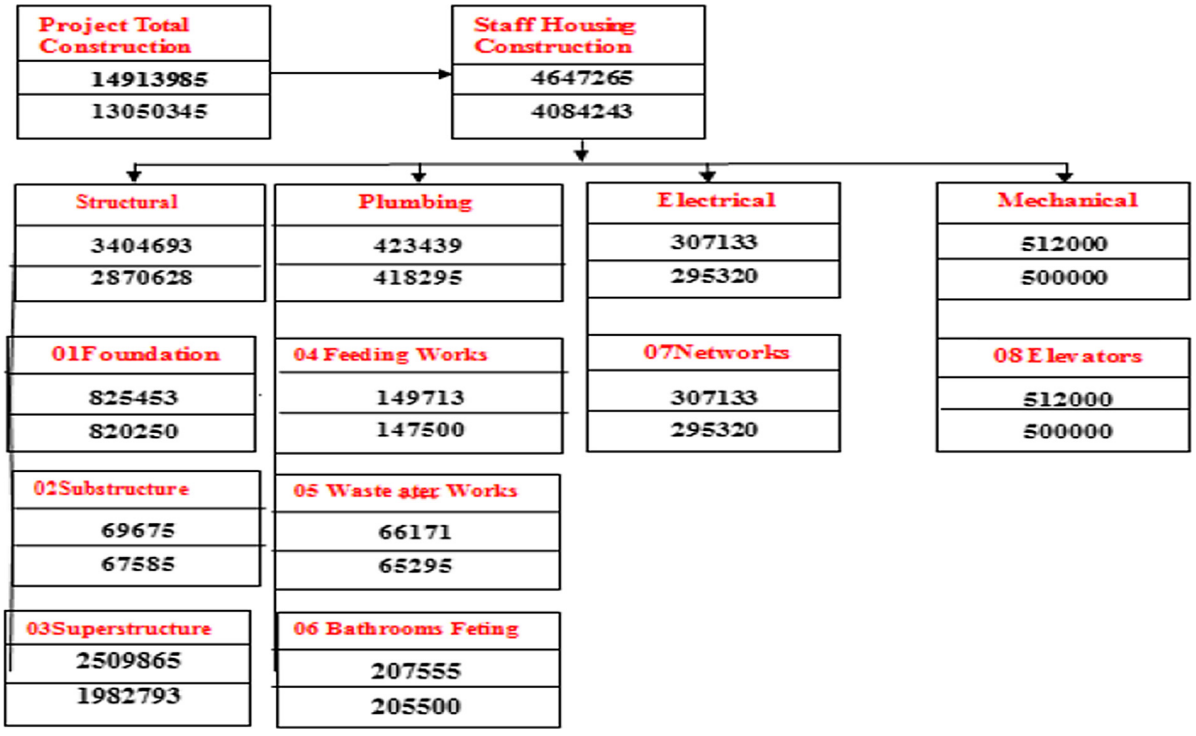

Fig. 7 Cost worth Model of Staff Housing Building.

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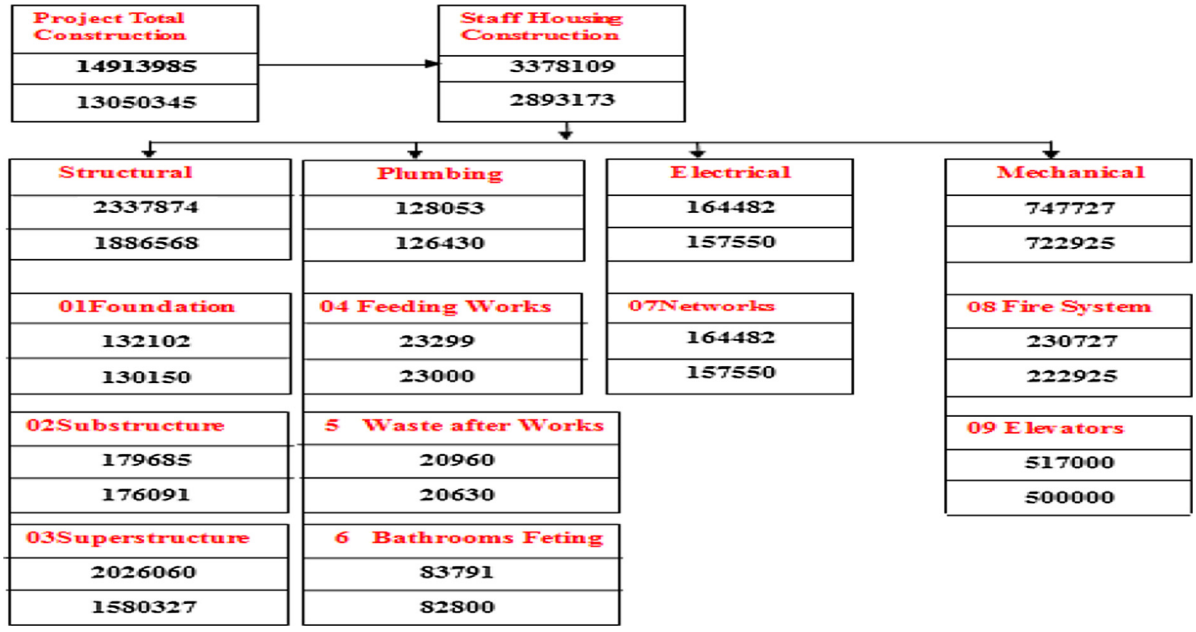

Fig. 8 Cost worth Model of Administration Building.

Table 12 Function analysis worksheet of hospital.

Component	Description	Function	Kind	Cost	Worth	Cost/Worth
Structural						
01 Foundation		Fixing the building	B	418,282	412,100	1.02
02 Substructure		Support foundation	B	194,400	190,512	1.02
03 Superstructure		Transfer load	B	4,983,350	3,986,680	1.25
Total				5,596,032	4,589,292	
Plumbing						
04 Feeding Works		Supply water	B	113,220	111,000	1.02
05 Waste water Works		Get out waste water	B	132,113	130,225	1.02
06 Bathrooms Feting		Make waste	B	134,600	121,140	1.11
Total				375,825	366,473	
Architectural						
07 Curtain Wall		Decorate walls	RS	203,100	153,100	1.3
08 Finishing Works		Decorate floors	B	180,000	112,500	1.6
Total				383,100	265,600	
Electrical						
09 Networks		Distributed load	RS	241,883	232,580	1.03
010 Lighting		Lighting hospital	B	42,925	41,675	1.02
Total				284,809	274,255	
Mechanical						
011 Fire system		Extinguish the fire	RS	428,296	417,850	1.03
012 Elevator		Transfer people	B	310,200	300,000	
Total				738,496	717,850	
Overall total				7,378,262	6,213,470	

9. Project cost worth model

Cost information used during the study is normally prepared by owner team estimators and cost model is prepared from this information. This model is shown in Figs. 6–8.

10. Function analysis phase

It consists of function analysis worksheet is shown in Tables 12–17. FAST Diagram worksheet is shown in Figs. 9–11.

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Table 13 Function analysis worksheet of staff housing building.

Component Description	Function	Kind	Cost	Worth	Cost/Worth
Structural					
01 Foundation	Fixing the building	B	825,453	820,250	1.02
02 Substructure	Support foundation	B	69,675	67,585	1.02
03 Superstructure	Transfer load	B	2,509,865	1,982,793	1.25
Total			3,404,993	2,870,628	
Plumbing					
04 Feeding Works	Supply water	B	149,713	147,500	1.02
05 Wastewater Works	Get out waste water	B	66,274	65,295	1.02
06 Bathrooms Feting	Make waste	B	207,555	205,500	1.11
Total			423,542	418,295	
Electrical					
07 Networks	Distributed load	RS	307,133	295,329	1.03
Total			307,133	295,329	
Mechanical					
08 Elevator	Transfer people	B	512,000	500,000	
Total			512,000	722,925	
Overall total			7,378,262	6,213,470	

Table 14 Function analysis worksheet of staff administration building.

Component Description	Function	Kind	Cost	Worth	Cost/Worth
Structural					
01 Foundation	Fixing the building	B	132,102	130,150	1.02
02 Substructure	Support foundation	B	179,685	176,091	1.02
03 Superstructure	Transfer load	B	2,026,060	1,580,327	1.25
Total			2,337,847	1,886,568	
Plumbing					
04 Feeding Works	Supply water	B	23,299	23,000	1.02
05 Waste water Works	Get out waste water	B	20,960	20,630	1.02
06 Bathrooms Feting	Make waste	B	83,794	82,500	1.11
Total			128,053	126,130	
Electrical					
07 Networks	Distributed load	RS	164,482	157,550	1.03
Total			164,482	157,550	
Mechanical					
08 Fire system	Extinguish the fire	RS	230,727	222,925	
09 Elevator	Transfer people	B	517,000	500,000	
Total			747,727	722,925	
Overall total			3,378,109	2,893,173	

Table 15 Function analysis of hospital.

Sub component description	Verb	Noun	Kind	Initial. Cost	Worth	Cost/Worth
Slabs	Transfer	Loads	B	400,000	320,000	1.25
	Protect	Moisture	S	100,000	78,000	1.28
	Protect	Heat	S	100,000	78,000	1.28
	Protect	Cold	S	100,000	80,000	1.25
	Protect	Sun	S	100,000	81,000	1.23
	Protect	Rain	S	100,000	82,000	1.22
	Build	Floors	B	280,000	224,000	1.25
	Make	Privacy	S	100,000	86,000	1.16
	Isolate	Noise	S	100,000	77,000	1.30
Total				1,380,000	1,106,000	1.25

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Table 16 Function analysis of staff housing building.

Sub component description	Verb	Noun	Kind	Initial. Cost	Worth	Cost/Worth
Slabs	Transfer	Loads	B	150,000	120,000	1.25
	Protect	Moisture	RS	50,000	39,000	1.28
	Protect	Heat	RS	50,000	39,000	1.28
	Protect	Cold	RS	50,000	40,000	1.25
	Protect	Sun	RS	50,000	40,500	1.23
	Protect	Rain	RS	50,000	41,000	1.22
	Build	Floors	B	122,500	98,000	1.25
	Make	Privacy	RS	50,000	43,000	1.16
	Isolate	Noise	RS	50,000	38,500	1.30
Total				622,500	499,000	1.25

Table 17 Function analysis of staff administration building.

Sub component description	Verb	Noun	Kind	Initial. Cost	Worth	Cost/Worth
Slabs	Transfer	Loads	B	100,000	80,000	1.25
	Protect	Moisture	RS	50,000	39,000	1.28
	Protect	Heat	RS	50,000	39,000	1.28
	Protect	Cold	RS	50,000	40,000	1.25
	Protect	Sun	RS	50,000	40,500	1.23
	Protect	Rain	RS	50,000	41,000	1.22
	Build	Floors	B	97,500	78,000	1.25
	Make	Privacy	RS	50,000	43,000	1.16
	Isolate	Noise	RS	50,000	38,500	1.30
Total				547,500	439,000	1.25

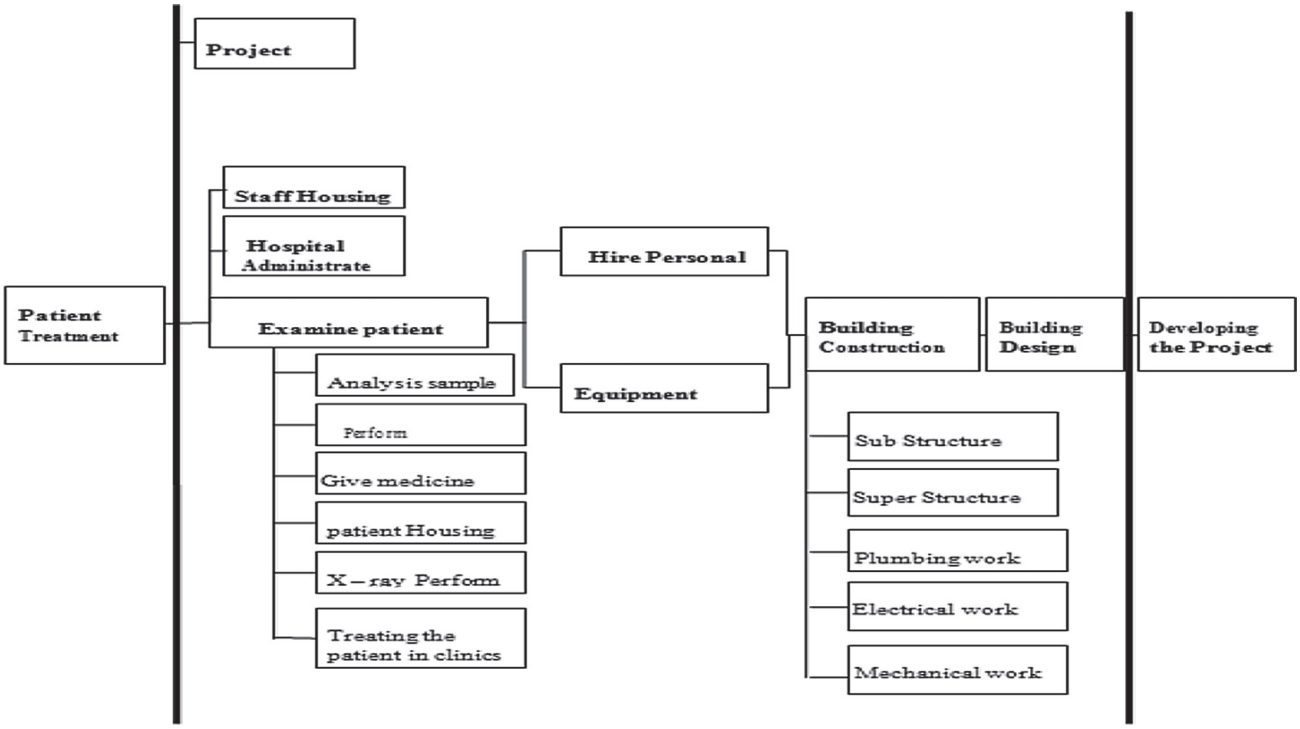

Fig. 9 FAST diagram of Hospital, Staff Housing and Administration building Project.

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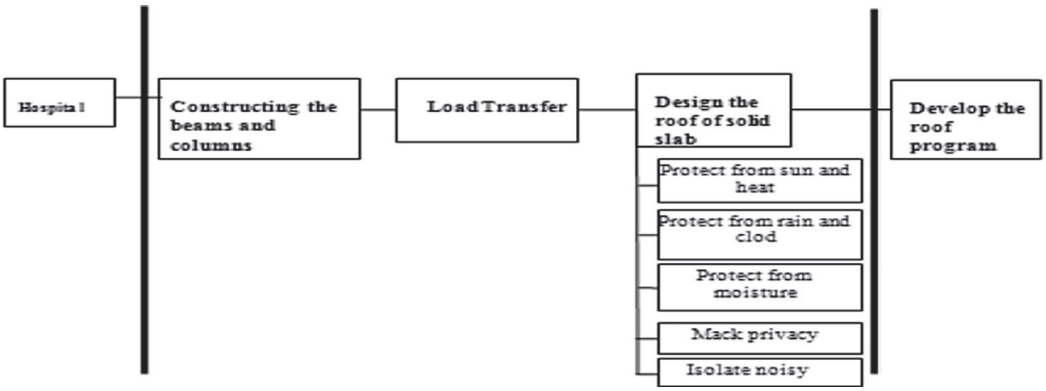

Fig. 10 FAST diagram of a solid slab.

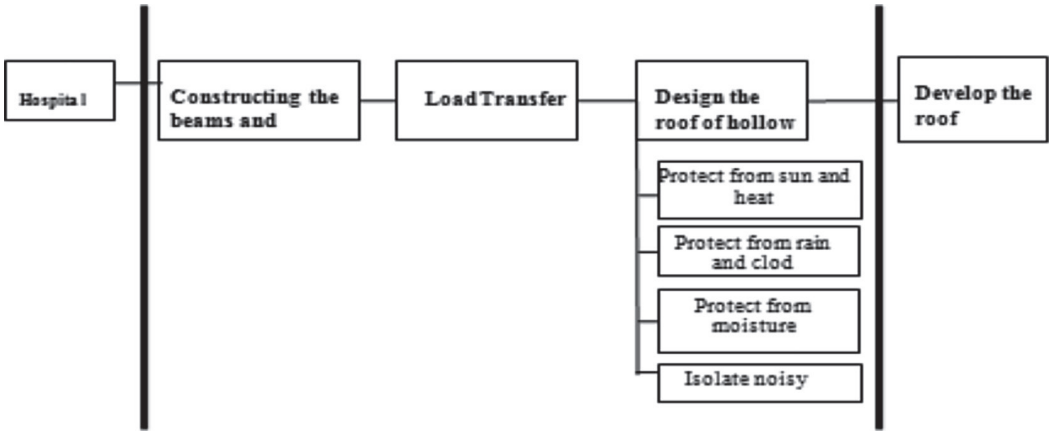

Fig. 11 FAST diagram of hollow blocks.

Table 18 Bill of quantity of interface (1).

Item	Description	Unit	Quantity	Unit Price	Total
1	Supply and install composite panel	M^2	250	650	162,500
2	Supply and install curtain wall	M^2	150	1200	180,000
3	The supply and implementation of paints Graviato.	M^2	180	45	8100
4	Supply and install marble skirting of stairs	M.L	65	500	32,500
Total					383,100

Table 19 Bill of quantity of interface (2).

Item	Description	Unit	Quantity	Unit Price	Total
1	Supply and install Aluminum partition	M^2	150	750	112,500
2	Supply and install skirting color marble for walls and columns	M^2	250	450	112,500
3	The supply and implementation of paints Graviato.	M^2	180	45	8100
4	Supply and install marble skirting of stairs	M.L	65	500	32,500
Total					265,600

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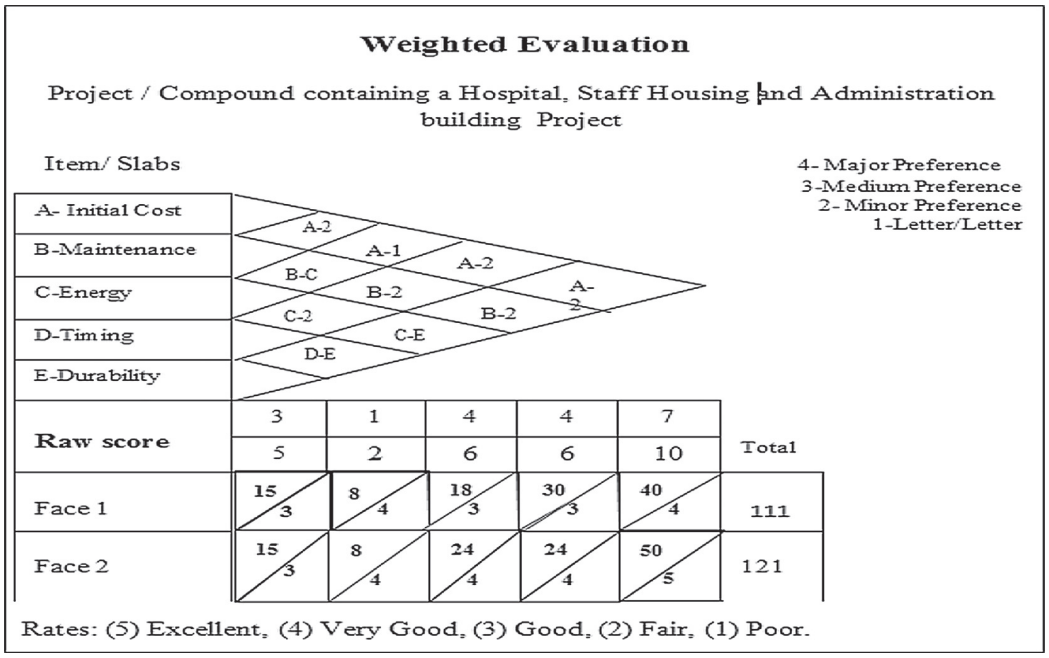

Fig. 12 Weighted evaluation matrix of hospital.

Table 20 Alternatives cost summary.

	Original design	1st alternative	2nd alternative
Initial cost (EGP) in million	6.957780	6.692780	6.485980
Life Cycle	25	25	25
Design cost	2%	2%	2%
Maintenance, operation	5%	3%	4%
Interest rate	10%	10%	10%
Alteration & replacement	10%ev. 8y	10%ev. 8y	10%ev. 8y

11. Creativity analysis phase

In this case study it must be create different alternatives [20] as: (1) Structural Alternative: Changing the slabs from solid to hollow blocks. (2) Architectural Alternative: Changing the materials of the hospital interface and changing the internal finish of the hospital. (3) Mechanical Alternative: Changing the Elevator system and changing the fire system. (4) Electrical Alternative: Changing the network system (see Table 18).

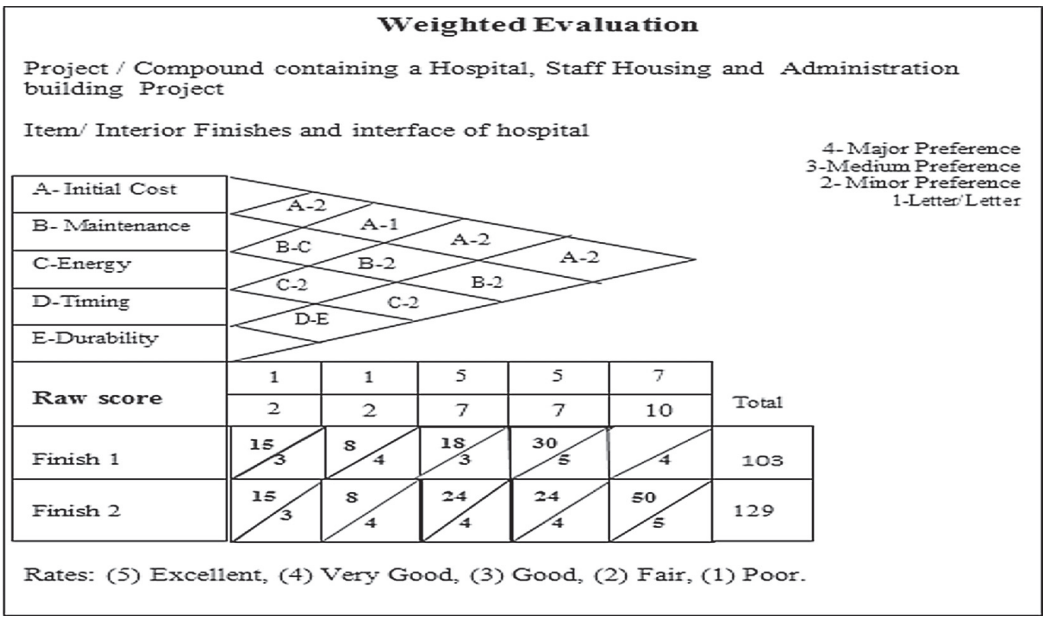

Fig. 13 Weighted evaluation matrix for interior finishes and interface of hospital.

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Table 21 Life cycle cost (annualized).

Item/Compound containing a Hospital, Staff Housing and Administration building Project Others Structural Mechanical Electrical Economic life: 25 Years Discount Rate: 10%					
	Item	Description	Original	Alternative no. 1	Alternative no. 2
Input data	Collateral & Instant	Initial Costs	6,957,780	6,692,780	6,485,980
		Basic Cost			
		Interface Cost			
		a-Design	139155.6	133855.6	129719.6
		Other initial Cost			
		a. Other owner equipment	200,000	200,000	200,000
		Total initial cost impact	909635.6	8826635.6	8915699.6
	Salvage & Replacement cost	Single Expenditure @ Interest present worth			
		1-8Years			1,000,000
		Factor (0.4665)			466,500
		2-16Years	2,500,000	2,000,000	1,500,000
		Factor (0.2176)	544,000	435,200	326,400
		3-25Years	4,000,000	3,500,000	3,000,000
		Factor (0.0923)	369,200	323,050	276,900
		Salvage Amount	7,413,200	6,258,250	6,569,800
Output data	Life Cycle cost (Annualized)	Annual Owing & Operating cost	1002482.3	972695.2	949450.1
		1.Capital IC X PP (0.1102)			
		Recovery 25 Year @ 10%			
		a-8Years			51408.3
		b-16Years	275,500	220,400	35969.3
		c-25Years	40685.8	35600.1	30514.4
		Annual Costs			
		a. Maintenance	347,889	334,639	324,299
		Total Annual Costs	1585185.5	1498134.1	1330612.3
		Annual Different (AD)		93051.3	254573.2
		Present Worth of Annual Different			
		PWA Factor X AD		844626.9	2310760.6

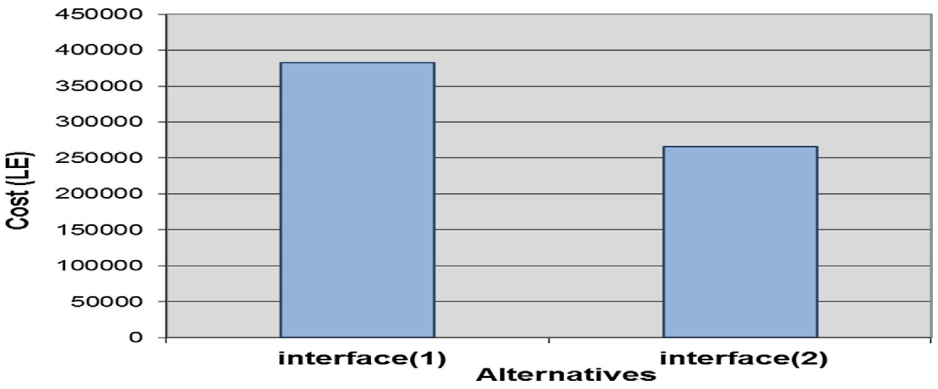

Fig. 14 Architectural alternatives weight (finishing hospital's interface).

12. Development phase

The Evaluation Analysis phase consists of life cycle cost. There were two ways to analyze total costs: (1) Annualized Costs. (2) Present Worth Costs (see Table 19).

First: Evaluation with (Annualized Cost Method); the method of converting all the expected costs and costs including the initial and periodic expected during a certain period of time are equal to the annual costs by using the coefficient of (Periodic Payment – PP) from economic analysis. Life cycle cost (Annualized) is shown in Fig. 12. PP is Periodic Payment; PWA is Present Worth of Annuity; and PW is Present Worth (see Table 20).

Second: Evaluation with (Present worth Method); this model is shown in Fig. 13 (see Table 21).

13. Presentation phase

Presentation usually includes the following: (1) Project Main Objective such as: (A) Reducing initial cost, (B) Saving wasted

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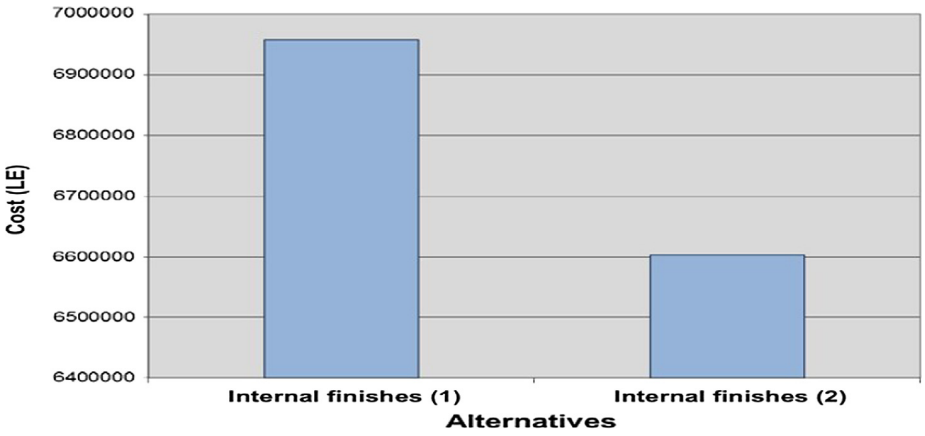

Fig. 15 Architectural alternatives weight (internal finish).

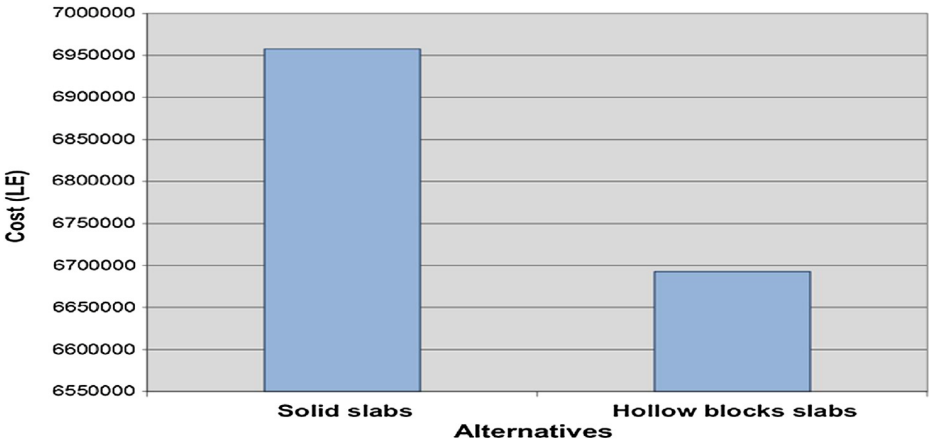

Fig. 16 Structural alternatives weight.

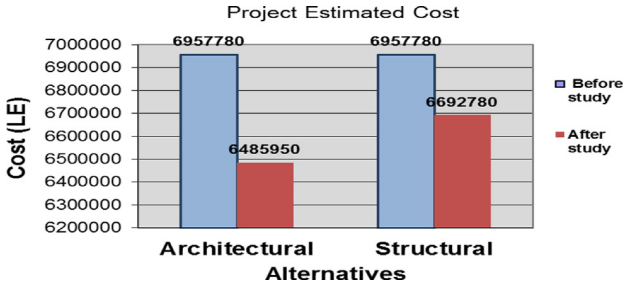

Fig. 17 Project estimation cost.

time and (C) Improving structural & architectural system. (2) Value Engineering (VE) Recommendations **as:** some ideas were generated during the initial review phase ideas to improve the value of the project. Three ideas were developed in the hospital recommending initial cost savings about 0.75 million EGP using these alternatives (see Fig. 14).

14. Architectural alternatives

Changing materials used in finishing the hospital's interface from curtain wall, composite panel and Graviato to marble by 383100, aluminum and Graviato by 265,600 which saved about 120,000 EGP (see Fig. 15).

Changing the internal finish of the hospital which saved about 350,000 EGP by Revising the finish practical floor finish by using ceramic by 6,603,450 EGP instead of porcelain, black granite instead of black marble and Cleopatra bathroom fittings instead of ideal standard fittings by 6,957,780 EGP (see Fig. 16).

15. Structural alternative

Change the structural system of the slabs of hospital from solid slabs by 6,957,780 to hollow blocks slabs by 6,692,780 which saved about 265,000 EGP (see Fig. 17).

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Table 22 Life cycle cost (PW).

Item/Compound containing a Hospital, Staff Housing and Administration building Project Others Structural Mechanical Electrical Economic life: 25 Years Discount Rate: 10%								
Item		Description	Original		Alternative no. 1		Alternative no. 2	
			Estimatedcost	Present worth	Estimatedcost	Present worth	Estimatedcost	Present worth
Input data	Collateral & Instant Contract cost	Initial Costs Basic Cost		8,967,780	8,892,780			8,485,980
		Interface Cost a-Design		139155.8		133855.8		129719.8
		Other initial Costs a. Other owner equipment		200,000		200,000		200,000
		Total initial cost impact		9098938.8		8828835.8		
	Salvage & Replacement cost	Single Expenditure @ 10% Interest 1.8Year Factor (0.4885)					1,000,000	488,500
		2.16Year Factor (0.2178)	2,500,000	844,000	2,000,000	435,200	1,500,000	328,400
		3.25Year Factor (0.0923)	4,000,000	389,200	3,500,000	323,050	3,000,000	2,789,000
		Total Present Worth		174,800		112,150		189,800
Output data	Annual Cost	Annual Cost@ 10 % interest a. Maintenance Factor (9.077)	347,889	3157188.5	334,839	3037518.2	32,499	2943882.02
		Total Annual Cost		3167788.5		3037618.2		294388.02
		Total Present Worth Cost				11978303.8		11808861.8
		Life cycle (PW) Saving				469220.25		820882.4

Table 23 Summary of potential cost savings from VE proposals.

Item		Cost of hospital (EGP)		Initial savings	Initial savings
		Before study	After study		
Hospital	Architectural	6,957,780	6,485,950	2	471,830
	Structural	6,957,780	6,692,780	1	265,000
	Total	6,957,780	6,220,950	3	736,830

16. Conclusion

The benefits of a formalized and effective of the Analytical Hierarchy Process (AHP) and Value Engineering (VE) are included advantage: (1) Minimize project time, (2) Minimize project cost and (3) Maximize project quality. This Paper explains the problem of assessing contractors through using the AHP in Construction management. Construction contractors will be checked by the project's owners and their representatives for performing successful projects, and to determine contractor's competence in project implementation. This process aims to eliminate incompetent contractors of tendering process. As it helps the owner in private/public divisions to achieve success and efficient use of their money through the use of qualified contractors to implement the project efficiently. Moreover, because of the skill, the ability and competence of the contractor, the project can be finished fixed estimated cost and more bearable time. It was also required the need to apply value engineering to raise the performance level of and reduce costs. The Paper presents also very important to use (VE) Value Engineering. VE can improve decision making to get best fund to owner and it is a useful technique that creates change on purpose rather than letting change happen accidentally. Selected case study gathers a number of contractor's or companies data. Taking part in the Youth Housing project. After studying, the Analytical Hierarchy Process

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(AHP) of a set of criteria. A table of technical evaluation of the contractors was concluded which were the previous experience, financial situation and the contractor's classification in the Union of Contractors. In addition labor's progress, available equipment for the contractor and the contractor applying Value Engineering (VE) (see Table 22).

One of the most prominent results of this Paper is the conclusion of an evaluative technical model evaluation of the contractors. As it explains the elements need to be available in the contractor or the company in order to be technically accepted. And also a financial evaluation model so that the contractor or the company will be financially accepted. Moreover to eliminate incompetent contractors in the tendering process. It is necessary to apply Value Engineering to raise the performance level and reducing costs (see Table 23).

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Electropolymerization of Nitrophenol Isomers in Various Aqueous Electrolytic Solutions

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This study focuses on the electrodeposition of 2-nitrophenol, 3-nitrophenol, and 4-nitrophenol in either acidic, alkaline or neutral aqueous solutions. All the isomers have been electropolymerized using cyclic voltammetry (CV). A notable feature in all CV measurements was that the insulating polymer films deposited on gold electrodes (A= 0.02 cm^2) from solutions were revealed by the rapid drop in current measured, when compared to the original CV scans. Generally, the anodic oxidation potential for 3-nitrophenol was slightly lower than that for 2-nitrophenol and 4-nitrophenol electropolymerized from solutions of similar pH. Values of the molecular orbital energies of the HOMO and LUMO orbitals of the nitrophenol monomers in various ionization states were determined. Energy values were calculated and used to explain the electrochemistry of nitrophenol isomers. Electropolymerization of nitrophenol isomers was found to be most difficult in acid and easiest in basic medium. This was also confirmed by the calculated diffusion coefficients of the monmers. In conclusion, 3-nitrophenol showed the best electropolymerization performance, and 2-nitropehnol showed very poor coverage on the electrode surface.

Keywords: Modified Electrodes; Thin Film; Oxidation; Diffusion.

1. INTRODUCTION

Electropolymerization is a well-known technique used for depositing a thin film of polymer on conducting substrates, for example on gold, by means of cyclic voltammetry.[1-5] Several researchers have performed electropolymerization on various derivatives of phenol to produce non-conducting polymers,[6-9] to protect surfaces from corrosion,[10] as membranes for biosensors,[11] or for waste water treatment.[12]

The electropolymerization of polyphenol derivatives has been extensively studied in the literature by several researchers. Samet *et.al.*[13] compared the electropolymerization of phenol

derivatives such as phenol, *o*-methoxyphenol and *o*-nitrophenol by cyclic voltammetry and optical microscopic techniques on gold and carbon steel electrodes. They could successfully prepare adherent polyphenol films using *o*-methoxyphenol to protect carbon steel against corrosion.[13]

Li *et. al.*[14] concluded that the electropolymerization of *p*-nitrophenyl-functionalized thiophene derivatives produced materials having the electronic properties of both polythiophene and nitrobenzene. Nitro groups exhibit a complex nature of the studied cyclic voltammetric curves in the obtained solid polymeric films.[14]

Bao *et. al.*[15] electrochemically coated polyphenol flakes on stainless steel samples in 0.1 mol dm^{-3} phenol neutral solutions with an electrolyte composed of 0.1 mol dm^{-3} sodium sulfate by cyclic voltammetry.[15] Pham *et. al.*[16] have proposed an electropolymerization mechanism of substituted phenols on steel electrodes. The electrochemical nature of the substituents and their positions are important factors in the stability of polymers. They concluded that the polymer film formation is quick when the *para* position of the hydroxyl group is free, whereas it cannot happen when the *para* and one of the *ortho* positions are barren.[16]

In previous works of this laboratory, we have studied the electropolymerization process of several non-conducting polymers that include poly-phenol derivatives, such as 1,2-dihydroxybenzene; 2-hydroxybenzyl alcohol; 1,3-dihydroxybenzene; 3-hydroxybenzyl alcohol; 1,4-dihydroxybenzene; 4-hydroxybenzyl alcohol; 2-aminophenol; 2-aminobenzyl alcohol; 3-aminophenol; and 3-aminobenzyl alcohol, from aqueous solutions at various pH values.[3, 4, 17-19] It was presented that the rapid drop in current values was indicative of polymeric film growth on gold working electrodes, as observed in cyclic voltammetry.

As far as our current knowledge goes, the electropolymerization of the nitrophenol isomers has not been extensively studied in the literature, and hence the need to conduct comprehensive electrochemical research in various aqueous media to enrich our knowledge of these compounds. Most of the papers in the existing literature focus on the determination of nitrophenol isomers in different samples environmentally or industrially.[20-23]

In the present research, we utilize nitrophenol isomers to deposit insulating non-conducting polymers on gold electrodes by electropolymerization. Consequently, monomer precursors are dissolved in solutions of different pH values that vary between acidic, neutral and basic mediums. When current was applied to these solutions, thin layers of the polymer could be synthesized and deposited on a wide range of conducting and semiconducting surfaces, e.g. gold. Thus, in this paper the electrochemical behavior of 2-nitrophenol, 3-nitrophenol and 4-nitrophenol is compared and contrasted, and a link is established between anodic oxidation potentials, calculated energies of the HOMO and LUMO molecular orbitals and the effect of pH/pKa on the entire electropolymerization process.

2. EXPERIMENTAL

2.1. Materials and reagents

All chemicals were used as received. 2-nitrophenol (>98%), 3-nitrophenol (>98%), 4-nitrophenol (>99%), potassium ferrocyanide trihydrate (>98%), potassium chloride (99%), and potassium ferricyanide (>98%) were all purchased from Alfa Aesar, Germany. Sulfuric acid (95-98%)

and sodium hydroxide (98%) were procured from PRS, Panreac, Spain. All aqueous solutions were prepared using deionized water from a Milli-pore Milli-Q system (resistivity= 18.2 MΩ cm).

2.2. Film Preparation

The electropolymerization experiments were conducted using a three electrode glass cell as previously described.[18] In brief, an EZstat Pro-potentiostat manufactured by NuVant Systems Inc. (IN, USA) and equipped with an EZware 2013 V7 analyzing software was used throughout the course of this work. At the beginning of each electrochemical experiment, the working electrode was mechanically polished for two minutes using the suspended solution of 0.05µm alumina performed on polishing pads (polishing kit number: PK-4) purchased from BASi Preclinical services (IN, USA). A platinum coiled wire (230 mm) mounted in a CTFE cylinder was used as the counter electrode. All the electrodes were supplied by BASi (IN, USA).

The polished gold electrode was immediately flushed with excess deionized water to remove any remaining alumina deposits. All the polished electrodes were tested before usage by performing cyclic voltammetry runs operated between -0.2 V and 0.6 V, in a solution of 5.0 mmol dm^{-3} $K_3Fe(CN)_6$/ $K_4Fe(CN)_6$ consisting of 0.1 mol dm^{-3} KCl vs. (Ag/AgCl, 3.0 mol dm^{-3} KCl) at a sweep rate of 20 mV s^{-1} for four sweeps of applied potential.[18]

All the nitrophenol isomers used in this study were electropolymerized at 1.6 mm diameter polished gold electrodes (A= 0.02 cm^2). Based on the supporting electrolyte, several solutions of 0.1 mol dm^{-3} 2-nitrophenol, 0.1 mol dm^{-3} 3-nitrophenol and 0.1 mol dm^{-3} 4-nitrophenol were prepared separately by using either KCl (0.1 mol dm^{-3}, neutral solution), H_2SO_4 (0.1 mol dm^{-3}, acid solution) or NaOH (0.1 mol dm^{-3}, basic solution). The prepared solutions were then electropolymerized vs. (Ag/AgCl, 3.0 mol dm^{-3} KCl) by applying the sweeping potential between 0.0−1.0 V for basic and neutral solutions, and for acidic samples the applied potential was 0.0−1.2 V. Various scan rates were used, such as 5, 10 and 20 mV s^{-1} for six sweeps of applied potential. It meant that the electrochemical polymerization was performed by using cyclic voltammetry in the mentioned potential region using six cycles. At the end of each electropolymerization experiment, all the modified electrodes were tested in a solution of 5.0 mmol dm^{-3} $K_3Fe(CN)_6$/ $K_4Fe(CN)_6$ consisting of 0.1 mol dm^{-3} KCl vs. (Ag/AgCl, 3.0 mol dm^{-3} KCl) at a sweep rate of 20 mV s^{-1} for four sweeps of applied potential. This necessary step was conducted to ensure that the polymer film was fully deposited at the electrode surface.

2.3. Molecular Orbital Calculations

In the present study, Spartan 14 (V1.1.4) software, the well-known molecular modelling suite, has been used here to calculate the HOMO and the LUMO frontier molecular energies.[18] At restricted Hartree–Fock level using HF/6-311G* model, all the neutral and ionic structures built followed by the geometrical optimization were calculated and modelled at the ground state.[18]

3. RESULTS AND DISCUSSION

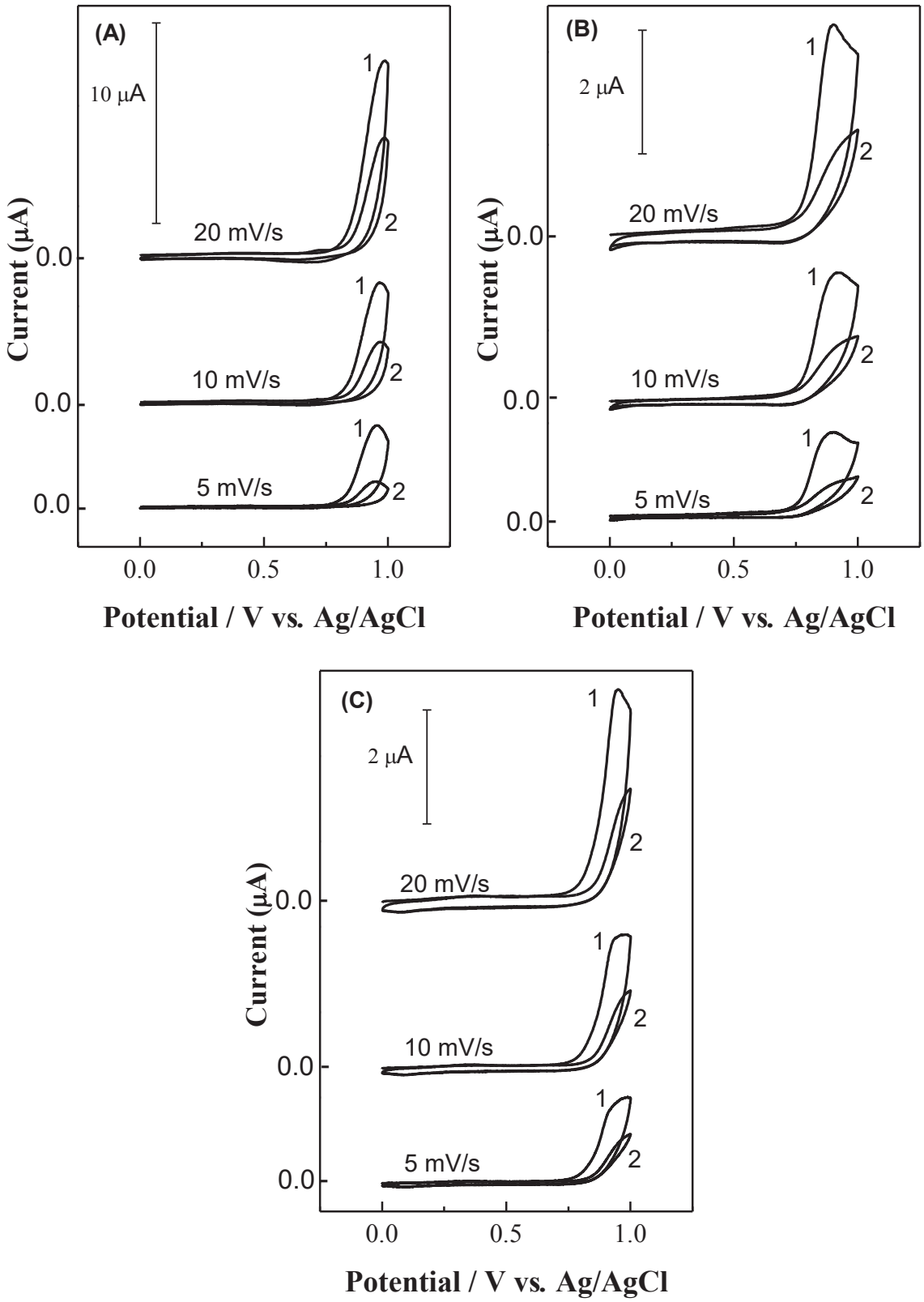


Figure 1. First two cyclic voltammograms of 0.1 mol dm^{-3} nitrophenol isomers that have been electropolymerized from neutral solutions at pH equal to 7.0 (0.1 mol dm^{-3} KCl): (a) 2-nitrophenol, (b) 3-nitrophenol, and (c) 4-nitrophenol.

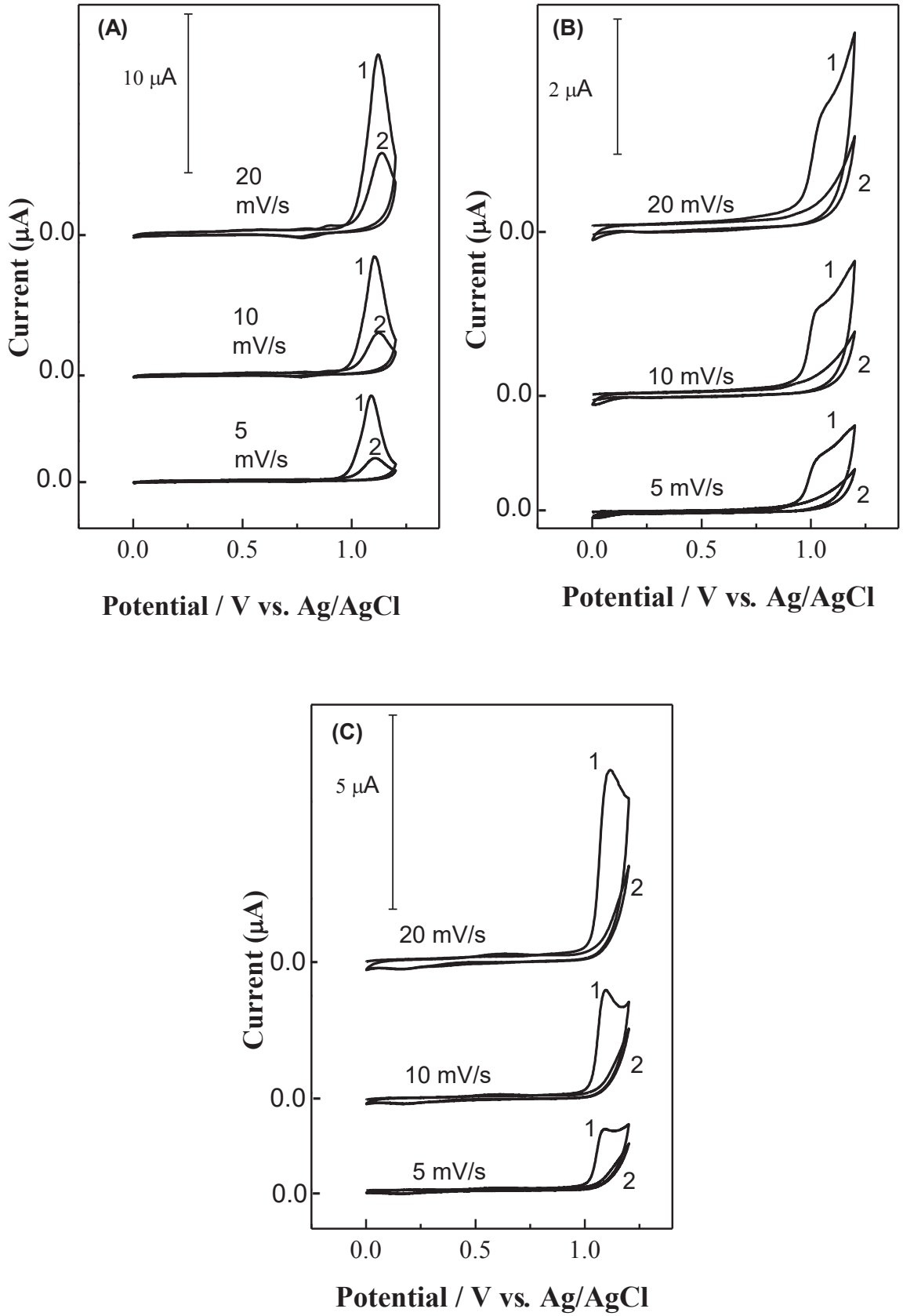


Figure 2. First two cyclic voltammograms of 0.1 mol dm^{-3} nitrophenol isomers that have been electropolymerized from sulfuric acid (0.1 mol dm^{-3} of H_2SO_4): (a) 2-nitrophenol, (b) 3-nitrophenol, and (c) 4-nitrophenol.

Fig. 1 presented the cyclic voltammogram (CV) scans for the first two cycles of 2-nitrophenol, 3-nitrophenol, and 4-nitrophenol in neutral solutions (pH = 7.0) recorded at different scan rates of 5, 10, and 20 mV s^{-1}. A general inspection of Fig. 1 shows that the CV curves for all isomers exhibited only anodic oxidation peaks ranging from 0.75 to 1.0 V. This is indicative of irreversible oxidation reaction of nitrophenol monomer at the surface of the electrode. The current of anodic peaks was decreased approximately 22-fold during the successive sweeps of potential. This behavior is explained by the deposition of a passivating layer of polynitrophenol on the electrode surface.

Fig.1a shows that the potential values of onset and peak for 2-nitrophenol were 0.78 and 1.00 V, respectively. These values were slightly higher when compared with 0.75 and 0.89 V for 3-nitrophenol (Fig. 1b) and 0.77 and 0.95 V for 4-nitrophenol (Fig. 1c). All isomers in question seem to follow an electropolymerization reaction, as indicated by the fact that the current is decreased clearly in the second CV scan.

At pH $\leq$ 7, the oxidation mechanism of 3-nitrophenol involves the removal of two electrons and one H^+ ion from the hydroxyl group. Three possible resonance structures could be drawn having a carbon atom that is electron deficient, a so-called phenoxonium ion, either at the ortho or para positions of the benzene ring. The phenoxonium ion will be stabilized by the resonance structures formed. In a similar approach to the monomer, the dimers are formed between the intermediate phenoxonium ions. They are further oxidized to form oligomers through a C-C coupling.[24] Finally, a polymer layer could be deposited at the electrode surface, as seen in Fig. 1b.

A similar mechanism has been proposed for the electrochemical oxidation of 2-nitrophenol and 4-nitrophenol at pH $\leq$ 7. The phenoxonium ion will be formed at the ortho or the para and not on the meta position. In this case, the nitro group could be involved in the resonance structures, and this will offer the para position priority. Hence, the stabilized phenoxonium ion is caused by both the resonance and the inductive effect at their maximum level. This phenomenon is responsible for lowering the pKa values of 2-nitrophenol and 4-nitrophenol, which behave as better acids compared to 3-nitrophenol.

Fig.2 illustrates that all the nitrophenol isomers prepared in acidic solutions of 0.1 mol dm^{-3} of H_2SO_4 exhibit electropolymerization, as clearly indicated by the CV curves of the two cycles. In Fig. 2a, two peaks are observed in the CV curves. However, the maximum current peaks are found to be dependent on the scan rate applied. For example, in the first cycle, the maximum current peak is 2-fold greater (at 20 mV s^{-1} scan rate) and 4-fold (at 5 mV s^{-1} scan rate) when compared with the same in the second cycle. On the other hand, peaks are not observed in Fig. 2b and 2c. From these figures, one can inspect that the levels in the second cycle are 4-fold and 6-fold smaller than that in the first cycle for 3-nitrophenol and 4-nitrophenol, respectively. Onset peak values and peak potentials for 2-nitrophenol are 0.9 and 1.1 V, respectively. These values are smaller than 0.7 and 1.0 V for 3-nitrophenol (Fig.2b), but nearly equivalent to 1.0 and 1.1 V for the oxidation of 4-nitrophenol (Fig.2c). The measured pH value for all the nitrophenol prepared in acidic solutions was 1.4.

Fig. 3 presents the CV curves of the first two cycles that lead to the electropolymerization of nitrophenol isomers prepared in basic aqueous solutions of 0.1 mol dm^{-3} NaOH. In the second cycle, anodic oxidation peak was absent from all the CV scans. This behavior is explained by the deposition of a strong passivating layer of polynitrophenol on the electrode surface.

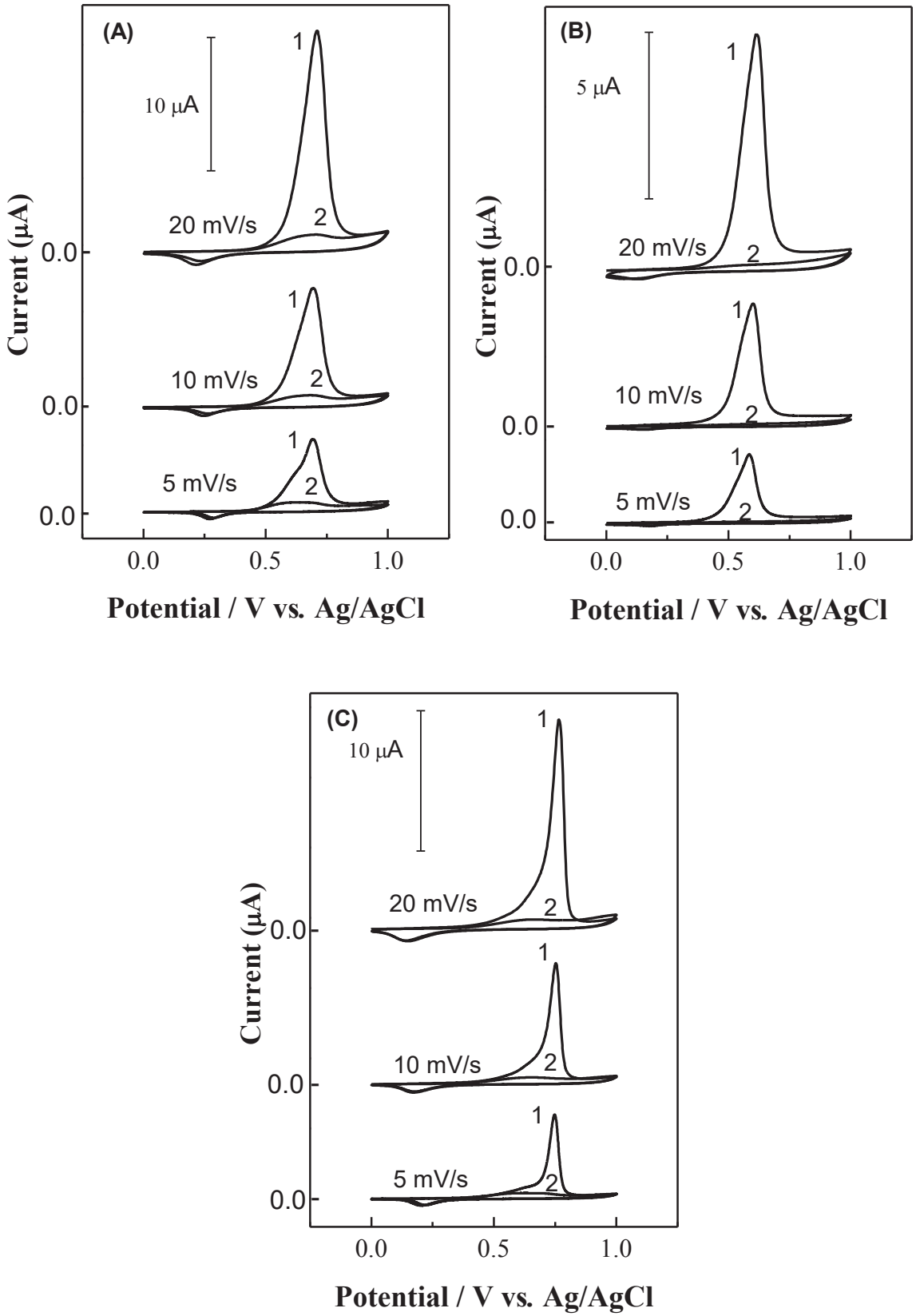


Figure 3. First two cyclic voltammograms of 0.1 mol dm^{-3} nitrophenol isomers that have been electropolymerized from sodium hydroxide (0.1 mol dm^{-3}): (a) 2-nitrophenol, (b) 3-nitrophenol, and (c) 4-nitrophenol.

In Fig. 3b, 3-nitrophenol showed the highest difference between the two cycles by approximately 38-fold (20 mV s^{-1}), 53-fold (10 mV s^{-1}), and 40-fold (5 mVs^{-1}). The difference in the peak currents between the two cycles for 2-nitrophenol was the lowest by approximately 10-Fold (Fig. 3a), whereas for the same in 4-nitrophenol it was approximately 24-fold (e.g. at 20 mV s^{-1}) (Fig. 3c).

The onset and peak potentials for 2-nitrophenol were determined at 0.40 and 0.70 V, respectively, as seen in Fig. 3a. These values were slightly similar compared to the values of 0.30 and 0.75 V for 3-nitrophenol (Fig. 3b) and for the oxidation of 4-nitrophenol of 0.50 and 0.60 V (Fig. 3c). The measured pH values in this laboratory for 2-nitrophenol, 3-nitrophenol, and 4-nitrophenol prepared in basic solutions are 10.2, 11.2 and 10.8, respectively.

In basic media, 2-nitrophenol, 3-nitrophenol and 4-nitrophenol are ionized when the H atom on the hydroxyl group is deprotonated to phenates by losing H^+ from the hydroxyl group on the benzene ring. The phenate ion will undergo oxidation upon electron removal to form a phenoxy radical represented by three different possible resonance species.

After the anodic oxidation of 3-nitrophenol occurred, the resonance structures between the three possibilities will stabilize the radical formed. We believe that the nitro group of 3-nitrophenol does not contribute to the polymerization process, as there are no radicals that will be end up on the meta position where the nitro group is located. In this case, in the mechanism of 3-nitrophenol the phenoxy radical is stabilized by the inductive effect only.

The story is different in the oxidation mechanism of 2-nitrophenol and 4-nitrophenol at pH > 7. In 2-nitrophenol, the phenoxy radicals will be formed at the ortho or the para and not on the meta position. In this case, the nitro group could be involved in the resonance structures, and this makes the para position a more resonating stabilized point. This will lead to a lower pKa value, because a more resonating stabilized conjugate base will result in a better acidic compound. Hence, the stabilized phenoxy radicals are caused by both the resonance and the inductive effect at their maximum effect.

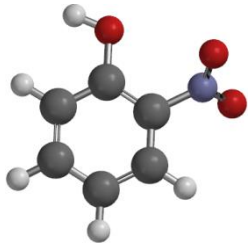
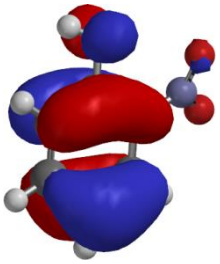
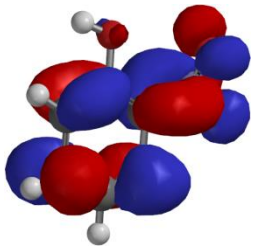
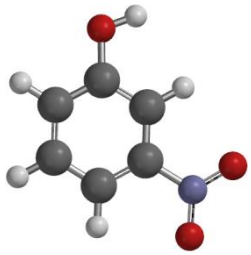
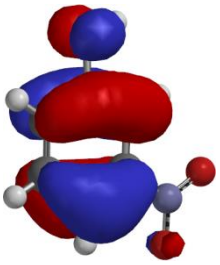
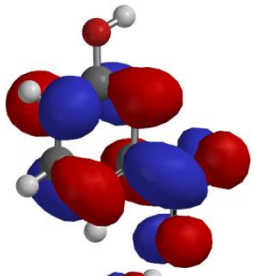
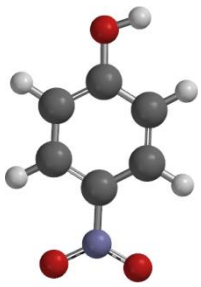
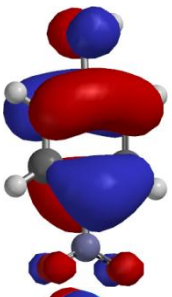
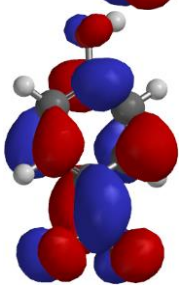
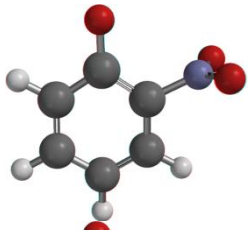
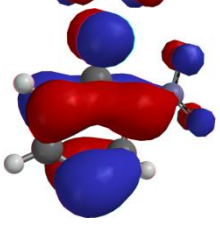
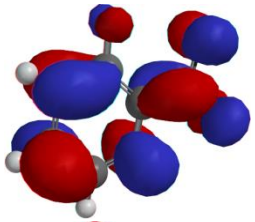
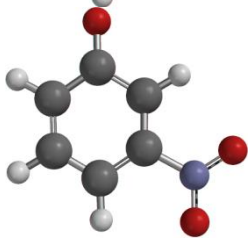
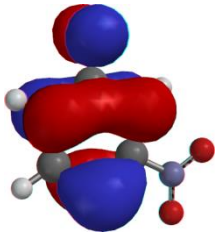
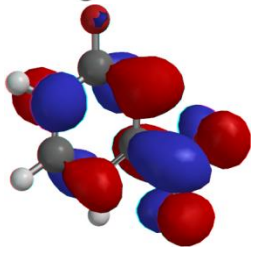
In a similar manner to the monomer, the dimers are formed between the intermediates radicals and they are further oxidized to form oligomers. In theory, there are several coupling possibilities, but practically it is the so-called head to tail (C-O-C) coupling that is virtually common.[24] Finally, a polymer layer deposit will be obtained at the electrode surface.

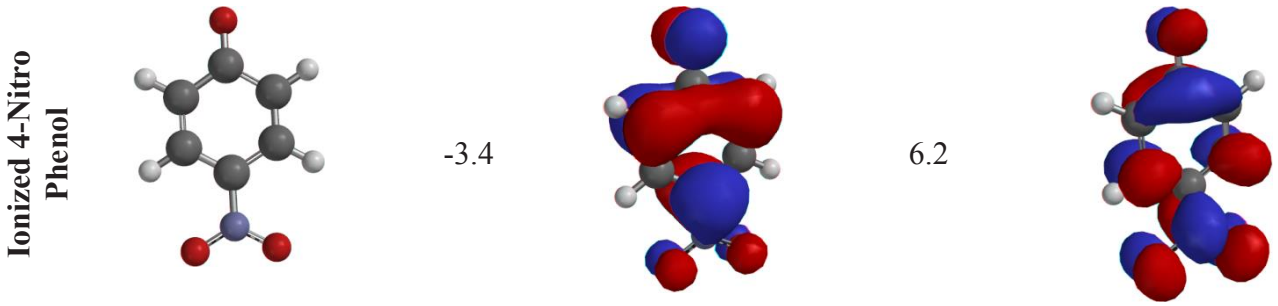
On the other hand, in 4-nitrophenol, the phenoxy radical is stabilized by both the resonance and the inductive effect at their minimum outcome. Therefore, based on the stability of the phenoxy radicals, the 2-nitrophenol seems to be more acidic than 4-nitrophenol, which in turn will be more acidic compared to the 3-nitrophenol. However, due to an intramolecular hydrogen bonding in 2-nitrophenol and the steric hindrance observed, it becomes difficult to remove the hydrogen atom from the structure of the isomer 2-nitrophenol. In this case, 2-nitrophenol seems to be less acidic than 4-nitrophenol.[25] At this point, the final order of decreasing acidity is 4-nitrophenol > 2-nitrophenol > 3-nitrophenol > phenol.

Table 1 presents the calculated energies of the HOMO and LUMO of the uncharged molecules at pH= 7. The calculated HOMO and LUMO values for 2-nitrophenol and 4-nitrophenol are quite close, explaining the slightly similar acidic behavior as observed above. The ionized 3-nitrophenol has the lowest energy values of the HOMO and LUMO compared to the other isomers.

Based on the literature, pKa value recorded at 25°C of 2-nitrophenol is 7.23, 3-nitrophenol is 8.36 and 4-nitrophenol is 7.15.[25] It is well known, that the higher the pKa the more basic the compound is, and one can prove this as described in the above paragraphs. These observations agree with the acidity order as observed above.

Table 1. Geometrical plots and the calculated energy values of the HOMO and LUMO molecular orbitals for 2-nitrophenol, 3-nitrophenol, and 4-nitrophenol.

		E_HOMO (eV)		E_LUMO (eV)	
2-Nitro Phenol		-9.5		1.9	
3-Nitro Phenol		-9.4		1.4	
4-Nitro Phenol		-9.6		1.8	
Ionized 2-Nitro Phenol		-3.3		6.4	
Ionized 3-Nitro Phenol		-2.9		5.8	



The electrochemical behavior of all the modified electrodes with polynitrophenol films prepared in different pH solutions by CV using a scan rate of 5mV s^{-1} is presented in Fig. 4. Fig. 4a presents a typical CV curve of the bare working gold electrode tested in equal concentrations of 5.0 mmol dm^{-3} $K_3Fe(CN)_6$/ $K_4Fe(CN)_6$ solution (0.1 mol dm^{-3} KCl as the supporting electrolyte). Peaks of the oxidation (+260 mV) and reduction (+170 mV) are observed in Fig. 4a.

Franco *et. al.* studied the electropolymerization of 3-aminophenol in acidic and basic media.[26] They tested their polyaminophenol modified electrodes in the presence of the aqueous 5.0 mmol dm^{-3} $K_3Fe(CN)_6$/ $K_4Fe(CN)_6$ redox couple. They contrasted the signal of graphite electrode with the bare electrode with the modified ones. The current peaks on the modified electrodes diminished. They found that the inclination angle and area of the peaks decreased as well. This suggested a higher resistance of the system. This reflects the covering of the electrode surface by insulator polymeric film.[26]

The deposition process of the polymer film on the electrode surface was confirmed in Fig. 4b-d as per the method described.[26] These figures presented the CV curves tested in $K_3Fe(CN)_6$/ $K_4Fe(CN)_6$ redox couple of the modified electrodes with different nitrophenol isomers that have been electropolymerized from different aqueous pH solutions.

The most remarkable feature of the CVs is that the current has dropped piercingly into the nano ampere range and the smooth peak features have totally vanished from the curves. This was clearly seen in all traces of Fig. 4c and in basic medium trace of Fig.4b and 4c, as a result of the electropolymerization and thin film formation of 3-nitrophenol isomer from different pH solutions.

Samet *et. al.*[13] studied the electropolymerization of 5.0 mmol dm^{-3} of 2-nitrophenol in 0.5 mol dm^{-3} H_2SO_4 by CV at a scan rate of 50 mV s^{-1}. During the reverse scan in their CV results, a well-defined peak was observed. They claimed that this peak is related to the reduction of the produced oxidation products of 2-nitrophenol. They concluded that the electropolymerization reaction in that case is not significant.[13] There is no reduction peak observed in all the electropolymerization CV scans (Fig. 1 and 2) in either cycle, although a higher concentration of the monomers has been used here of 0.1 mol dm^{-3} with a 20-fold slower scan rate between 20 to 5 mV s^{-1} compared with Samet et. al.[13]

In the presence of $K_3Fe(CN)_6$/ $K_4Fe(CN)_6$ redox couple (Fig. 4b), CV traces of 2-nitrophenol that has been electropolymerized from neutral and acidic solutions showed both oxidation and reduction peaks as seen in Fig.4a. In neutral, the oxidation reduction peaks were at +400 mV and 0 mV, respectively, whereas in acidic medium, the oxidation reduction peaks were at +320 mV and 50 mV, respectively.

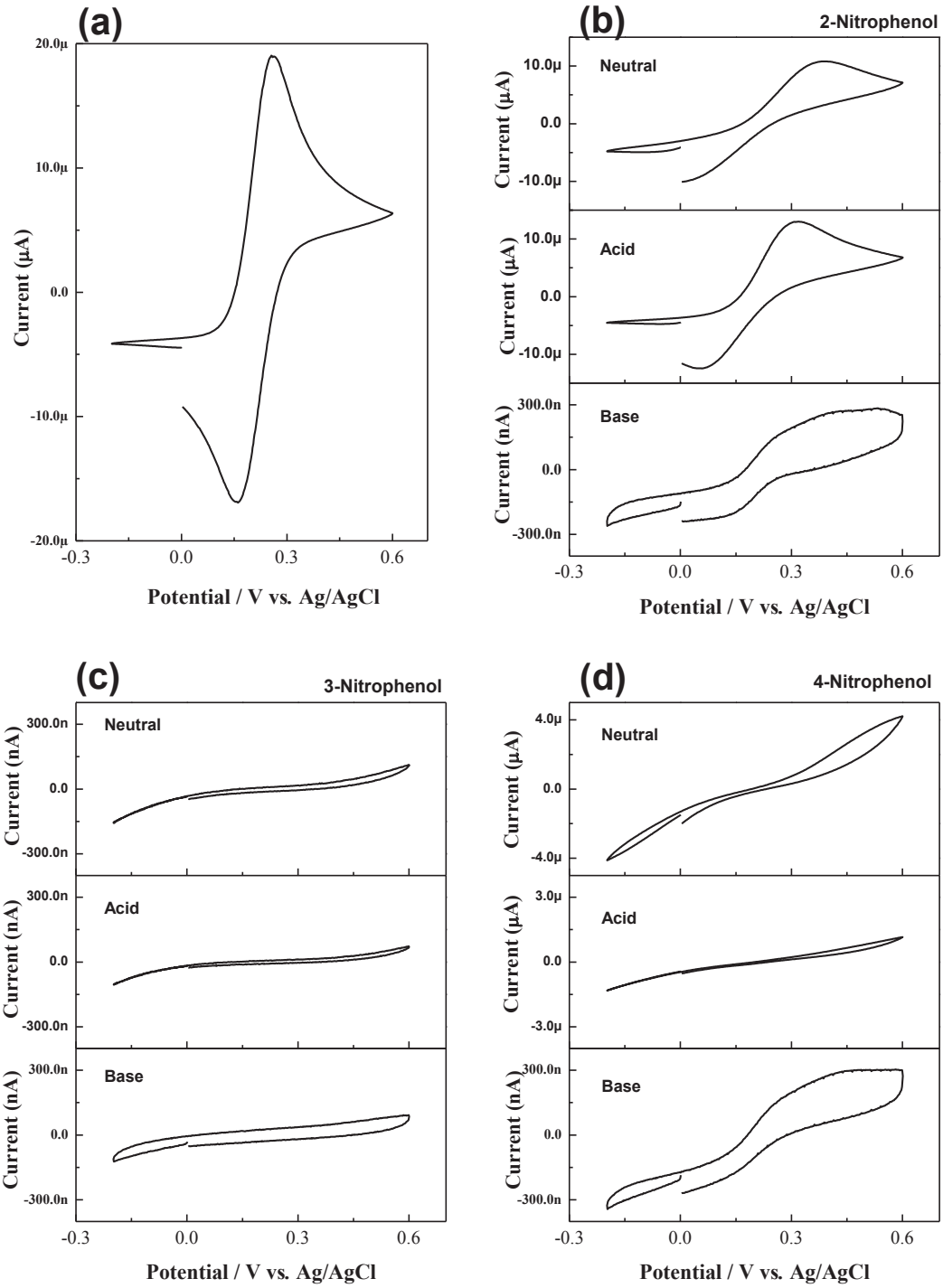


Figure 4. Cyclic voltammogram of the bare gold electrode (A= 0.02 cm^2) and the modified gold electrodes with electropolymerized nitrophenol isomers, (0.1 mol dm^{-3}, 5 mVs^{-1} scan rate) in aqueous solution containing equal concentrations of 5.0 mmol $dm^{-3}K_3Fe(CN)_6$/ $K_4Fe(CN)_6$ (0.1 mol dm^{-3} KCl), 20 mVs^{-1}. (a) Gold electrode without film and the modified electrodes at (b) 0.1 mol dm^{-3} of 2-nitrophenol in neutral solutions (0.1 mol dm^{-3} KCl), acid (0.1 mol dm^{-3} H_2SO_4), and base (0.1 mol dm^{-3} NaOH), (c) same as in (b) using 3-nitrophenol isomer, (d) same as in (b) using 4-nitrophenol isomer. For all experiments in this work, 0.1 mol dm^{-3} was used in the preparation of all the nitrophenol isomers from aqueous solutions.

The shift in peak positions showed the irreversibility of the process when compared with the CV of the polished bare electrode. This change in electrochemical behavior can be simply explained by a passivation of the electrode surface that prevents reduction of ferricyanide as opposed to electrostatic repulsion.

In Fig. 4d, CVs of both neutral and acid media seem to behave similar to those in Fig. 4c. They experienced a drop in anodic current in the micro-ampere range between 1-3 µA without a distinct inclination of angle peaks. This phenomenon is related to the electropolymerization of nitrophenol isomers, as an insulating polymer layer was electrochemically synthesized at the surface of the gold electrode.

Table 2 shows the diffusion coefficients for nitrophenol isomers measured from the first cycle of the electroploymerization CVs at different scan rates ranging from 5 to 45 mV s^{-1}. It was found that with increasing scan rate, the peak current (i_p) increased linearly with the square root of the potential scan rate ($v^{1/2}$). This confirms that the electropolymerization of nitrophenol isomers is a linear diffusion controlled process. The diffusion coefficients are measured using Randles–Sevcik Eq. 1:[27, 28]

$$I_p = (2.69 \times 10^5) n^{2/3} A \sqrt{D} \sqrt{v}\, C \quad \text{.....equation 1}$$

Where: I_p: the peak current, n: the number of electrons, A: the surface area of the working electrode, D: the diffusion coefficient of the electroactive species, v: the scan rate of voltammograms, and C: the bulk concentration of the electroactive species.

Table 2. Calculated values of diffusion coefficients.

Nitrophenol Isomers	**Diffusion Coefficients $cm^2\ s^{-1} \times 10^{-5}$**		
	Acid	Neutral	Alkaline
2-Nitrophenol	4.0	6.2	2.2
3-Nitrophenol	158.0	53.1	13.3
4-Nitrophenol	26.3	43.9	2.8

By comparing the results between Fig. 4 and Table 2, 3-nitrophenol has the highest diffusion coefficients among the isomers studied. The variation in the diffusion coefficients of the isomers at the different pH values used in this study is in the order of 40-fold. The calculated diffusion coefficient values in alkaline aqueous solutions for 2-nitrophenol and 4-nitrophenol are approximately the same but the value for 3-nitrophenol is approximately ten times higher with an increase of a 10-fold factor in 3-nitrophenol. Accordingly, the electropolymerization process is favored in basic solutions. This appears to assist the monomer tendency to form a polymeric thin film as presented above.

4. CONCLUSION

This paper demonstrates that the electrodeposition of polymeric films consequential to 2-nitrophenol, 3-nitrophenol, or 4-nitrophenol isomers at the surface of gold electrodes is feasible. It was concluded that the electropolymerization process can be harvested from different pH media such as acidic, alkaline or neutral aqueous solutions. With pH increase, the cyclic voltammetric measurements revealed that anodic oxidation, and polymerization of 2-nitrophenol, 3-nitrophenol or 4-nitrophenol becomes increasingly favored. Hence, the anodic potential for 3-nitrophenol is slightly lower than that for the corresponding values of 2-nitrophenol and 4-nitrophenol for solutions of similar pH.

In conclusion, the electropolymerization of nitrophenol isomers was found to be most difficult in acid and easiest in alkaline aqueous medium. This was also confirmed by the calculated diffusion coefficients of the monmers. In alkaline aqueous solutions, the calculated diffusion coefficient values are approximately the same for 2-nitrophenol and 4-nitrophenol, with the value for 3-nitrophenol being approximately ten times higher. Indeed, 3-nitrophenol has the highest diffusion coefficients among the isomers. Therefore, 3-nitrophenol showed the best electropolymerization performance, and 2-nitrophenol showed very poor coverage on the electrode surface.

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ORIGINAL ARTICLE

Engineering approach to allocate and evaluate performance influencing factors for ready mixed concrete batch plant under different effects

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KEYWORDS

Ready mix concrete;
Concrete batch plant;
Construction projects;
Productivity;
Factors;
Performance ratio and statistics package for social science (SPSS)

Abstract Growth of construction motion in the world specially Egyptian construction areas and ready mixed concrete production growth mainly in mega projects such as real estate projects, tourism projects and infrastructure projects, which they want high quality ready mixed concrete. The main objective of this paper is to analyze a clear understanding for measuring any concrete batch plant performance ratio by using analysis of collected data from more real concrete batch plants and determining the most effective factors that have great affect on concrete batch plants performance ratio. Predicting the actual future performance ratio and production rates for any concrete batch plant according to groups of effective factors is the essential sector which is suggest in this study using smart modeling analysis. Improve performance ratio of concrete batch plant was selected because of its importance in construction field by studying and analyzing the most effective factors. The study will be done by collecting and studying large detailed data through start of 2012 till the end of 2016 and it will be illustrated the time, quantities, distances and factors which affecting concrete batch plants performance ratio. This paper will be divided into main three groups, which are illustrated as follows: (1) It was mentioned the designing tables which is divided into three levels: (A) Field data recording sheet; (B) Field data processing sheet and (C) Field data analysis sheet to observe the most convincing variables that has large affect on concrete batch plant performance ratio. It was analyzed and checked the concrete batch plant performance ratio by optimizing its most effective variables. (2) It was mentioned how to analyze and use the collected detailed data from field and classified their variables affecting concrete batch plant performance ratio and getting the relation between concrete batch plant performance ratio and each variable separately considering all remaining variables are obviated then all statistical analysis were mentioned, all relations were proved to get proportion correlation for each variable. (3) It was summarized the conclusion.

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Finally this paper serve construction stakeholders to achieve a competitive level of time and quality for effective construction management.

1. Overview

Ref. [1] stated the companies of ready mixed concrete require for equipping themselves by latest equipment's, such as concrete pumps, transit mixers and batch plants of concrete, which need additionally visualized management of production as Programmable Logic Controller (PLC) and softwares. Pumped concrete might defined as it is conveyed by pressure by flexible hose or rigid pipe and discharged directly into the required place. All mixed concrete transported to placement place by methods of pumping which are divided into three main types: (1) pneumatic pumps, (2) piston pumps and (3) squeeze pressure pumps. From practices of field right planning deliver concrete, line layout, pump locations, entire pumping operation and placing sequence will result for saving cost and time. Ready mixed concrete is passed through more ways such as handling material, concrete batching, concrete mixing, product loading on truck mixers and transport it to placing site. Number of concrete batch plant, truck mixers and pumps typically the crucial elements inside the system. Concrete batch plants may additionally represent one of biggest periods for a contractor capital investments. The successful aim of construction management is to complete any project within budget, at least available cost, on time and with high quality. Insufficient equipment management can be resulted from low production or/and idle equipment either of which can effect on project cost and duration. Therefore, it is very important for construction managers, contractors and every person directly responsible for management of equipment, to be familiar with strategies for estimating equipment productivity for certain jobs. Ref. [2] stated at ready mix concrete dispatching, common practices are to rely on human professionals of essential decision making for real time, additional investigations is suggested that minimize this optimality gap between optimization models and expert may be occurs because of critical situations experts agree higher cost of ready mixed concrete to ensure a stable dispatching system. To maximize profitability of ready mixed concrete companies, the experts of that field try to find convenient matches between available resources and demands [3]. Simulation is currently conventional inside the construction project management as a formal tool to solve related problems in construction. The key of modeling operations is to determine productivity between needed resources and is to identify the sequences which are repeated during production level for construction projects [4].

2. Problem statement

Performance ratio is productivity relative loss compared with some baseline periods and capability to perform tasks without wasting times and materials or the relative ratio between actual Production Rate abd ideal Production Rate [5] as presented in Eq. (1):

$$\text{Performance ratio} = \frac{\text{Actual Production Rate}}{\text{Ideal Production Rate}} \quad (1)$$

In this paper it was collected different detailed data from many concrete batch plants in Egypt, these data illustrates delivery quantities, transportation time and transportation distance. Brainstorming was done using questionnaires to show factors affecting concrete batch plant performance ratio. Also, this study focuses on most effective variables that directly have a great affect on productivity, which was checked by Statistics Package for Social Science (SPSS) software.

3. Paper objectives and layout

Concrete batch plant is selected for this study because the RMC is sensitive part in the construction sector, it can be optimized to save time and cost. Major objective of this study is to focus on measuring concrete batch plant performance ratio. Also, sub objectives of this paper will provide, study and analyze a clear understanding for: (1) Analyzing large scale of detailed data which is collected from more and different concrete batch plants, this will be done through studying them during start of 2012 till the end of 2016; (2) Determining most effective factors affecting concrete batch plants performance ratio using three main sheets: (A) Field data recording sheet; (B) Field data processing sheet and (C) Field data analyzing sheet to monitor the most expected persuasive variables; (3) Classifying expected variables that affecting concrete batch plant performance ratio and predicting the relation between concrete batch plant performance ratio as dependant variable with each variable separately as independent variable considering all remaining variables are obviated then more statistical analysis is suggested, all models were proved to get proportion correlation between each individual variable with concrete batch plant performance ratio; and (4) Summarization of conclusion.

This paper is categorized into main seven groups as follows: (1) Introduction; (2) Literature Review; (3) Methodology of Data Source, Field Measurement; (4) Collecting Data and Analyze its Effect on Concrete batch Plant Performance Ratio using Statistics Package for Social Science (SPSS) software.

4. Paper methodology

The main aim of this paper is to determine some main objectives as follows: (1) Selecting some different concrete batch plants in Egypt and determine design capacity of them. (2) Getting hourly/daily information data for: (a) concrete quantities, (b) trip time, (c) boring location, (d) selecting equipment, (e) determining variables, (f) projects and (g) designing tables to tabulate collected data. (3) Collecting data since 2012 till 2016 and was made the comparison between average actual productivity with theoretical capacity. (4) Making detailed study and analysis for collected data using SPSS software to

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assure which variables affect concrete batch plants performance ratio.

5. Designing tables

5.1. Field recording data sheet

A questionnaires are prepared to give data for fourty effective variables that have direct impact on concrete batch plants performance ratio. Table 1 presents the sample of daily collected data from concrete batch plant for more of different construction projects. This table contain: (1) projects ID, (2) truck number, (3) driver name, (4) boring place, (5) cement quantity, (6) cement type, (7) concrete quantity, (8) cycle time and (9) timing schedule.

5.2. Field processing data sheet

The processing data sheet was designed for analyzing and predicting concrete batch plant performance ratio as presented in Table 2.

Table 2 shoes the data analysis detailed summary of all recourses in selected concrete batch plants with different projects. The table contains: (1) projects ID, (2) boring date, (3) cycle time, (4) daily quantity of concrete, (5) actual productivity, (6) theoretical productivity, (7) concrete batch plant performance ratio and (8) all variables affecting the performance ratio.

Where: Actual Time for operating concrete batch plant was measured per minutes; Actual Quantity of concrete was measured by cubic meter per each day, actual production rate was calculated by get the ratio between actual quantity per cubic meter over actual time per hr., theoretical capacity is the ideal production rate for the concrete batch plant which was assumed to be constant from manuals; PR concrete batch plant performance ratio which was calculated as a ratio between actual production rate over ideal production rate; X_1, X_2,..., X_n are variables that affecting concrete batch plant performance ratio as declared in Table 3.

6. Variables affecting concrete batch plants performance ratio

Refs. [5–7] determined the general factors affecting construction equipment productivity which were classified into three major groups: (1) factors related to job conditions, (2) factors related to management conditions, and (3) factors related to equipment, where the major variables affecting concrete batch plants performance ratio were categorized into three major groups as presented in the following subsections.

6.1. Group (A) concrete batch plant variables

This group was broken down into seventeen variables as follows: (1) concrete batch manager efficiency (X_1) which was expressed as a percentage; (2) batch plant operator efficiency (X_2) which was expressed as a percentage; (3) truck mixers drivers efficiency (X_3) which was expressed as a percentage, (4) concrete pump operator efficiency (X_4) which was expressed as a percentage; (5) concrete pump efficiency (X_5) which was expressed as a percentage either new one that give efficiency is equal to 95% or old one that give efficiency is equal to 75%; (6) procurement plan efficiency (X_6) such as plans which provide cement, sand, gravel, ... etc. to fill the needs of RMC which was expressed as a percentage, (7) batch plant market plan efficiency (X_7) that it was presented as a percentage if concrete batch plant is worked in maximum capacity or not as shown in Eq. (4).

$$\text{Batch plant market plan efficiency} = \frac{\Sigma(\text{Actual Quantities per day})}{(\text{theoretical capacity per day})} \times 100 \quad (2)$$

(8) truck mixers efficiency (X_8) that was stated in Eq. (5).

$$\text{Truck mixers efficiency} = \frac{T12 * 0.9 + T10 * 0.85 + T6 * 0.75}{T12 + T10 + T6} \quad (3)$$

where T_{12} is the number of concrete truck mixers its capacity is equal to 12 m^3 that has corresponding efficiency is equal to 90%; T_{10} is the number of concrete truck mixers its capacity is equal to 10 m^3 that has corresponding efficiency is equal to 85%; T_6 is the number of concrete truck mixers its capacity is equal to 6 m^3 that has 75% corresponding efficiency.

(9) 12 m^3 concrete truck mixers number that used for transportating concrete from batch plant to sites (X_9); (10) 10 m^3 concrete truck mixers number that used for transportating concrete from batch plant to sites (X_{10}); (11) 6 m^3 concrete truck mixers number that used for transportating concrete from batch plant to sites (X_{11}); (12) concrete pumps number

Table 1 Concrete batch Plant information for all studied projects.

ID	Driver name	Truck No.	Location	Cement type	Cement quantity	Receipt no.	Go out time	Quantity (m^3)	Return back time	Total time (h)
1	Awad Mahmoud	8652	Bourtage Misr	Anti.	400	23,588	9:20	6	10:20	1:00
2	Aly Mahmoud	8259	Elsafa	Nor.	250	23,589	9:50	10	11:15	1:25
3	Mohamed Sharaf	8654	Bourtage Misr	Anti.	400	23,590	10:00	12	11:10	1:10
4	Mansour Selim	8572	AboKhalifa	Nor.	250	23,591	10:10	10	11:40	1:30
5	Ahmed Elshafey	432	AboKhalifa	Nor.	250	23,592	10:45	12	12:05	1:20

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Table 2 Concrete batch Plant information for all selected projects with effective variables.

ID	Date	Act. time by Min.	Act. quantity	Act. production rate	Ideal production rate	Eff. %	X_1	X_2	X_3	X_4	X_{27}
1	2015/01/01	415	218	31.52	35	90.05	0.90	0.90	0.90	0.80	14.00
2	2015/01/02	290	35	7.24	35	20.69	0.60	0.60	0.70	0.90	14.00
3	2015/01/04	255	102	24.00	35	68.57	0.70	0.70	0.80	0.80	15.00
4	2015/01/05	95	36	22.74	35	64.96	0.60	0.90	0.90	0.90	14.00
5	2015/01/06	110	31	16.91	35	48.31	0.60	0.60	0.80	0.80	13.00

(X_{12}) that used for casting; (13) machines maintenance efficiency in the plant (X_{13}) which was expressed as a percentage, (14) workers bonus system inside batch plant (X_{14}) which was expressed as EGP for every trip; (15) raw material transportation method from washing area to the concrete batch area and washing plant efficiency (X_{15}) which was expressed as a percentage, (16) average distance between construction projects and concrete batch plant (X_{16}) that was presented in Eq. (6).

$$\text{Average Distance} = \frac{\Sigma(Q * d)}{\Sigma Q} \tag{4}$$

where d: is distance between concrete batch plants and construction projects; Q: is concrete truck mixer quantity per a trip; and ΣQ: is the quantity of used concrete per day.

(17) construction projects schedules (X_{17}) that supply the concrete referring to daily concrete quantities production.

6.2. Group (B) road variables

It was broken down into six variables: (18) sites number, which are gives order for using RMC (X_{18}), (19) plant safety with efficiency (X_{19}) which was expressed as a percentage, (20) site arrangement (X_{20}) which was expressed as a percentage, (21) casted items types (X_{21}) which was expressed as a percentage, (22) communications between site crews (X_{22}) which was expressed as a percentage, (23) machines damages number (X_{23}) which was expressed as a number.

6.3. Group (C) project variables

It was broken down into four variables: (24) roads quality (X_{24}), which was expressed as a percentage, (25) traffic conditions (X_{25}) which was expressed as a percentage, (26) weather conditions (X_{26}) which was expressed as a percentage, and (27) average temperature (X_{26}) it was measured by Celsius.

By studying these factors that will lead to maximize concrete batch plant performance ratio, Concreting procedures that consist of mixing concrete, transporting concrete and placing concrete are the major operations in construction projects. This study started from early of 2012 till end of 2016 to monitor concrete quantities, distances, times, and transportation system. As mentioned before more variables affect concrete batch plant performance ratio. These variables were concluded to forty variables, they might be reduced to twenty seven effective variables and classified into 14 qualitative variables and 13 quantitative variables as presented in Table 3:

6.4. Variables classification

These variables should categorize into two parts according to their measuring classifications.

6.4.1. Qualitative variables

These variables are not having measurable values; they are (X_1, X_2, X_3, X_4, X_6, X_{13}, X_{15}, X_{19}, X_{20}, X_{21}, X_{22}, X_{24}, X_{25}, and X_{26}). They were expressed by using one of four choices: Excellent, Good, Medium, or Poor and were converted to equivalent percentage 90%, 80%, 70%, or 60%.

6.4.2. Quantitative variables

These variables are having measurable values; they are (X_5, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{14}, X_{16}, X_{17}, X_{18}, X_{23}, and X_{27}).

7. Relation between concrete batch plant performance ratio with all variables

Graphical relationships were showed in this section to demonstrate effect of all variables on concrete batch plant performance ratio. The average of concrete batch plant performance ratio was proved as shown in Eq. (5):

$$\text{APR} = \frac{\sum(\text{A. Prod.} \div \text{T. Prod.})}{\text{N}} \tag{5}$$

where APR is the average of all performance ratios; A. Prod. is the Actual Productivity that was collected all data from field; T. Prod. is the concrete batch plant Theoretical Productivity which was assumed constant for each one; N is the daily records number.

7.1. Relation between manager efficiency (X_1) and batch plant performance ratio

Concrete batch manager efficiency impacts on concrete batch plant performance ratio, when concrete batch plant manager efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and Poor manager efficiency produces an average concrete

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Table 3 Selected variables information.

No.	Factor	Definition	Type
X_1	Concrete batch manager efficiency	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_2	Batch plant operator efficiency	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_3	Truck mixers drivers efficiency	It was expressed by using one from three choices: Excellent or Good or Medium	Qualitative (0.9 or 0.8 or 0.7)
X_4	Concrete pump operator efficiency	It was expressed by using one from three choices: Excellent or Good or Medium	Qualitative (0.9 or 0.8 or 0.7)
X_5	Concrete pump efficiency	It was expressed by using one from two choices: new one or old one	Quantitative (0.95 or 0.75)
X_6	Procurement plan efficiency	It was expressed by using four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_7	Batch plant market plan efficiency	It was calculated as a ratio between quantities of used concrete per day over theoretical capacity per day	Quantitative See Eq. (2)
X_8	Truck mixers efficiency	It was calculated as a weighted average efficiency by putting 90% for 12 m^3 trucks, 85% for 10 m^3 trucks, 75% for 6 m^3 trucks	Quantitative See Eq. (3)
X_9	12 m^3 Concrete truck mixers number	Counted which it used for transportation	Quantitative Counted
X_{10}	10 m^3 Concrete truck mixers number	Counted which it used for transportation	Quantitative Counted
X_{11}	6 m^3 Concrete truck mixers number	Counted which it used for transportation	Quantitative Counted
X_{12}	Concrete pumps number	Counted which it used for casting	Quantitative Counted
X_{13}	Machines maintenance efficiency	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{14}	Workers bonus system	Extra cost to workers per each trip by (EGP)	Quantitative Calculated
X_{15}	Raw material transportation method and washing plant efficiency	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{16}	Average distance between construction projects and concrete batch plant	It was calculated by (km)	Quantitative See Eq. (4)
X_{17}	Construction projects schedules	It was calculated for needed quantities of concrete by (m^3)	Quantitative Calculated
X_{18}	Sites number, which are gives order for using RMC	It was calculated by (number)	Quantitative Counted
X_{19}	Plant safety with efficiency	Arrangement methods and schedules for trucks and it was expressed by using one from three choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7)
X_{20}	Site arrangement	It was expressed by using one from three choices: Excellent or Good or Medium	Qualitative (0.9 or 0.8 or 0.7)
X_{21}	Casted items types (raft – columns – slabs – etc.)	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{22}	Site crews communications	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{23}	Machines damages number	Number of trucks damages and pumps damages	Quantitative Counted
X_{24}	Roads quality (bumpy – slopes)	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{25}	Traffic conditions	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)

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Table 3 (*continued*)

No.	Factor	Definition	Type
X_{26}	Weather conditions (humidity – rain – wind)	It was expressed by using one from four choices: Excellent or Good or Medium or Poor	Qualitative (0.9 or 0.8 or 0.7 or 0.6)
X_{27}	Average temperature	It was measured by Celsius	Quantitative Measured

batch plant performance ratio as 88.192, 74.656, 61.120 and 47.584% respectively. The efficiency of batch plant manager has major effect on concrete batch plant performance ratio.

$$PR = -33.632 + 135.360X_1 \quad (6)$$

Eq. (6) was developed and it presents a relationship between manager efficiency (X_1) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.2. Relation between operator efficiency (X_2) and batch plant performance ratio

Concrete batch plant operator efficiency impacts on concrete batch plant performance ratio, when concrete batch plant operator efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and Poor operator efficiency produces an average concrete batch plant performance ratio as 84.184, 70.719 57.254 and 43.789% respectively. The efficiency of batch plant operator has major effect on concrete batch plant performance ratio.

$$PR = -37.002 + 134.651X_2 \quad (7)$$

Eq. (7) was developed and it presents a relationship between operator efficiency (X_2) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.3. Relation between drivers efficiency (X_3) and batch plant performance ratio

Truck mixers drivers efficiency impacts on concrete batch plant performance ratio, when truck mixers drivers efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Medium truck mixers drivers efficiency produces an average concrete batch plant performance ratio as 79.532, 56.766 and 34.001% respectively (3). The efficiency of truck mixers drivers has major effect on concrete batch plant performance ratio.

$$PR = -125.357 + 227.654X_3 \quad (8)$$

Eq. (8) was developed and it presents a relationship between truck mixers drivers efficiency (X_3) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.4. Relation between concrete pump operator efficiency (X_4) and batch plant performance ratio

Concrete pump operator efficiency impacts on concrete batch plant performance ratio, when concrete pump operator efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Medium pump operator efficiency produces an average concrete batch plant performance ratio as 66.928, 64.109 and 61.291% respectively. When site labors do not use pump that will give batch plant performance ratio is equal to 41.561%. The efficiency of concrete pump operator has minor effect on concrete batch plant performance ratio.

$$PR = 41.561 + 28.185X_4 \quad (9)$$

Eq. (9) was developed and it presents a relationship between concrete pump operator efficiency (X_4) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.5. Relation between concrete pump efficiency (X_5) and batch plant performance ratio

Concrete pump efficiency impacts on concrete batch plant performance ratio, when concrete pump efficiency increases, concrete batch plant performance ratio will increase without same rate. When ($X_5 = 1$ then PR = 39.296) & ($X_5 = 0.9$ then PR = 39.264) & ($X_5 = 0.8$ then PR = 39.232) & ($X_5 = 0.7$ then PR = 39.2) and ($X_5 = 0$ then PR = 38.975%). The efficiency of concrete pump has minor effect on concrete batch plant performance ratio.

$$PR = 38.975 + 0.321X_5 \quad (10)$$

Eq. (10) was developed and it presents a relationship between concrete pump efficiency (X_5) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.6. Relation between procurement plan efficiency (X_6) and batch plant performance ratio

Procurement plan efficiency impacts on concrete batch plant performance ratio, when procurement plan efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor procurement plan efficiency produces an average concrete

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batch plant performance ratio as 96.114, 78.878, 61.641 and 44.405% respectively. The efficiency procurement plan has major effect on concrete batch plant performance ratio.

$$PR = -59.015 + 172.366X_6 \quad (11)$$

Eq. (11) was developed and it presents a relationship between procurement plan efficiency (X_6) with concrete batch plant performance ratio by SPSS considering all remaining variables were obviated.

7.7. Relation between batch plant market plan efficiency (X_7) and plant performance ratio

Batch plant market plan efficiency impacts on concrete batch plant performance ratio, when batch plant market plan efficiency increases, concrete batch plant performance ratio will increase without same rate. When ($X_7 = 100$ then PR = 84.024) & ($X_7 = 75$ then PR = 74.099) & ($X_7 = 50$ then PR = 64.174) and ($X_7 = 0$ then PR = 44.32%). The efficiency of batch plant market plan has very major effect on concrete batch plant performance ratio.

$$PR = 44.324 + 0.397X_7 \quad (12)$$

Eq. (12) was developed and it presents a relationship between batch plant market plan efficiency (X_7) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.8. Relation between truck mixers efficiency (X_8) and batch plant performance ratio

Truck mixers efficiency impacts on concrete batch plant performance ratio, when truck mixers efficiency increases, concrete batch plant performance ratio will increase without same rate. When ($X_8 = 1.0$ then PR = 89.716) & ($X_8 = 0.90$ then PR = 67.778) & ($X_8 = 0.80$ then PR = 45.839) & ($X_8 = 0.70$ then PR = 23.90) and ($X_8 = 0.60$ then PR = 1.962%). The efficiency of truck mixers has major effect on concrete batch plant performance ratio.

$$PR = -129.67 + 219.386X_8 \quad (13)$$

Eq. (13) was developed and it presents a relationship between truck mixers efficiency (X_8) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.9. Relation between 12 m^3 concrete truck mixers number (X_9) and plant performance ratio

12 m^3 concrete truck mixers number impacts on concrete batch plant performance ratio, when 12 m^3 concrete truck mixers number increases, concrete batch plant performance ratio will increase without same rate. When ($X_9 = 8.0$ then PR = 95.473) & ($X_9 = 7.0$ then PR = 87.996) & ($X_9 = 4.0$ then PR = 65.565) and ($X_9 = 1.0$ then PR = 43.134%). The 12 m^3 concrete truck mixers number has very major effect on concrete batch plant performance ratio.

$$PR = 35.657 + 7.477X_9 \quad (14)$$

Eq. (14) was developed and it presents a relationship between 12 m^3 concrete truck mixers number (X_9) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.10. Relation between 10 m^3 concrete truck mixers number (X_{10}) and plant performance ratio

10 m^3 concrete truck mixers number impacts on concrete batch plant performance ratio, when 12 m^3 concrete truck mixers number increases, concrete batch plant performance ratio will increase without same rate. When ($X_{10} = 4.0$ then PR = 90.04) & ($X_{10} = 3.0$ then PR = 79.775) & ($X_{10} = 2.0$ then PR = 69.51) and ($X_{10} = 1.0$ then PR = 59.248%). The 10 m^3 concrete truck mixers number has major effect on concrete batch plant performance ratio.

$$PR = 48.980 + 10.265X_{10} \quad (15)$$

Eq. (15) was developed and it presents a relationship between 10 m^3 concrete truck mixers number (X_{10}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.11. Relation between 6 m^3 concrete truck mixers number (X_{11}) and plant performance ratio

6 m^3 concrete truck mixers number does not impact on concrete batch plant performance ratio, when 6 m^3 concrete truck mixers number increases, concrete batch plant performance ratio will negligible increase without same rate. When ($X_{11} = 2.0$ then PR = 62.874) and ($X_{11} = 1.0$ then PR = 62.82%). The 6 m^3 concrete truck mixers number has negligible effect on concrete batch plant performance ratio.

$$PR = 462.766 + 0.054X_{11} \quad (16)$$

Eq. (16) was developed as relationship between 6 m^3 concrete truck mixers number (X_{11}) with concrete batch plant performance ratio using SPSS considering all remaining variables were obviated.

7.12. Relation between concrete pumps number (X_{12}) and batch plant performance ratio

Concrete pumps number impacts on concrete batch plant performance ratio, when concrete pumps number increases, concrete batch plant performance ratio will increase without same rate. When ($X_{12} = 2.0$ then PR = 84.103) & ($X_{12} = 1.0$ then PR = 62.158) and ($X_{12} = 0.0$ then PR = 40.213%). The concrete pumps number has major effect on concrete batch plant performance ratio.

$$PR = 40.213 + 21.945X_{12} \quad (17)$$

Eq. (17) was developed and it presents a relationship between concrete pumps number (X_{12}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

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7.13. Relation between machines maintenance efficiency (X_{13}) and plant performance ratio

Machines maintenance efficiency impacts on concrete batch plant performance ratio, when machines maintenance efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor machines maintenance efficiency produces an average concrete batch plant performance ratio as 65.85, 60.760, 55.666 and 550.571% respectively. The machines maintenance efficiency has minor effect on concrete batch plant performance ratio.

$$PR = 20.002 + 50.948X_{13} \quad (18)$$

Eq. (18) was developed and it presents a relationship between machines maintenance efficiency (X_{13}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.14. Relation between workers bonus system (X_{14}) and batch plant performance ratio

Workers bonus system impacts on concrete batch plant performance ratio, when workers bonus system increases, concrete batch plant performance ratio will increase without same rate. When (X_{14} = 185 then PR = 99.374) & (X_{14} = 150 then PR = 88.664) & (X_{14} = 100 then PR = 73.364) and (X_{14} = 5 then PR = 44.294%). The workers bonus system has major effect on concrete batch plant performance ratio.

$$PR = 42.764 + 0.306X_{14} \quad (19)$$

Eq. (19) was developed and it presents a relationship between workers bonus system (X_{14}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.15. Relation between washing plant efficiency (X_{15}) and batch plant performance ratio

Raw material transportation method and washing plant efficiency impacts on concrete batch plant performance ratio, when raw material transportation method and washing plant efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Medium raw material transportation method and washing plant efficiency produces an average concrete batch plant performance ratio as 78.25, 55.475 and 32.699% respectively. The raw material transportation method and washing plant efficiency has major effect on concrete batch plant performance ratio.

$$PR = -126.727 + 227.752X_{15} \quad (20)$$

Eq. (20) was developed and it presents a relationship between raw material transportation method and washing plant efficiency (X_{15}) with batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.16. Relation between average distance between batch & projects (X_{16}) and performance ratio

Average distance between construction projects and concrete batch plant impacts on concrete batch plant performance ratio, when average distance between construction projects and concrete batch plant increases, concrete batch plant performance ratio will decrease without same rate. When (X_{16} = 100 then PR = 34.67) & (X_{16} = 75 then PR = 43.595) & (X_{16} = 50 then PR = 52.52) & (X_{16} = 29 then PR = 60.017) & (X_{16} = 25 then PR = 61.445) and (X_{16} = 0.50 then PR = 70.192%). The average distance between construction projects and concrete batch plant has medium effect on concrete batch plant performance ratio, the best distance range between concrete batch plant and projects is ranged between (0.5:29 km) to give the acceptable concrete batch plant performance ratio.

$$PR = 70.370 - 0.357X_{16} \quad (21)$$

Eq. (21) was developed and it presents a relationship between average distance between construction projects and concrete batch plant (X_{16}) with plant performance ratio by using SPSS considering all remaining variables were obviated.

7.17. Relation between construction projects schedules (X_{17}) and batch plant performance ratio

Construction projects schedules impacts on concrete batch plant performance ratio, when construction projects schedules increases, concrete batch plant performance ratio will increase without same rate. When (X_{17} = 375.0 then PR = 97.575) & (X_{17} = 285.0 then PR = 84.795) & (X_{17} = 140.0 then PR = 64.205) & (X_{17} = 35.0 then PR = 49.295) and (X_{17} = 2.0 then PR = 44.609%). The construction projects concrete quantities schedules has very major effect on concrete batch plant performance ratio, the best daily demand of concrete that should be produced are ranged between (285.0:375.0 m^3/day) to get optimized concrete batch plant performance ratio.

$$PR = 44.325 + 0.142X_{17} \quad (22)$$

Eq. (22) was developed and it presents a relationship between construction projects concrete quantities schedules (X_{17}) with batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.18. Relation between sites number (X_{18}) and batch plant performance ratio

Number of sites, which are gives order for using RMC impacts on concrete batch plant performance ratio, when number of sites increases, concrete batch plant performance ratio will increase without same rate. When (X_{18} = 10.0 then PR = 89.426) & (X_{18} = 8.0 then PR = 82.558) & (X_{18} = 6.0 then PR = 75.69) & (X_{18} = 4.0 then PR = 68.822) and (X_{18} = 2.0 then PR = 61.954%). The sites number which are need RMC has medium effect on concrete batch plant performance ratio, the good number projects are ranged (4.0–6.0

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projects/day) to get optimized concrete batch plant performance ratio.

$$PR = 55.086 + 3.434X_{18} \quad (23)$$

Eq. (23) was developed and it presents a relationship between daily sites number (X_{18}) with batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.19. Relation between plant safety with efficiency (X_{19}) and batch plant performance ratio

Plant safety with efficiency impacts on concrete batch plant performance ratio, when plant safety with efficiency increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Medium plant safety with efficiency produces an average concrete batch plant performance ratio as 67.899, 40.071 and 12.242% respectively. The plant safety with efficiency has major effect on concrete batch plant performance ratio.

$$PR = -182.559 + 278.287X_{19} \quad (24)$$

Eq. (24) was developed and it presents a relationship between daily sites number (X_{19}) with batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.20. Relation between site arrangement (X_{20}) and concrete batch plant performance ratio

Site arrangement impacts on concrete batch plant performance ratio, when site arrangement increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good and Medium site arrangement produces an average concrete batch plant performance ratio as 71.628, 54.730 and 37.832% respectively. Site arrangement has major effect on concrete batch plant performance ratio.

$$PR = -80.453 + 168.979X_{20} \quad (25)$$

Eq. (25) was developed and it presents a relationship between site arrangement (X_{20}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.21. Relation between casted items types (X_{21}) and concrete batch plant performance ratio

Casted items types impacts on concrete batch plant performance ratio, when casted items types increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor casted items types produces an average concrete batch plant performance ratio as 65.855, 60.760, 55.666 and 50.571% respectively. The items types that will be casted (raft – columns – slabs – etc.) has medium effect on concrete batch plant performance ratio.

$$PR = -55.295 + 147.942X_{21} \quad (26)$$

Eq. (26) was developed and it presents a relationship between casted items types (X_{21}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.22. Relation between site crews communications (X_{22}) and batch plant performance ratio

Site crews communications impacts on concrete batch plant performance ratio, when site crews communications increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor casted items types produces an average concrete batch plant performance ratio as 87.642, 66.474, 45.307 and 24.139% respectively. The site crews communications has very major effect on concrete batch plant performance ratio.

$$PR = -102.866 + 211.675X_{22} \quad (27)$$

Eq. (27) was developed and it presents a relationship between site crews communications (X_{22}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.23. Relation between machines damages number (X_{23}) and batch plant performance ratio

Machines damages number impacts on concrete batch plant performance ratio, when machines damages number increases, concrete batch plant performance ratio will decrease without same rate. When ($X_{23} = 3.0$ then PR = 48.822) & ($X_{23} = 2.0$ then PR = 52.909) & ($X_{23} = 1.0$ then PR = 56.996) and ($X_{23} = 0.0$ then PR = 61.083%). The machines damages number has very minor effect on concrete batch plant performance ratio.

$$PR = 61.083 - 4.087X_{23} \quad (28)$$

Eq. (28) was developed and it presents a relationship between machines damages number (X_{23}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.24. Relation between roads quality (X_{24}) and concrete batch plant performance ratio

Roads quality impacts on concrete batch plant performance ratio, when roads quality increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor roads quality produces an average concrete batch plant performance ratio as 64.280, 62.580, 60.879 and 59.179% respectively. The roads quality has very minor effect on concrete batch plant performance ratio.

$$PR = 48.975 + 17.006X_{24} \quad (29)$$

Eq. (29) was developed and it presents a relationship between roads quality (X_{24}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.25. Relation between traffic conditions (X_{25}) and concrete batch plant performance ratio

Traffic conditions impacts on concrete batch plant performance ratio, when traffic conditions increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor roads quality produces an average concrete batch plant performance ratio as 88.192,

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74.656, 61.120 and 47.584% respectively. The traffic conditions has very major effect on concrete batch plant performance ratio.

$$PR = -33.632 + 135.360X_{25} \quad (30)$$

Eq. (30) was developed as a relationship between traffic conditions (X_{25}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.26. Relation between weather conditions (X_{26}) and concrete batch plant performance ratio

Weather conditions impacts on concrete batch plant performance ratio, when weather conditions increases, concrete batch plant performance ratio will increase without same rate. The Excellent, Good, Medium and poor weather conditions produces an average concrete batch plant performance ratio as 67.832, 64.274, 60.715 and 57.157% respectively. The weather conditions has very minor effect on concrete batch plant performance ratio.

$$PR = 35.808 + 35.582X_{26} \quad (31)$$

Eq. (31) was developed and it presents a relationship between weather conditions (X_{26}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated.

7.27. Relation between average temperature (X_{27}) and concrete batch plant performance ratio

Average temperature impacts on concrete batch plant performance ratio, when average temperature increases, concrete batch plant performance ratio will decrease without same rate. Changes of temperature affect both concrete batch plant equipment performance ratio and manpower, all temperatures were recorded at studied period. When ($X_{27} = 40$ then PR = 42.89) & ($X_{27} = 30$ then PR = 48.19) & ($X_{27} = 20$ then PR = 53.49) and ($X_{27} = 11$ then PR = 58.26%). Average temperature has minor effect on concrete batch plant performance ratio, a suitable temperature is ranged between (10.0:20.0 °C) to optimize concrete batch plant performance ratio.

$$PR = 64.090 - 0.53X_{27} \quad (32)$$

Eq. (32) was developed and it presents a relationship between average temperature (X_{27}) with concrete batch plant performance ratio by using SPSS considering all remaining variables were obviated, this equation is valued between 10 and 50 Celsius.

In previous sub sections it was mentioned how to collect data from construction fields, to classify variables affecting concrete batch plant performance ratio, to analyze the data and results, to estimate the relation between each variable separately with concrete batch plant performance ratio considering remaining variables are obviated, to mention statistical analysis, finally to prove models and find the proportion correlation per each variable.

8. Conclusion

In this paper, it was concluded engineering approach to allocate and evaluate effective variables that is affecting concrete batch plant performance ratio under different effects and are listed and ranked in descending order respectively as: (truck mixers efficiency, batch plant market plan efficiency, truck mixers drivers efficiency, weather conditions, communications between site crews, casted items types, batch plant operator efficiency, raw material transportation method from washing area to the concrete batch area and washing plant efficiency, machines maintenance efficiency in the plant, and concrete batch manager efficiency) based on questionnaires results and collected data analysis. Each effective variable values were studied carefully and final study results were mentioned as follows: (1) Concrete batch plant performance ratio increases when (manager efficiency, operator efficiency, driver efficiency, concrete pump operator efficiency, procurement plan efficiency, marketing plan efficiency, truck mixers efficiency, number of 12 m^3 capacity truck mixers, number of 10 m^3 capacity truck mixers, pumps number, regular equipment maintenance efficiency, pumps efficiency, washing plant efficiency) increase, (2) weighted average distance between projects and concrete batch plant impacts on concrete batch plant performance ratio, when the distance increases; concrete batch plant performance ratio will decrease; it was studied a acceptable distance between projects and concrete batch plant and it should be ranged between (0.5:29 km), (3) projects schedules and orders of concrete quantities affecting concrete batch plant performance ratio, when it increases, concrete batch plant performance ratio will increase; it was studied optimal daily concrete quantities range that should to be produced is ranged between (285:375 m^3), (4) daily projects orders number affecting concrete batch plant performance ratio, when it increases, concrete batch plant performance ratio will increase; it was studied optimal daily projects orders number should be ranged between (4:6 projects), (5) items types that will be casted effects on concrete batch plant performance ratio, when items types that will be casted are same and easy, concrete batch plant performance ratio will increase, (6) communication between site crews impact on concrete batch plant performance ratio, when it is a good communication, concrete batch plant performance ratio will increase, (7) unexpected damages impacts on concrete batch plant performance ratio, when it increases, concrete batch plant performance ratio will decrease, (8) roads quality effects on concrete batch plant performance ratio, when they are good, concrete batch plant performance ratio will increase, (9) traffic conditions influences on concrete batch plant performance ratio, when it is not crowded, concrete batch plant performance ratio will increase, (10) weather conditions effects on concrete batch plant performance ratio, when it is good weather, concrete batch plant performance ratio will increase.

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Enhancing the ductility and mechanical behavior of Sn-1.0Ag-0.5Cu lead-free solder by adding trace amount of elements Ni and Sb

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ABSTRACT

The present paper investigates the microstructural and mechanical properties of Sn-1.0Ag-0.5Cu (SAC105) solder alloy with 0.06 wt% Ni and 0.5 wt% Sb additions. The study revealed that the microstructure properties and elastic moduli of such solder alloy improved. Results indicated that Ni element diffused from the molten solder matrix into the IMC particles to form the Ni_3Sn_4 IMC phase during solidification. Thus, Ni improved the solder microstructure and increased the drop lifetime of the electronic assembly. Meanwhile, by adding Sb element, no new IMCs formed due to the high solubility of Sb in Sn, but provide solid solution strengthening. In terms of tensile behavior, the SAC105–0.5Sb exhibited the highest strength and largest ductility. As well, all examined alloys exhibited higher mechanical properties with increasing strain rate and/or decreasing testing temperature. Moreover, notable improvements of 31.25% and 101.1% in elongation were obtained with addition of Ni and Sb elements, respectively. Consequently, ductility was enhanced by Ni or Sb additions. Furthermore, the average activation energy (Q) for SAC105, SAC105-0.06Ni, and SAC105-0.5Sb solders were 49, 57 and 63.5 kJ/mol, respectively, which is close to that of pipe-diffusion mechanism in Sn-based solder matrix.

1. Introduction

In the past decades, lead-tin solders had been used in a wide spectrum electronic packaging, aviation, satellite, automotive, and energy industries because of their superior physical, thermal and mechanical properties [1, 2]. Nevertheless, studies indicated that human exposure to lead via inhalation or ingestion of lead in water, food, soil, or dust can result in damage to the central nervous system and may be associated with high blood pressure [1]. In view of these human safety concerns, the development of lead-free solder alloys is considered as an essential and crucial task in the electronics industry. More properties should be taken into account such as melting point, mechanical properties, wettability, and solderability characteristics. So far, Sn–Ag–Cu (SAC) solders have been regarded as a favorable candidate for replacing standard eutectic Sn–Pb solder due to their advantageous properties [3, 4]. However, high Ag content Sn-xAg-Cu ($x \geq 3$ wt%) solders encouraged the formation of large thick brittle Ag_3Sn IMC within the bulk solder matrix that be able to simply initiate cracks [5, 6]. The brittle nature of Ag_3Sn IMC degrades the drop impact performance, frequently causing failures in portable electronic devices [7, 8]. Hence, low-Ag-content (Ag < 2%) SAC solders have been considered as a solution to both cost and poor drop-impact reliability factors [9, 10]. Unfortunately, reducing the content of Ag degrades the thermal mechanical fatigue performance, leads to the formation of larger β-Sn dendrites, and thus gives lower elastic modulus and yield strength [11]. In order to overcome these drawbacks and improve the mechanical properties with the modification of the microstructure, trace amount of elements such as Bi, In, Sb, Zn, Ni etc. have been added into low-Ag SAC solders [4].

In previous studies, it was reported that adding a trace amount of Ni to Sn–1.0Ag–0.5Cu (SAC105) solder alloy improved the growing of Cu_6Sn_5 but hindered Cu_3Sn growth through subsequent solid-state aging [12]. Also, it was noted from microstructural characterization that doping (< 1 wt% Ni) into SAC105 alloy, suppressed growth of Cu_3Sn layer on aging for 120 h at 150 °C [13]. On the other hand, it was revealed that the UTS and YS for SAC105–0.05Ni are higher while the elongation is lower compared with SAC105–0.02Ni solder [14]. Giuranno et al. indicated that the liquidus temperatures of SAC187 and SAC194Sb solders are 222 and 229 °C, respectively, showing comparable melting behavior to that reported in the literature. In terms of wettability, for the SAC187/Cu system, during non-isothermal heating up to 234 °C, the contact angle θ = 81° was obtained after 17 min. During non-isothermal heating of about 15 min, the contact angles of the SAC187/Ni and SAC194Sb/Ni systems decreased monotonically to

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θ = 119° and θ = 118°, measured at T = 238 °C and T = 244 °C, respectively [15].

Song et al. found that incorporating Zn into SAC105 alloy enhanced tensile properties but the elongation decreased [16]. Likewise, it was mentioned that doping 2.0 wt% Zn into Sn–1.0Ag–0.3Cu (SAC103) solder alloy produced an excessive tensile strength and low ductility even though 3.0 wt% Zn addition showed both the highest strength and large ductility [17]. Meanwhile, Shnawah et al. demonstrated that Fe addition to SAC105 inhibited the coarsening of Ag3Sn IMC, nevertheless the melting point was not affected [8]. In some cases, modification of SAC alloys compositions with minor Sb addition resulted in the formation of thinner intermetallic layers that may contribute to better quality of the solder joints and the electronic assembly [18, 19]. Furthermore, it was reported that In, Bi, Al and Ni addition to low-Ag SAC solder refined the β-Sn dendrites and distributed IMCs uniformly [20, 21]. Consequently, UTS and YS increased with the improvement of elastic modulus and creep resistance. Meanwhile, a trace amount of Zn and Al elements addition suppressed Ag3Sn plates formation [11, 22]. In our previous study, three types of multi-constituent lead-free solder alloys, i.e., SAC105, SAC105-0.06Ni, and SAC105-0.5Sb were investigated in view of melting behavior, microstructure, and creep property [23]. It was found that SAC105-0.5Sb exhibited the best creep property and better creep lifetime.

In a tensile test it is possible to choose arbitrarily the crosshead speed (or strain rate) and the temperature level to obtain definite values of ultimate tensile stress at maximum uniform strain levels which the material can withstand under this condition. Since the selection of materials for solder alloys is critical and plays an important role in the design and reliability evaluation of portable consumer electronics, the main aim of the present work is to investigate the effect of Ni and Sb additions on the tensile behavior of Sn–1.0Ag–0.5Cu under different strain rates and temperatures. In a tensile test it is possible to choose arbitrarily the crosshead speed (or strain rate) and the temperature level to obtain definite values of ultimate tensile stress at maximum uniform strain levels which the material can withstand under this condition. Furthermore, the microstructural characterization, mechanical properties and their relationship with each other of Sn–1.0Ag-0.5Cu–0.06 wt% Ni and Sn–1.0Ag-0.5Cu–0.5 wt% Sb were evaluated and compared with those of the baseline Sn–1.0Ag-0.5Cu solder alloy.

2. Experimental procedures

2.1. Material processing

In this study, Sn–1Ag–0.5Cu (SAC105), Sn–1Ag–0.5Cu–0.06Ni (SAC105-0.06Ni), and Sn–1Ag–0.5Cu–0.5Sb (SAC105-0.5Sb) bulk solder specimens were investigated. Table 1 shows the chemical composition of the examined solder alloys. For the preparation of the alloys, ingots of Sn, Ag, Cu, Ni and Sb with high purity 99.99% were melted in a vacuum arc furnace under high purity argon atmosphere to produce rod-like specimen with a diameter of approximately 10 mm.

The melt was held at 500 ± 2 °C for 1 h to complete the dissolution of Sn, Ag, Cu, Ni, and Sb. Subsequently, the molten alloys poured into a steel mold to prepare the chill cast ingot then the molds were air cooled naturally to room temperature. The solder ingots were then mechanically machined into a wire sample with a gauge length marked 4×10^{-2} m and 2.5×10^{-3} m in diameter, as developed in our previous work [24]. To stabilize microstructure and remove residual stress and defects produced during the specimen preparation, all specimens were heat-treated at 130 °C for 30 min.

Table 1
Chemical composition of the solders studied (wt%).

Alloy	Ag	Cu	Ni	Sb	Pb	Bi	As	Sn
Sn-1.0Ag-0.5Cu	1.0	0.5	–	–	0.009	0.007	0.006	Bal.
Sn-1.0Ag-0.5Cu-0.06Ni	1.0	0.5	0.06	–	0.011	0.009	0.008	Bal.
Sn-1.0Ag-0.5Cu-0.5Sb	1.0	0.5	–	0.5	0.011	0.010	0.009	Bal.

2.2. Microstructure investigation

The common metallographic practices of grinding and polishing were used to prepare the samples of the original SAC105, SAC105-0.06Ni and SAC105-0.5Sb solders. Then the samples were etched with a solution of 5 ml HCl + 30 ml H_2O + 60 ml C_2H_5OH for about 50 s and the subsequent microstructure investigations were performed by scanning electron microscope (SEM) (JEOL model JSM-5410, Japan). Chemical composition of the IMC phases was determined by using dispersive spectrometry (EDS). The phase formation of the solder alloy was analyzed by using X-ray diffraction (XRD). X-ray diffractometer operated at 40 kV, and the Cu-Kα radiation was used at diffraction angles (2θ) from 20° to 100° with a scanning speed of 1°/min. Hence, the crystal structures were identified by matching the characteristic XRD peaks against the Joint Committee on Powder Diffraction Standards (JCPDS) data.

2.3. Tensile tests

The solder wire was set onto a testing grip at two ends of the specimen using Instron 3360 Universal Testing Machine at constant strain rate and different temperatures ranging from 25 to 110 °C. Five samples were tested under the same testing conditions for each solder specimen and the tensile properties were obtained by averaging the test data.

In a joint, the solder is usually subjected to a variety of loading or straining rates, and temperature excursions. In response to these, the solder may deform elastically, plastically or even fracture. Even under simple loading conditions, multiaxial stresses and strains occur in solder joints. This is mostly true near the interface between solder and the constraining intermetallic reaction layers existing in all joints. Research is underway to find out how these complex stress and strain states may reduce solderability and limit joint reliability. Since the stress-strain data reported in the literature is uniaxial. Multiaxial specimens tested using the same universal testing machine as used for the tensile tests, but with modification. The future study will perform to establish a correlation between uniaxial behavior and the complex multiaxial behavior that occurs near the intermetallic layers.

The tensile tests in the current work were conducted at constant temperature 25 °C, 70 and 110 °C for all solders composition under a strain rate ranging from $10^{-4}\,s^{-1}$ to $10^{-2}\,s^{-1}$ to investigate the effects of Ni and Sb additions on the mechanical properties of the solder, yield stress, ultimate tensile strength (UTS), and elongation. The environment chamber temperature could be monitored by using a thermocouple contacting with the specimen.

3. Results and discussion

3.1. X-ray diffraction (XRD)

The XRD patterns of the as-prepared SAC105, SAC105-0.06Ni, and SAC105-0.5Sb alloys are shown in Fig. 1a–c. The results reveal that the main peaks are indexed by β-Sn, Ag_3Sn and Cu_6Sn_5 in the SAC105 solder alloys, as seen in Fig. 1a. According to the Sn-Cu phase diagram, Cu_6Sn_5 had at least two crystal structures in the solid state as shown in Fig. 2a and b: the η′ monoclinic phase, stable at temperatures below 186 °C and the η hexagonal phase, stable at temperatures above 186 °C [25, 26]. In the present work, the excessive η-Cu_6Sn_5 growth and the absence of η′-Cu_6Sn_5 IMC phase are suggested that η-Cu_6Sn_5 does not transform to η′-Cu_6Sn_5 during cooling period of the solder alloys. It was found that with adding amount of Ni, Sb there was some alteration and modification of SAC105 phases. Trace amounts of Ni element were detected from IMC particles in the SAC105-0.06Ni solder matrix and

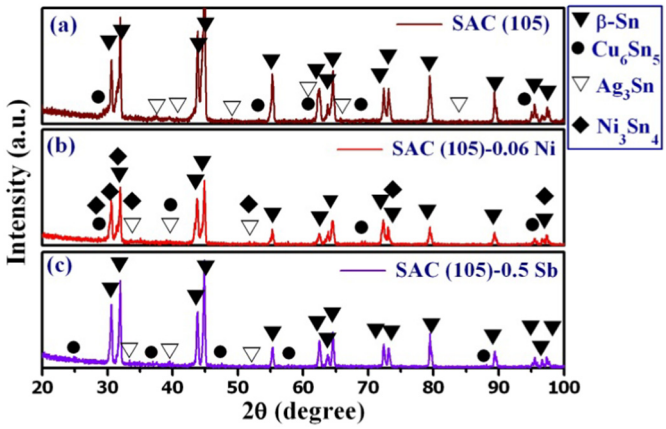

Fig. 1. XRD patterns of (a) SAC (105), (b) SAC (105)-0.06Ni and (c) SAC (105)-0.5Sb solder alloys.

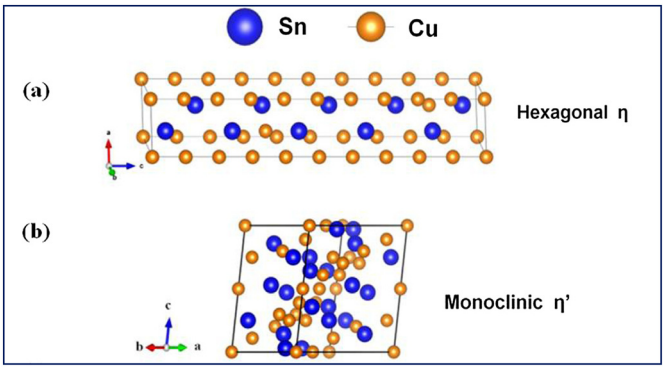

Fig. 2. Crystal structures of Cu6Sn5 phases [25].

could be expressed as Ni_3Sn_4 (Fig. 1b). Thus, Ni will be predicted to improve the solder microstructure and increase the drop lifetime of an electronic assembly. However, the Sb phase was not detected in the XRD pattern of the SAC105-0.5Sb due to the high solubility of Sb in Sn, as shown in Fig. 1c. The main peaks in XRD patterns become sharper and narrower with Sb addition, indicating an enhanced crystallinity, which is attributed to additional nucleation sites introduced by Sb [27].

3.2. Microstructural characterization

Fig. 3a–c shows the representative microstructures of the as-fabricated SAC105, SAC105-0.06 wt% Ni and SAC105-0.5 wt% Sb alloys, respectively. The micrographs affirm the observations described in the literature survey about a few Ag_3Sn and Cu_6Sn_5 intermetallic particles besides relatively large primary β-Sn grains in the solder matrix of the base SAC105 solder alloy, as shown in Fig. 3a. The IMCs precipitates in between β-Sn were identified according to corresponding EDS analysis. These results are confirmed by XRD, as exhibited in Fig. 1. Ni and Sb act as nucleation sites, leading to accelerated solidification of Sn and shorter time spans for IMC growth, resulting in microstructural refinement and suppression of IMC growth. The Ni-containing sample displays Ni–Sn IMC and a eutectic phase. The acquired atomic compositions propose that this IMC is Ni_3Sn_4, which is consistent with the previously published data [28]. As well, dot- and fiber-like IMCs are shown at the surface of β-Sn matrix easily, as shown in Fig. 3b. According to the classical heterogeneous nucleation theory, IMC prefers to nucleate and grow on the surface of Ni particles, which aid nucleation by reducing the thermodynamic barrier, so the IMC growth rate is increased. It has been reported that the transformation from hexagonal to a monoclinic structure can be retarded by adding Ni [29].

In previous studies, researchers demonstrated that the presence of strongly bonded adjacent phases can establish the equilibrium structure. As a result, the IMCs Ni_3Sn_4 can enhance the stability of equilibrium phases and refine the crystal structure [30]. In addition, it was reported that Ni-Sn demonstrates the most advantages for SiC device packaging. Ni metallizations are widely used in power devices and have a close coefficient of thermal expansion (CTE) match with SiC, furthermore, Ni-Sn transient liquid phase (TLP) bonding is cost-effective and the formed Ni_3Sn_4 joints have the high remelting temperature of 794 °C [31]. On the other hand, Sb alloying triggers the morphology change of β-Sn grains into light-gray β-Sn primary dendrites surrounded by dark eutectic regions of refined Cu_6Sn_5 and Ag_3Sn IMC phases, as illustrated in Fig. 3c. Due to the high solubility of Sb in Sn, no IMCs were formed, and Sb atoms are in solution into the *β–Sn* matrix which not only contributes to suppress the coarsening of Ag_3Sn phase but also provides solid solution strengthening.

3.3. Tensile properties of solder alloys

The study of mechanical properties and microstructure is essential to understand the main characteristics of the possible solder alloys. Thus, tensile true stress (σ_t) - true strain (ε_t) testing of the studied solders is performed at room temperature (T = 25 °C) and constant strain rate of $8.8 \times 10^{-4}\,s^{-1}$, as shown in Fig. 4. In general, the solders experience simultaneous work hardening and dynamic recovery when they are deformed. Work hardening and dynamic recovery have contrary influences on the mechanical properties of solders. The former hardens the solders while the latter leads to recovery and softening. Hence, the obtained stress–strain curves presented the combined effects of both factors for all examined alloys. Besides, the average values of the mechanical characteristics namely, the ultimate tensile strength (UTS), 0.2% yield strength (0.2YS), and percentage of elongation are presented in Fig. 5 and Table 2. It is clear that, the average UTS values were 19.7, 23.3 and 30.1 MPa, the average 0.2YS values were 17.4, 20.3 and 23.8 MPa, and the average elongation percentages were 19.2, 25.2 and 38.6% for the SAC105, SAC105-0.06Ni and SAC105-0.5Sb solders, respectively. It is observed that tensile characteristics of SAC105 plain solder are strongly affected by adding Ni and Sb elements. The UTS and YS variation can be explained by the microstructural features that were already explained above. In addition, the formations of finer IMCs, as well as a much smaller grain size, contribute to improve the mechanical properties. Indeed, consistent with the study in Ref [32], these fine strengthening precipitates can effectively obstruct the dislocation movement initiated in Sn matrix which leads to an increase to the effective properties of the alloy. Therefore, the strength of SAC105 benefits from solid solution hardening and refinement by Sb elements. These are the main evidence to account for the improved strength of SAC105 by adding a small amount of Ni and Sb elements. In addition, elongation of SAC105 alloy enhanced by adding Ni and Sb to be 25.2 and 38.6%, respectively. It can be seen that the UTS, YS, and elongation of SAC105-0.5Sb are 52.8%, 36.8% and 101.1% greater than that of SAC105 base solder alloy.

3.4. Effect of strain rate on solder mechanical properties

Figs. 6 and 7 show the mechanical characteristics of different SAC solders at a temperature of 25 and 70 °C, respectively with varying tensile strain rates ranging from 10^{-4} to $10^{-2}\,s^{-1}$. It is very clear that the true strain rate played a significant role and affected the UTS, YS, and elongation. The UTS and YS increase with increasing strain rate for the studied alloys. This is because increasing strain rate is accompanied by an increase in the dislocation density. As these dislocations move they become mixed. It is then more difficult for other dislocations to glide through the material, especially at the lower deformation temperatures. At high testing temperature; dislocation annihilation seems to occur more rapidly than dislocation generation during deformation. Therefore, at higher testing temperatures the lower strain rate provided

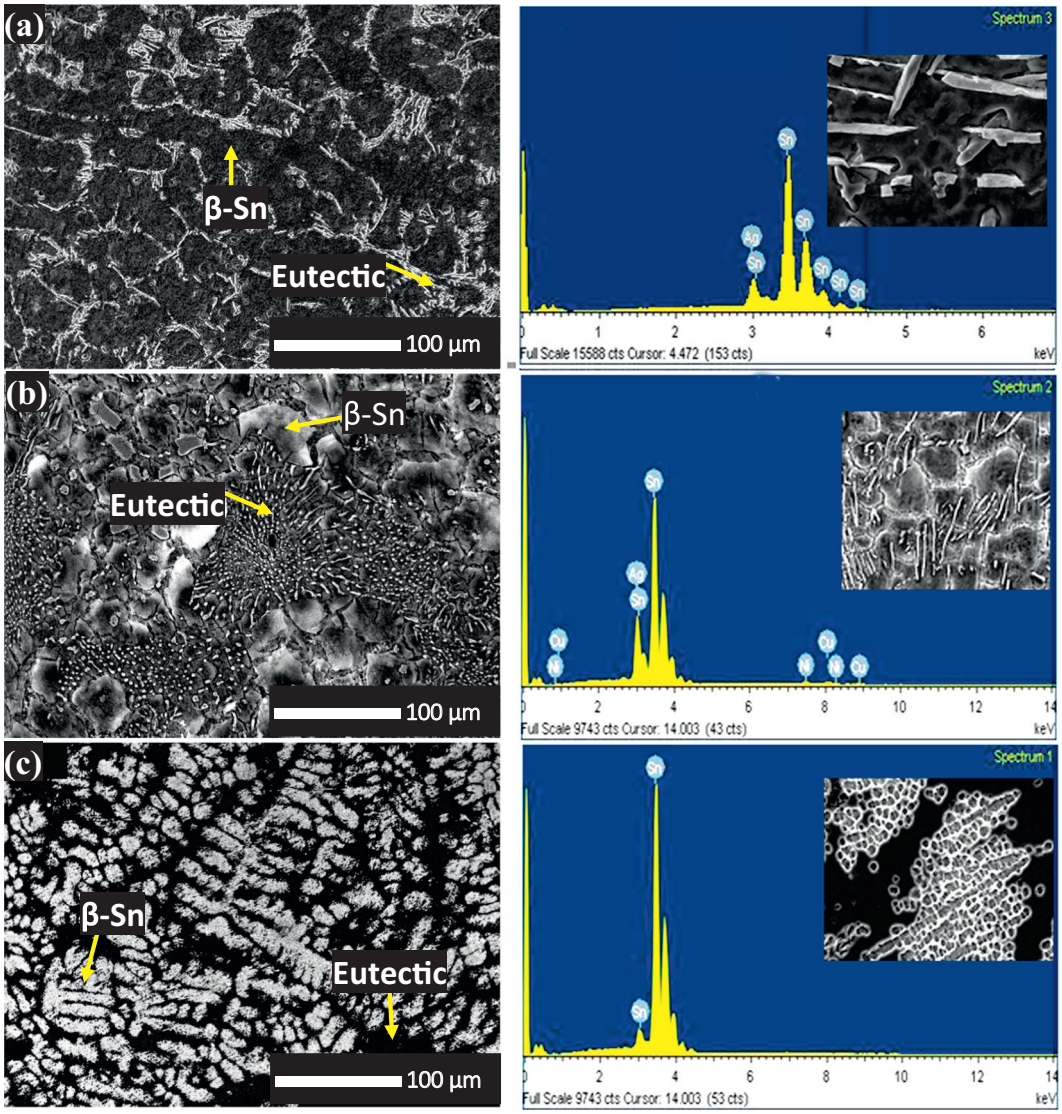

Fig. 3. SEM microstructures of as-solidified (a) SAC (105), (b) SAC (105)-0.06Ni and (c) SAC (105)-0.5Sb solder alloys and corresponding EDS.

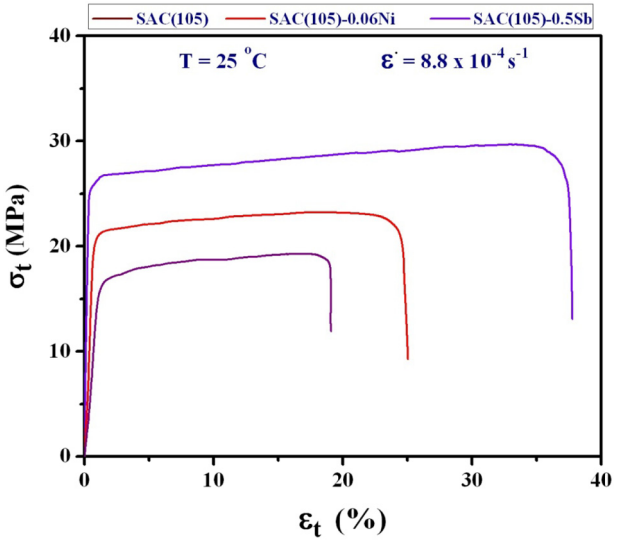

Fig. 4. Comparative tensile stress–strain curves obtained at T = 25 °C and $\dot{\varepsilon} = 8.8 \times 10^{-4}\,s^{-1}$ for SAC (105), SAC (105)-0.06Ni and SAC (105)-0.5Sb solder alloys.

lower strength in the tested solder and dynamic recovery seems to occur, leading to reduce the tensile strength.

Results show that alloying Ni into SAC105 alloy improves solder joint reliability because Ni addition improves significantly solder microstructures and tensile properties, as in references [33–35]. Also, the previous study reported that Ni addition to SAC alloy increased the impact strength of solder joint based on Izod impact test results which led to improvements in the drop reliability of electronic assembly [13]. Furthermore, Sb-content alloy displays the largest UTS, YS and elongation. The improvement of tensile strength is corresponding to the microstructure of SAC105-0.5Sb alloys is much more refined. It can be concluded that the solid solution strengthening mechanism associated with Sb addition is the dominant mechanism for the improvement in mechanical properties of SAC105-0.5Sb quaternary solder alloys, as compared with SAC105 ternary alloy. Similar strengthening mechanism can be found in SAC105 alloys bearing minor amount of Ni [27]. The change of elongation with the strain rate is due to the interaction between IMCs or precipitates with the dislocation motion.

3.5. Effect of temperature on solder mechanical properties

Fig. 8 shows the influence of temperature ranging from 25 to 110 °C at a constant strain rate of $4.4 \times 10^{-3}\,s^{-1}$ on the UTS, YS and

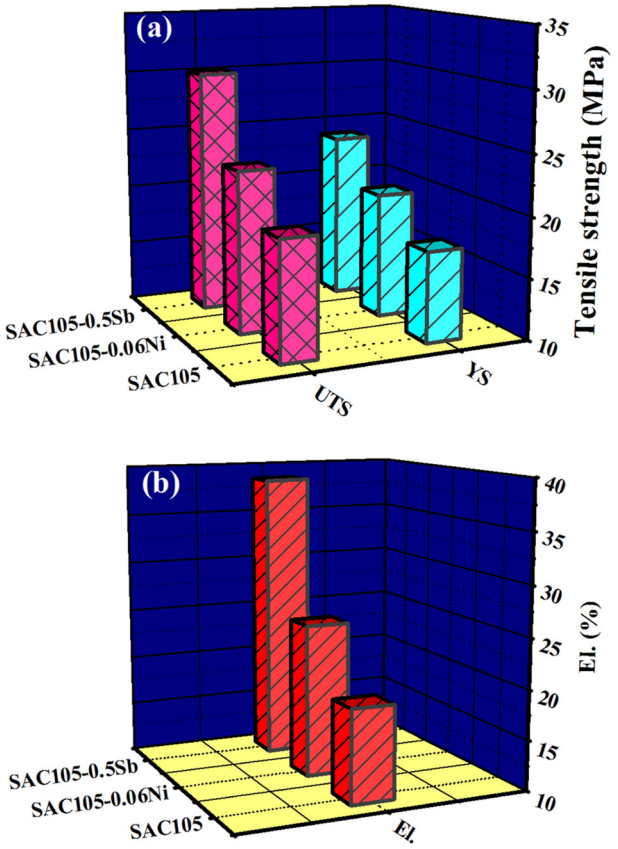

Fig. 5. Tensile properties and average values of: (a) ultimate tensile strength (UTS) and yield stress (YS) and (b) elongation (El.) of the samples.

Table 2
Stress-strain characteristics of SAC105, SAC105–0.06Ni and SAC105–0.5Sb solder alloys at T = 25 °C and $\dot{\varepsilon} = 8.8 \times 10^{-4}\,s^{-1}$.

Solder	UTS (MPa)	YS (MPa)	Elongation (%)
SAC 105	19.7	17.4	19.2
SAC105-0.06Ni	23.3	20.3	25.2
SAC 105-0.5Sb	30.1	23.8	38.6

elongation for the investigated solders. It is clear that the UTS, and YS of each solder decrease as the temperature increases, thus registering positive temperature sensitivity. The decrease in tensile strength, as well as the strain hardening with temperature can be due to the higher dislocation recovery rate, higher dislocation mobility and ease of overcoming short range barriers, such as Peierls-Nabarro stress, etc., with an increase in the temperature [36]. Several possible explanations exist for sensitivity of ductility to testing temperatures such as, compositional and heat treatment effects on the matrix phase and IMC chemistries, impurity segregation to interfaces, the nature of interface formed between the IMCs and the matrix, the growth rate and stability of the soft and hard IMCs in the alloy matrix [37]. Obviously, doping 0.06 wt% Ni and 0.5 wt% Sb to SAC105 solder increased UTS, YS and elongation at temperature range. Hence, the SAC105-0.5Sb alloy possesses high tensile strength and ductility at all tested temperatures.

3.6. Constitutive equation and thermodynamic parameters

The dominant mechanical deformation mechanisms can be reflected by the values of the stress exponent n and the activation energy Q. Although laws describing the mechanical deformation behaviors over a wide range of stresses are different, the following Garofalo hyperbolic-sine law is the most universally accepted [38, 39]:

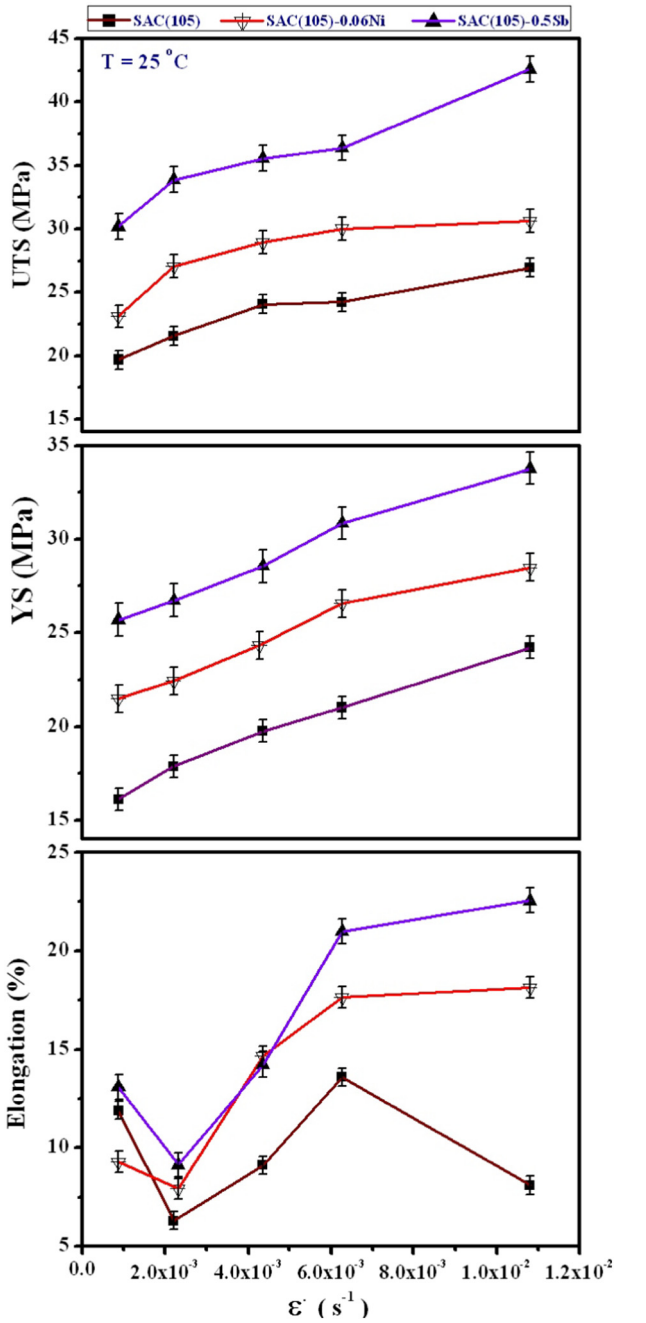

Fig. 6. Effect of strain rate on: ultimate tensile strength (UTS), yield stress (YS) and elongation at T = 25 °C for SAC (105), SAC (105)-0.06Ni and SAC (105)-0.5Sb solder alloys.

$$\dot{\varepsilon} = A\left[\sinh(\alpha\sigma)^n \exp\left(-\frac{Q}{RT}\right)\right] \quad (1)$$

where A is a constant, α is a temperature-independent material constant, n denotes the stress exponent, $\boldsymbol{R}$ is the universal gas constant, $\dot{\varepsilon}$ is the strain rate, $\boldsymbol{T}$ (K) is thermodynamic deformation temperature, Q is the activation energy for deformation and $\boldsymbol{\sigma}$ is the steady flow stress. The value of $\boldsymbol{\alpha}$ was calculated by $\alpha = \frac{\beta}{n_1}$, where β and n_1 are the average slopes of the lines $\boldsymbol{\sigma} - \ln \dot{\varepsilon}$ (Fig. 9) and $\ln\boldsymbol{\sigma} - \ln \dot{\varepsilon}$ (Fig. 10) at a constant temperature for the three solder alloys, respectively.

From Eq. (1), the stress exponent can be written as

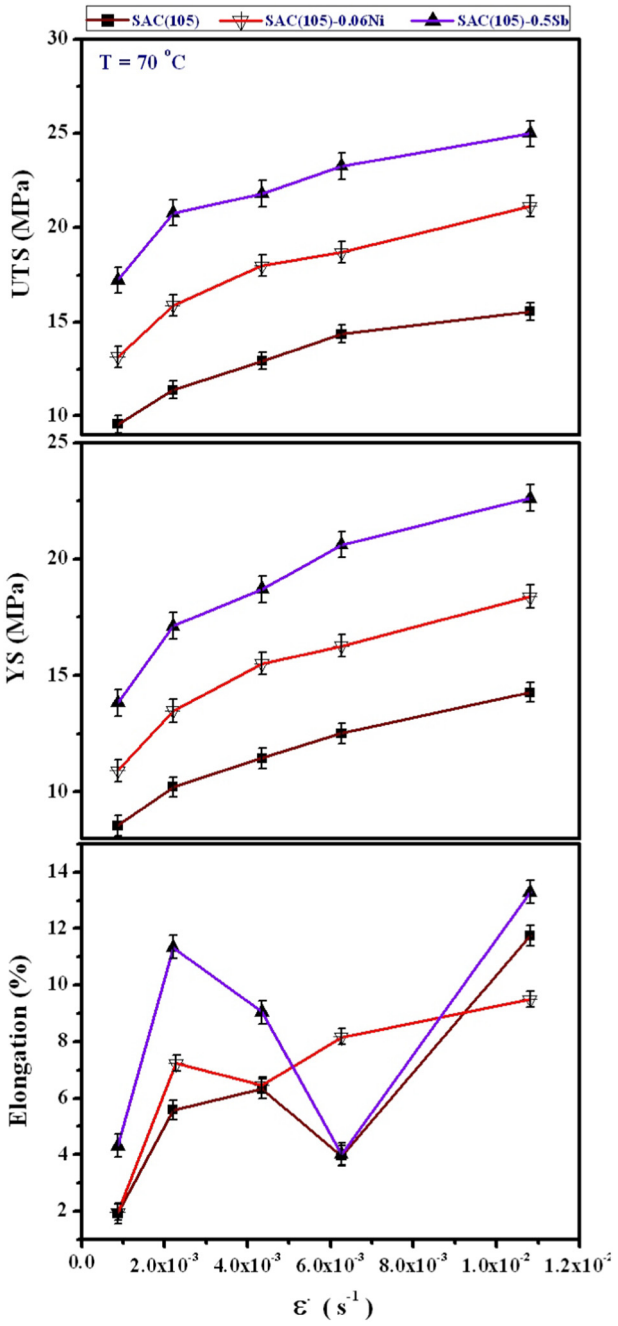

Fig. 7. Effect of strain rate on: ultimate tensile strength (UTS), yield stress (YS) and elongation at T = 70 °C for SAC (105), SAC (105)-0.06Ni and SAC (105)-0.5Sb solder alloys.

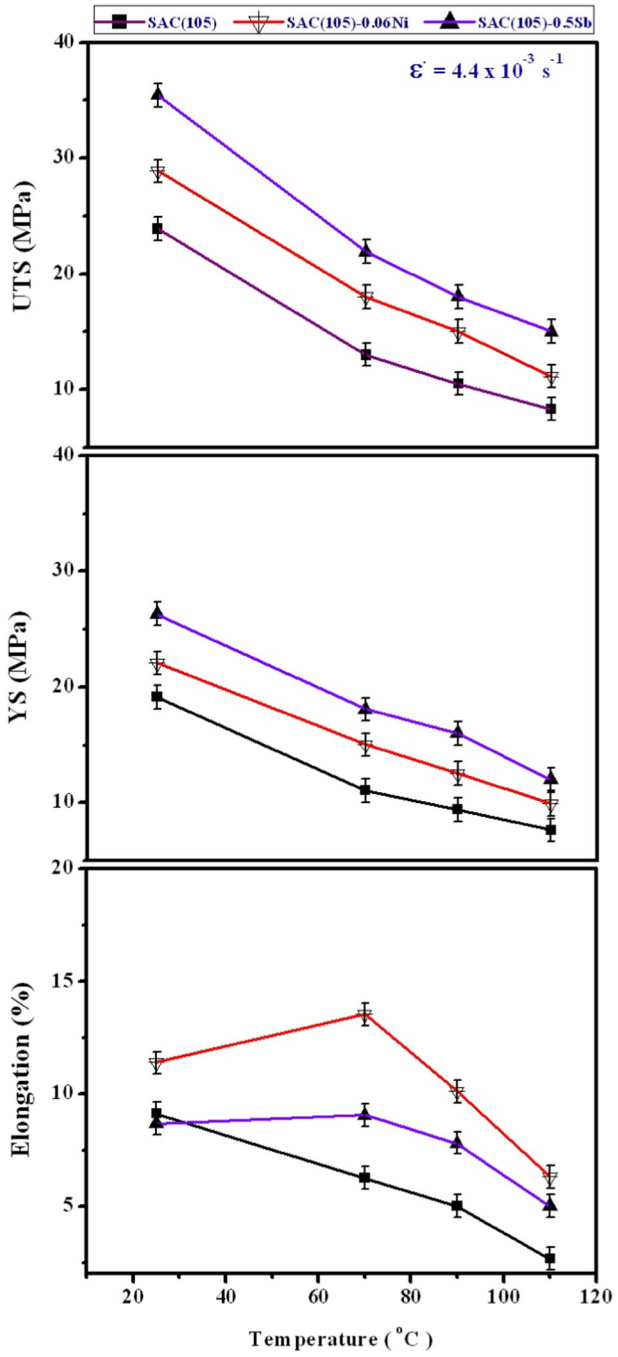

Fig. 8. Effect of temperature on: ultimate tensile strength (UTS), yield stress (YS) and elongation at $\varepsilon\cdot = 4.4 \times 10^{-3} s^{-1}$ for SAC (105), SAC (105)-0.06Ni and SAC (105)-0.5Sb solder alloys.

$$n = \left[\frac{\partial \ln \dot{\varepsilon}}{\partial \ln[\sin h(\alpha\sigma)]}\right]_T$$

In general, $\ln\varepsilon\cdot$ has linear relation with $\ln[\sin h(\alpha\sigma)]$.

The activation energy Q can be derived as

$$Q = Rn\left[\frac{\partial \ln[\sin h(\alpha\sigma)]}{\partial (1/T)}\right]_\varepsilon.$$

The above-mentioned constitutive analysis yielded the values of n, Q and the materials parameters for the studied alloys, as shown in Figs. 11 and 12, respectively. These results are summarized in Table 3. Since the dynamic recovery process was dominant at high temperatures, the n values for SAC105, SAC105–0.06Ni and SAC105-0.5Sb are decreased from 6.3 to 4.0, 8.1 to 5.2 and 9.8 to 6.6, respectively, with increasing temperature in range of 25–110 °C. In fact, the drop of n values with temperature reflects the instability of microstructure at high deformation temperatures. Softening and dissolution of second phase particles are possible causes for the observed instability. It means that the precipitation-strengthening effect is greater at lower temperatures for all of the Pb-free alloys. It is generally known that, additions of second-phase particles in matrix Sn can affect the distance that dislocations move between obstacles and the forces that cause them to overcome these obstacles. However, several activated processes can occur in particle-strengthened materials, such as particle by-pass by dislocation climb and attractive interactions between dislocations and particles. Clearly, the n values of SAC105-0.5Sb solder alloy is larger

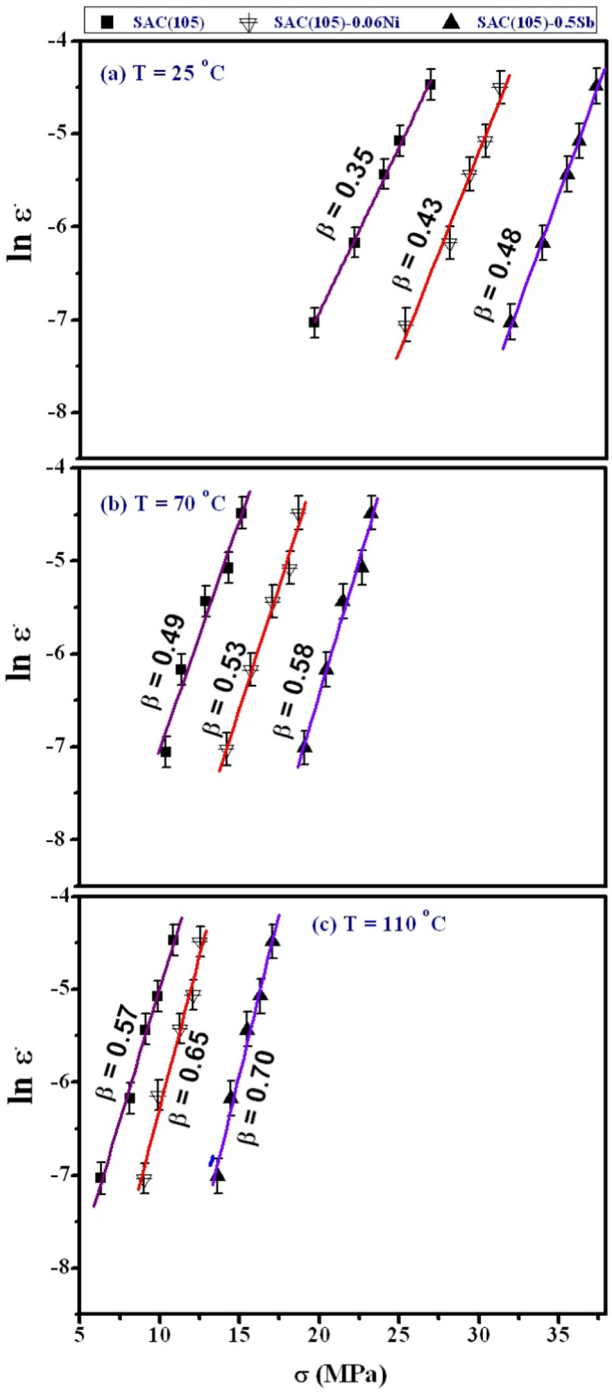

Fig. 9. Relationship between σ and ln (ε·) of SAC (105), SAC (105)-0.06Ni and SAC (105)-0.5Sb solder alloys at (a) T = 25, (b) T = 70 and (c) T = 110 °C.

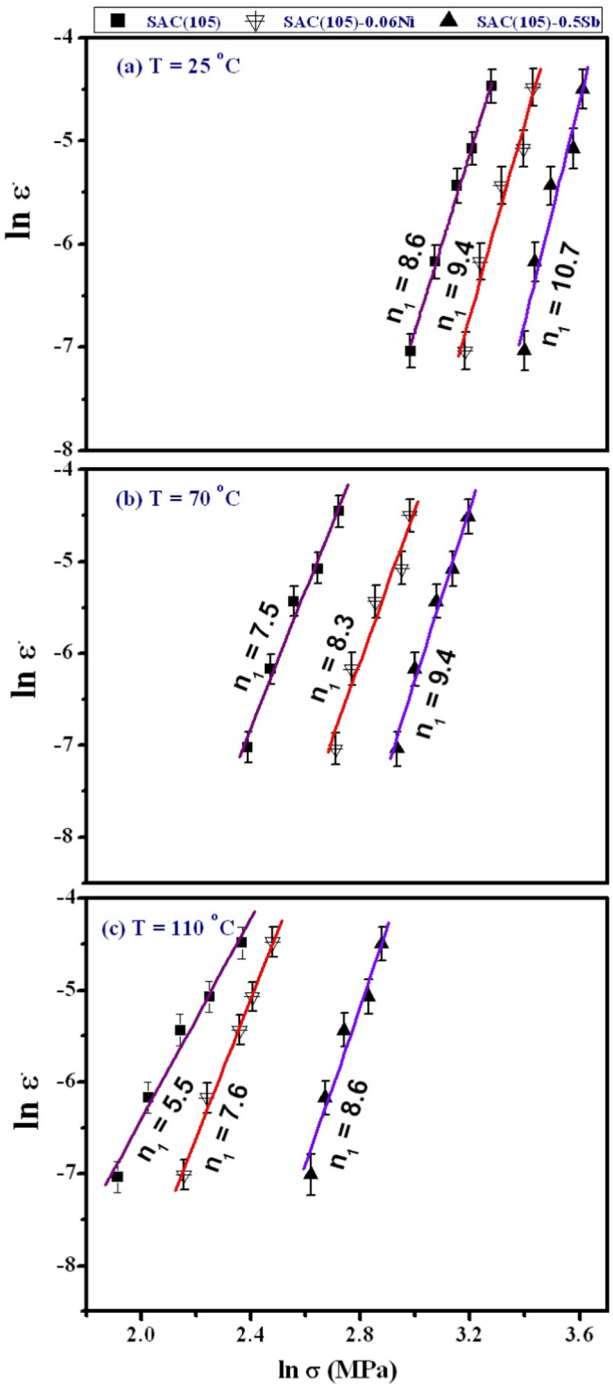

Fig. 10. Relationship between ln σ and ln (ε·) of SAC (105), SAC (105)-0.06Ni and SAC (105)-0.5Sb solder alloys at (a) T = 25, (b) T = 70 and (c) T = 110 °C.

than that of the other two solder alloys over the whole temperature range tested.

As shown in Fig. 12 and Table 3, the activation energies were estimated to be 49.0, 57.0 and 63.5 kJ/mol for SAC105, SAC105-0.06Ni and SAC-0.5Sb, respectively. They are much lower than the activation energy for the lattice self-diffusion of tin (102 kJ/mol) [40]. The activation energies investigated in this study are relatively close to that for the tensile creep of tin controlled by pipe diffusion [41], and thus the tensile creep behavior can be related to a slip creep mechanism controlled by pipe diffusion [42]. Therefore, the slip creep mechanism dominates in these lead-free solders in the strain rate range investigated [42].

4. Conclusions

In this paper, tensile tests were conducted on solder specimens based on SAC105 lead-free solder alloy, to investigate the effect of 0.06Ni and 0.5Sb additions and that of the testing conditions (strain rate and temperature) on the mechanical characteristics and microstructure. The results are summarized as follows:

(1) The morphology of the microstructure of the SAC105 solder alloy changed after Ni and Sb additions. The Ni addition leads to creation of particular intermetallic compounds, Ni_3Sn_4 beside Ag_3Sn and Cu_6Sn_5 IMCs. Nevertheless, Sb addition, no new IMCs were formed

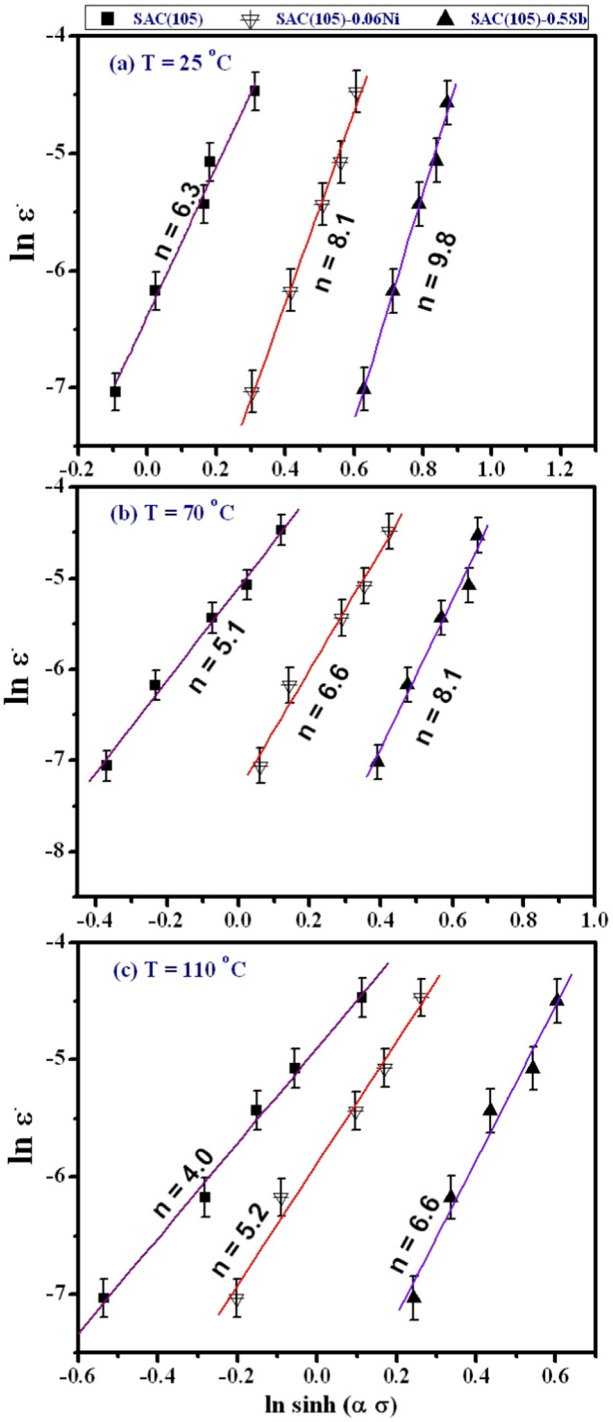

Fig. 11. Relationship between ln sinh (ασ) and ln (ε̇) of SAC (105), SAC (105)-0.06Ni and SAC (105)-0.5Sb solder alloys for determination stress exponent (n) values at (a) T = 25, (b) T = 70 and (c) T = 110 °C.

due to the high solubility of Sb in Sn, but provide solid solution hardening.

(2) The ultimate tensile strength, yield stress and percentage elongation of the SAC105 alloy improved significantly with addition of 0.06 wt% Ni and 0.5 wt% Sb elements over the entire range of strain rate and temperature examined in this study.

(3) The Sb-containing solder has higher UTS and YS than Sb-free solder resulting from the solid solution hardening.

(4) The mechanical properties of tensile tests are highly dependent on atoms addition and testing conditions. For the present alloys, it decreases with increasing temperature and/or decreasing strain rate.

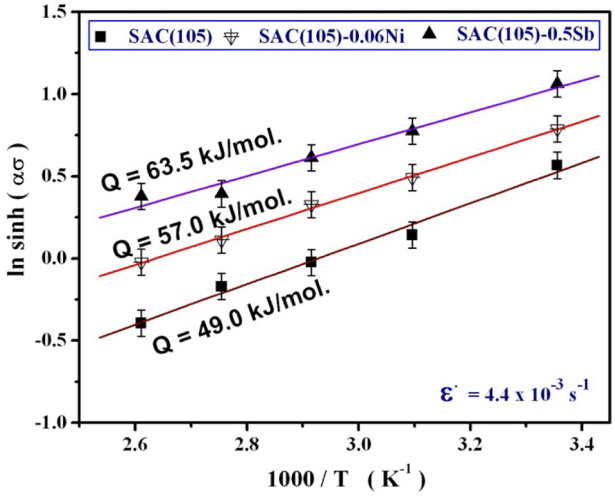

Fig. 12. Relationship between 1000/T and ln sinh (ασ) of SAC (105), SAC (105)-0.06Ni and SAC (105)-0.5Sb solder alloys for determination activation energy (Q) values.

Table 3
The activation energy (Q), stress exponent (n) and parameter (α) values for SAC105, SAC105–0.06Ni and SAC105–0.5Sb solder alloys.

Alloy	Q (kJ/mol)	Temperature (°C)	α (MPa^{-1})	n
SAC105	49.0	25	0.04070	6.3
		70	0.06533	5.1
		110	0.10363	4.0
SAC105-0.06Ni	57.0	25	0.04574	8.1
		70	0.06386	6.6
		110	0.08553	5.2
SAC105-0.5Sb	63.5	25	0.04459	9.8
		70	0.06170	8.1
		110	0.08139	6.6

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Fabrication of microelectrode ensembles on thin-film single electrodes: The degradation of electropolymerized benzene-1,3-diol films in caustic solutions

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Article

ABSTRACT

This paper explores the degradation of poly benzene-1,3-diol films in caustic solutions. A polymer film was deposited on Micrux® thin film gold electrodes ($A = 0.008$ cm^2) or gold-coated silicon wafer chips ($A = 1.0$ cm^2). The deposition parameters, exposure time and the concentrations of caustic solutions were optimized to obtain the efficient microelectrode ensembles. The electrochemical behavior of the deposited material was studied by cyclic voltammetry. The final morphology of the films was investigated by scanning electron microscopy (SEM), atomic force microscopy (AFM), and transmission electron microscopy (TEM). Through exposure to caustic solutions, polymer removal from the electrode surfaces resulted in the creation of a microelectrode ensemble. The voids on the surfaces were filled successfully with polyaniline by electropolymerization process. TEM and AFM analyses revealed the existence of polyaniline spherical nanoparticles in the modified films with a diameter slightly above 50 nm. The calculated average inter-pore distance using SEM micrographs was approximately 543 nm for the Micrux® electrode, and approximately 860 nm for gold-coated Si-chips. The number density of the pores was equal to 4.9×10^8 electrodes/cm^2 for Micrux® modified electrode, while 2.0×10^8 electrodes/cm^2 for gold-coated Si-chips. The present work allows the production of high-density microelectrode ensembles using a cost-effective route, and a platform for a wide range of applications including sensor technology.

Keywords: Electropolymerization, Etching, Polyaniline Nanoparticles, Oxidation.

1. INTRODUCTION

Microelectrode arrays are electrode platforms with a geometrically ordered regime of electrodes available in numerous sizes and shapes. They can be used in many applications and technologies such as in sensors,[1–8] batteries,[9–12] catalysis and electrocatalysis[13–19] and the study of mass transport phenomena.[20–23]

Microelectrodes (radius < 50 μm) have many advantages in usage over macroelectrodes. Mass transport at the microelectrode surface is enhanced due to hemispherical diffusion phenomena.[24] Microelectrodes have a smaller

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electrode area than macroelectrodes and thus produce lower charging currents at the surface. Moreover, the effect of solution resistance at the microelectrodes surface is reduced when compared with that seen at macroelectrodes. However, the currents at microelectrodes are extremely small compared to macroelectrodes, and are therefore difficult to detect.[24, 25] This encouraged many researchers to develop several methods of generating microelectrodes by improving measured currents from thousands of microelectrode pinholes. Lithography is a technique used in fabrication of microelectrode arrays.[26–29] This method of fabrication can produce microstructure arrays with reproducible structural height and aspect ratio, resulting in geometrically ordered microelectrode arrays. However, the production costs and instruments used in this method are expensive. Therefore, researchers are working on means to develop relatively cheap and simple methods to produce microelectrode arrays. Myler et al. have sonochemically fabricated a polymer modified glucose oxidase microelectrode array with population densities up to 2.5×10^5 electrodes/cm^2.[30] This work was accomplished by depositing an insulating polymer layer on commercially available screen-printed electrodes, followed by ultrasonication to generate regular-sized pinholes in the polymer film. Then, electropolymerization of aniline into the microelectrode pinholes was achieved, resulting in the formation of polyaniline and entrapped glucose oxidase into the pinholes of the microelectrode arrays.[30, 31] Kadara et al. fabricated and characterized in-house screen-printed microelectrode arrays. The analytical utility of the shallow recessed microelectrode arrays was demonstrated with the cathodic stripping of Mn^{2+} allowing nano-molar levels to be readily detected, exhibiting a superior performance over conventional carbon-based electrodes.[32] Rossem et al. reported the fabrication of novel sensing arrays for measuring dissolved oxygen concentrations in sample solutions. The sensor was fabricated from platinum and oxide-nitride-oxide as an insulating material, and electrodes were recessed in a glass substrate.[33] Tiggemann et al. fabricated a so-called electronic nose from microelectrode arrays based on polyaniline films on graphite electrodes. They doped with different acids such as camphor sulfonic and dodecylbenzenesulfonic acids to distinguish three artificial aromas: strawberry, grape and apple.[34] Rusinek et al. produced boron doped diamond microelectrodes arrays adapting traditional semiconductor microfabrication processes. The resulting microelectrodes were patterned in different geometries to find an optimum electrochemical response. They observed an excellent sigmoidal voltammogram shape of different microelectrode arrays geometries.[35]

Kennedy and Cunnane demonstrated that polymer films deposited on gold electrodes by the electrochemical oxidation of 1,3-dihydroxybenzene and 3-aminophenol can be degraded when exposed to caustic solutions.[36, 37] They electropolymerized 0.1 mol dm^{-3} 1,3-dihydroxybenzene on Teflon shrouded gold disk electrode ($A = 0.07$ cm^2) then treated the blocked electrodes in 10.0 mmol dm^{-3} caustic solutions.[36] They showed that caustic solutions could remove the polymer layer completely from the gold surface upon providing sufficient exposure. Exposure time of 8 minutes was used to produce the microelectrode ensembles. In their work, they did not show any morphology of the prepared electrodes and therefore, the spacing and size of the pores were not accessible. Moreover, the used exposure time in caustic solutions was too fast and difficult to track the development of the pores.

In this paper, we prepared a poly benzene-1,3-diol polymer in caustic solution and deposited on Micrux® thin film gold electrodes and gold-coated silicon wafer chips to obtain microelectrode ensembles. The deposition parameters; exposure time and the concentration of caustic solutions were optimized to obtain the efficient microelectrode ensembles. A detailed morphology of the modified electrodes along with the development of the pores on the electrode surfaces, that was tracked from 0 minute to 3 days using scanning electron microscopy (SEM), transmission electron microscopy (TEM) and atomic force microscopy (AFM). The development of polymer films on Micrux® electrodes and gold-coated silicon-chips was investigated by cyclic voltammetry (CV). Finally, the number density of the pores was calculated for Micrux® and gold-coated Si-chip electrodes. It is believed that the results of this study enable the production of microelectrode ensembles in a cost-effective manner and provide a platform for a wide range of applications, such as sensor technology.

2. EXPERIMENTAL DETAILS

2.1. Chemicals and Materials

All chemicals were analytical grade and used without further purification. benzene-1,3-diol (>99%), potassium ferrocyanide trihydrate (>98%), potassium chloride (99%), potassium ferricyanide (>98%) were all procured from Alfa Aesar, Germany. Sodium hydroxide (98%) and sulfuric acid (95–98%) were procured from PRS, Panreac, Spain. Aniline (>99.5%) was procured from Sigma Aldrich, Germany. All aqueous solutions were prepared using deionized water from a Milli-pore Milli-Q system (resistivity = 18.2 MΩcm).

2.2. Fabrication of Microelectrode Ensembles

All electrochemical experiments were carried out using EZstat-Pro-potentiostat (NuVant Systems Inc., IN, USA) equipped with EZware 2013 V7 software. Micrux® gold electrodes (Ref.ED-SE1-Au) were purchased from Micrux technologies, Oviedo (Asturias), Spain. Gold-coated silicon wafer (Au.1000.SL1) with a layer of 100 nm gold and 5.0 nm titanium thicknesses was purchased from Platypus technologies, Madison, U.S.A. The gold-coated

Si wafer was cut into small chips of 1.0 cm × 1.0 cm using LatticeAx™ 120, LatticeGear, U.S.A.

Micrux® electrodes are based on a three-electrode (working—WE, reference—RE and auxiliary—AE) approach. Specification of the WE was 50/150 nm Ti/Au (1 mm Ø) and for the RE—AE was 50/150 nm Ti/Au. Based on the manufacturer catalogue, these electrodes were fabricated as a thin-film on a glass substrate by means of sputtering. A protective layer of SU-8 resin was placed on the electrodes by the manufacturer to delimit the electrochemical cell; thereby enabling the use of a very small sample volume (1–5 μl). The Micrux® electrodes require a surface pre-cleaning in order to remove any particle or dust that can affect the electrochemical performance, reproducibility and shelf life. Therefore, the fresh electrodes were cleaned before usage by sweeping the potential of the working electrode between −1.0 and +1.3 V at 0.1 V s^{-1} (20 cycles), 0.05 (mol dm^{-3}) of H_2SO_4 as the background electrolyte.

Neutral solutions consisting of 0.2 mol dm^{-3} of benzene-1,3-diol and 0.2 mol dm^{-3} potassium chloride as the supporting electrolyte at pH of 7.0 were prepared. The prepared solutions were electrochemically polymerized at Micrux® Gold (Ref.ED-SE1-Au) electrodes versus (Au) and gold-coated silicon chips versus (Ag/AgCl, 3.0 mol dm^{-3} KCl). The electropolymerization was conducted using CV by sweeping the potential between 0.0 and 1.0 V at 0.005 V s^{-1} (20 cycles). The blocked electrodes were washed with deionized water and dried at ambient temperature.

After the electropolymerization stage, CV scans were conducted using 20 mmol dm^{-3} $K_3Fe(CN)_6/K_4Fe(CN)_6$ couple to make sure that the electrodes have been blocked with poly benzene-1,3-diol. In the case of Micrux® electrodes, the potential window was between −0.3 V and 0.5 V at 0.02 V s^{-1} (4 cycles) and the applied potential was recorded versus (Au). In gold-coated silicon chips, the potential window was between −0.2 V and 0.6 V at 0.02 V s^{-1} (4 cycles) and the applied potential was recorded versus (Ag/AgCl, 3.0 mol dm^{-3} KCl).

The blocked electrodes with poly benzene-1,3-diol were immersed in caustic solutions of sodium hydroxide in a small beaker or dish. It was maintained in caustic for definite periods of time. Concerning the gold-coated Si-chips (A = 1.0 cm^2), a solution of 1 mmol dm^{-3} NaOH was used to etch the surface of the blocked chips. The caustic immersion period varied between 0 minutes to 300 minutes, extending up to three days. For the blocked Micrux® electrodes (A = 0.008 cm^2), a solution of 1 mol dm^{-3} NaOH was used to etch the surface between 0 minutes up to ten minutes. A freshly blocked electrode was used for both the Micrux® and the gold-coated Si-chips every time during the entire assigned immersion period.

Subsequent to caustic exposure period, the degradation test of all modified electrodes was conducted by CV in a solution of 20 mmol dm^{-3} $K_3Fe(CN)_6/K_4Fe(CN)_6$ couple. The potential was between −0.3 V and 0.5 V versus (Au) at 0.02 V s^{-1} (4 cycles) used with Micrux® electrodes; whereas, the potential was between −0.2 V and 0.6 V versus (Ag/AgCl, 3.0 mol dm^{-3} KCl) at 0.02 V s^{-1} (4 cycles) for gold-coated silicon chips. The modified microelectrodes were washed with deionized water and dried at ambient temperature.

Following the degradation test, polyaniline was deposited electrochemically on the modified microelectrodes by CV. Polyaniline deposition was carried out by sweeping the potential of the working electrode between −0.2 and +0.8 V, at 0.05 V s^{-1} (7 cycles), in a 0.2 mol dm^{-3} aniline and 0.2 mol dm^{-3} of KCl aqueous solution. The applied potential recorded at Micrux® electrodes was measured versus (Au). For gold-coated silicon chips, the applied potential was measured versus (Ag/AgCl, 3.0 mol dm^{-3} KCl). The modified microelectrode ensembles were dried out at ambient temperature and kept in a sample holder for further analysis.

2.3. Characterization

Morphological features of the electrode surfaces were examined at different magnifications, using SEM (FEI Company, INSPECT S50, Czech Republic). The electronic images were acquired at applied acceleration potential of 20 kV, working distance 10 mm and spot size 3. For high magnification images, the spot size reduced to 2 (small beam) and working distance to 5 mm to obtain high resolution images with high signals. The samples were mounted on a metallic stub with a double-sided adhesive tape. To reduce sample charging, a thin layer of gold coating was applied on the spherical point of the Micrux® electrode, located in the middle of the chip using a sputter coating machine (Quorum, Q150R ES, UK). This step was not required in the case of unmodified gold-coated Si-chip specimen where no film was deposited (as received).

TEM and AFM were performed on the modified gold-coated Si-chips with polyaniline deposition to show the nanoparticles formation at the defects of the coating. For TEM and AFM, the chips were prepared by electrochemical deposition of poly benzene-1,3-diol films. The blocked chips were then exposed to 1.0 mmol dm^{-3} NaOH caustic solution for 240 minutes. The modified chips were then electrochemically coated with polyaniline to facilitate the observation of the nanoparticles on the surface. A small amount of the electrode material was carefully removed from the surface of the modified gold-coated Si-chips. The sample layer was dispersed in ethanol and deposited onto the TEM grid having carbon support film. The grid was dried before being mounted into the TEM. TEM (FEI Company, Morgagni 268, Czech Republic) was operated at 80 kV to record the images of the transferred film onto TEM grid. For AFM (Dimension Icon-Bruker) the untouched area of the modified film was scanned to obtain the topological images of the electrodes.

3. RESULTS

3.1. Electrochemical Properties

The CV for the polymerization of 0.2 mol dm^{-3} benzene-1,3-diol (0.2 mol dm^{-3} KCl) using Micrux® electrodes ($A = 0.008$ cm^2) is shown in Figure 1(a). All potentials related to the Micrux® electrodes were measured versus (Au). For clarity, the first two cycles plus the 20th are presented in the figure. A notable feature is that an oxidation peak is observed in the first cycle at 0.90 V with a value of 430 $\mu A/cm^2$ current density. This peak disappeared in the subsequent cycles, indicating that an irreversible oxidation reaction had occurred at the electrode's surface. Subsequently, this resulted in the electropolymerization of benzene-1,3-diol monomer and a passivating layer of poly benzene-1,3-diol could be deposited on the electrode's surface.

Figure 1(b) presented the CV scans of polyaniline deposition using 0.2 mol dm^{-3} aniline (0.2 mol dm^{-3} KCl) on the modified Micrux® electrodes after the exposure in caustic solution for 1.0 mol dm^{-3} NaOH for five minutes. An oxidation peak is observed in the first cycle at 0.70 V with a corresponding current density of 520 $\mu A/cm^2$. The electrochemistry of aniline and polyaniline is more complex than that of benzene-1,3-diol leading to more complicated CV. This electrochemistry has been extensively studied by other authors and is not the focus of this study.

The electrochemical behaviour of the bare Micrux® electrode in 20 mmol dm^{-3} $K_3Fe(CN)_6/K_4Fe(CN)_6$ couple versus (Au) is presented in Figure 2(a). Peaks of the oxidation (+72 mV) and reduction (−65 mV) are observed. Figure 2(b) presented the CVs of the blocked Micrux® electrode with polybenzene-1,3-diol and the modified Micrux® electrode upon exposure to 1.0 mol dm^{-3} NaOH caustic solution for 5 minutes. When the CVs of the blocked electrode with the same of the bare electrode are contrasted, the current peaks related to the bare electrodes

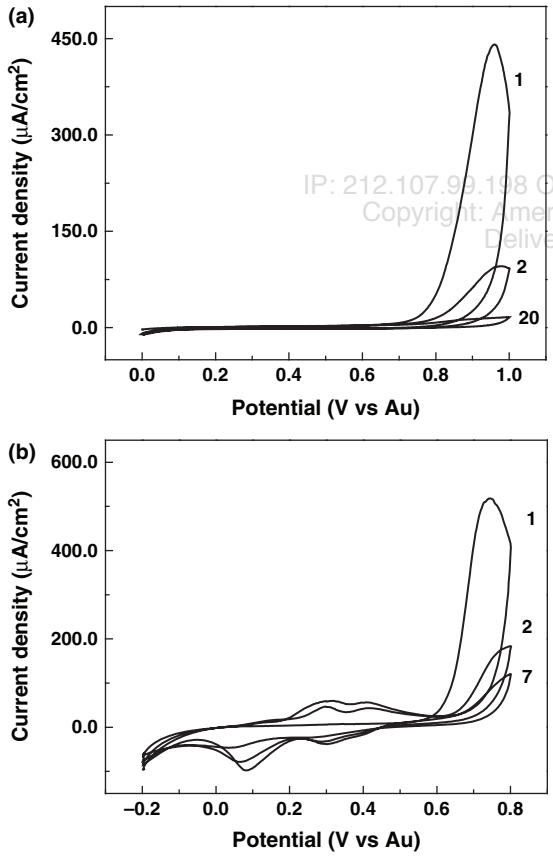

Fig. 1. Cyclic voltammograms recorded using Micrux® ED-SE1-Au electrode ($A = 0.008$ cm^2) of: (a) Electropolymerization of 0.2 mol dm^{-3} benzene-1,3-diol (0.2 mol dm^{-3} KCl) conducted at the bare electrode versus (Au), at 0.005 V s^{-1} (20 cycles), pH = 7.0, cycles of the first, second and 20th are shown in the figure, (b) polyaniline deposition using 0.2 mol dm^{-3} aniline (0.2 mol dm^{-3} KCl) at the modified Micrux® electrode versus (Au), upon exposure to 1.0 mol dm^{-3} NaOH caustic solution for 5 minutes, at 0.05 V s^{-1} (7 cycles), pH = 7.0, cycles of the first, second and 7th are shown in the figure.

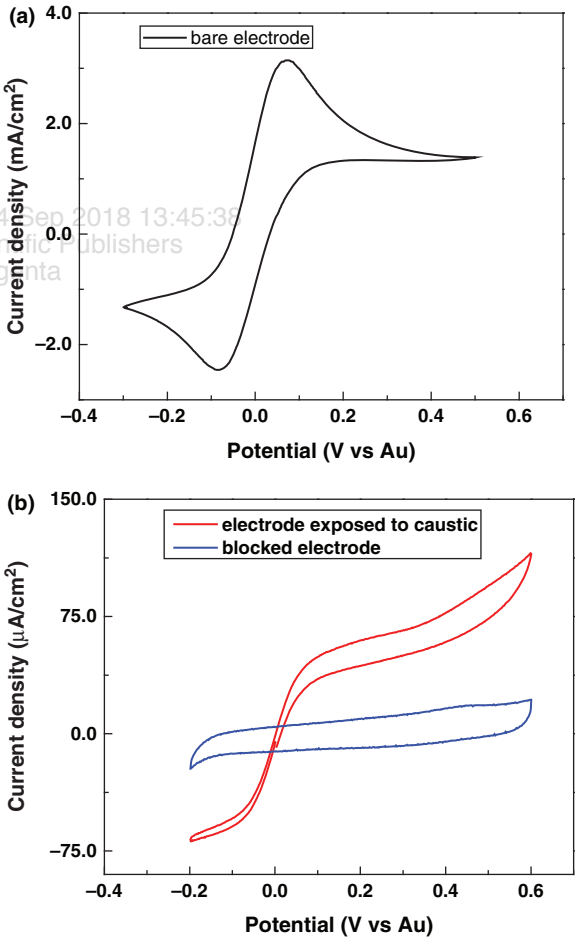

Fig. 2. Cyclic voltammograms of Micrux® ED-SE1-Au ($A = 0.008$ cm^2) recorded using 20 mmol dm^{-3} $K_3Fe(CN)_6/K_4Fe(CN)_6$ consisting of 0.1 mol dm^{-3} KCl versus (Au) at 20 mV s^{-1} (4 cycles) at: (a) Bare Micrux® electrode, (b) blocked Micrux® electrode with polybenzene-1,3-diol (in blue) and the modified Micrux® electrode (in red) upon exposure to 1.0 mol dm^{-3} NaOH caustic solution for 5 minutes.

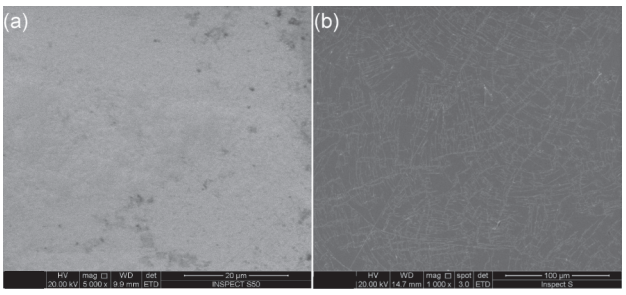

Fig. 3. SEM images of Micrux® ED-SE1-Au of: (a) Bare Micrux® electrode, (b) blocked Micrux® electrode upon the electropolymerization of 0.2 mol dm^{-3} benzene-1,3-diol (0.2 mol dm^{-3} KCl) using CV versus (Au) at 0.005 V s^{-1} (20 cycles), pH = 7.0.

diminished. However, the CV response of the modified Micrux® electrode upon caustic exposure was what would be expected for a microelectrode array, i.e., the response was sigmoidal.

SEM images of bare gold Micrux® electrode and blocked Micrux® electrode with poly benzene-1,3-diol were presented in Figures 3(a) and (b), respectively. The bare gold surfaces are largely featureless. This is, as one would expect, the gold electrode is formed by a sputtering process. However, poly 1,3-dydroxybenzene surface showed faint scratches, which appear similar to the tree-like structure. The poly benzene-1,3-diol films are very thin and thus conformal to the gold surface.

Figure 4 presents the CV scans recorded for the electropolymerization of 0.2 mol dm^{-3} benzene-1,3-diol (0.2 mol dm^{-3} KCl) using gold-coated Si-chips ($A = 1.0$ cm^2). CV cycles of the 1st, 2nd, and 20th were shown in the figure. In the first CV cycle, one oxidation peak is observed at 0.70 V recorded versus (Ag/AgCl, 3.0 mol dm^{-3} KCl). During successive cycles, the currents

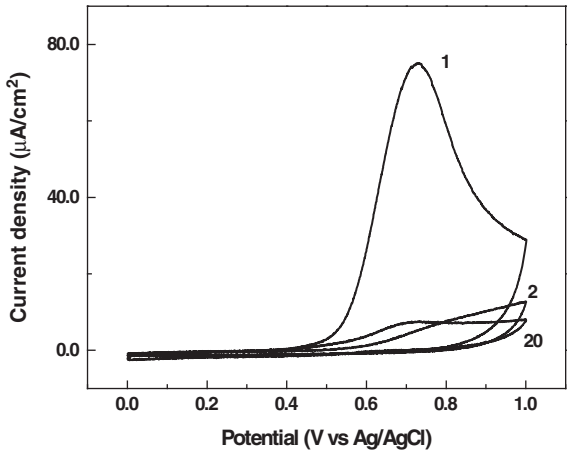

Fig. 4. Cyclic voltammograms recorded using gold-coated Si-chip ($A = 1.0$ cm^2) performed by electropolymerization of 0.2 mol dm^{-3} benzene-1,3-diol (0.2 mol dm^{-3} KCl) conducted on the bare electrode versus (Ag/AgCl, 3.0 mol dm^{-3} KCl) at 0.005 V s^{-1} (20 cycles), pH = 7.0. The first, second and 20th cycles are presented in the figure.

of the anodic peak decreased by approximately two-fold of potential density. It was presented that the electrochemical polymerization of benzene-1,3-diol first proceeds by the oxidation of the molecule, removing an electron, forming a radical cation.[38] The commonly accepted mechanism for polymerization then requires two radicals to couple together to form a dimer. This dimer can then further react and trimers, oligomers, polymer etc. are further formed in this manner. The current generated by this process cannot be ascribed to the first oxidation process and is a complex sum of all electrochemical oxidation processes involving monomer, dimer, trimer etc. The films formed by the oxidation of benzene-1,3-diol are self-limiting in thickness and the subsequent output potential difference does not show large currents due to the blocked nature of the interface.

The coherence of the polymer film is probed by CV using 20 mmol dm^{-3} $K_3Fe(CN)_6/K_4Fe(CN)_6$ couple.

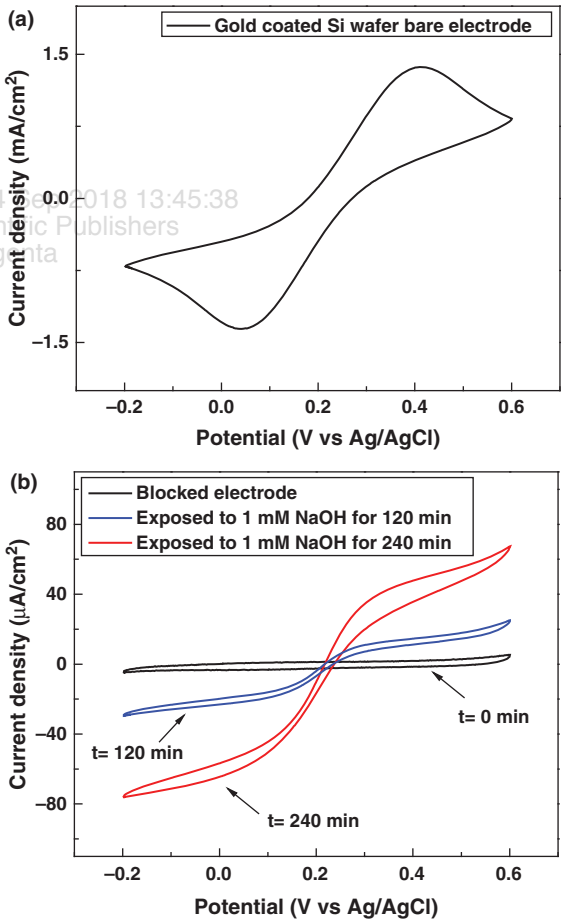

Fig. 5. Cyclic voltammograms of gold-coated Si-chips ($A = 1.0$ cm^2) recorded using 20 mmol dm^{-3} $K_3Fe(CN)_6/K_4Fe(CN)_6$ consisting of 0.1 mol dm^{-3} KCl versus (Ag/AgCl, 3.0 mol dm^{-3} KCl) at 20 mV s^{-1} (4 cycles): (a) gold-coated Si-chip bare electrode, (b) blocked electrode with polybenzene-1,3-diol (in black), the modified electrode upon exposure to 1.0 mmol dm^{-3} NaOH caustic solutions for 120 minutes (in blue) and 240 minutes (in red).

In Figure 5(a), the couple's response to large gold-coated Si-chips ($A = 1.0$ cm^2) is revealed. In the potential window scanned, the response, which was generated in Figure 5(a), is the standard response expected at such electrodes. Whereas, the response of the blocked electrode with poly benzene-1,3-diol is shown in Figure 5(b). No faradaic response is seen, showing that the interface is completely blocked and that the polymer is electrically insulating.

Two blocked electrodes with poly benzene-1,3-diol films were separately treated in 1.0 mmol dm^{-3} sodium hydroxide for 120 minutes for the first blocked electrode and 240 minutes for the second blocked electrode. Both electrodes were then rinsed in deionized water to quench the reaction of caustic with the polymer film. The electrochemical response of the two modified electrodes in 20 mmol dm^{-3} $K_3Fe(CN)_6/K_4Fe(CN)_6$ couple were presented in Figure 5(b). It is clear that the interface between the solution and gold is no longer blocked and that a faradaic response is obtained. The conclusion is that the caustic has removed a portion of the polymer film allowing the faradaic current to flow.

After caustic exposure, the modified gold-coated Si-chips were further fabricated by polymerization of aniline into the pores of the electrode as shown in Figure 6. The purpose behind using the polyaniline in this work was to facilitate the observation of the pores on electrode surfaces by filling them with polyaniline. It was confirmed by performing SEM analysis on the modified electrodes after they exposure to caustic solutions. It was not possible to observe the pores without polyaniline deposition.

Figure 6(a) presents the polymerization of aniline on the bare gold surface. The notable feature in the CVs is the absence of an oxidation peak at +0.49 V versus (Ag/AgCl, 3.0 mol dm^{-3} KCl). However, in Figure 6(b), an oxidation peak was noted at +0.49 V with a current density value of 110 μA/cm^2. The same story was observed in Figure 6(c), a notable oxidation peak was determined at +0.49 V with a current density value of 660 μA/cm^2. Therefore, the oxidation peak was observed on the blocked chips before and after treating in caustic solution, e.g., 240 minutes. This was absent from the CVs of the bare chips. It seems that polyaniline deposition interacted differently to the bare/blocked/modified surfaces. As a general trend, when portions of the poly benzene-1,3-diol have been removed from the electrode surfaces, an increase in

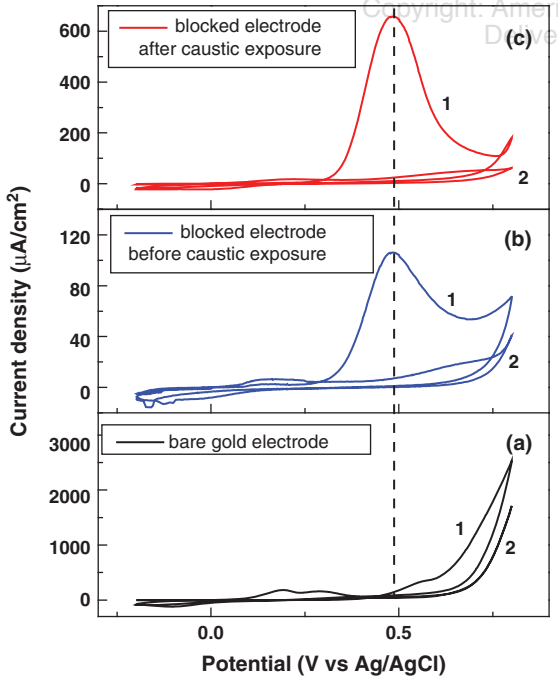

Fig. 6. Cyclic voltammograms of polyaniline deposition using 0.2 mol dm^{-3} aniline (0.2 mol dm^{-3} KCl) versus (Ag/AgCl, 3.0 mol dm^{-3} KCl), at 0.05 V s^{-1} (7 cycles) performed on gold-coated Si-chips ($A = 1.0$ cm^2) at: (a) Bare gold electrode, (b) blocked electrode with poly benzene-1,3-diol before being exposed to caustic solution, and (c) modified electrode after being exposed to caustic solution of 1.0 mmol dm^{-3} NaOH for 240 minutes. The first and second cycles are shown in the figure.

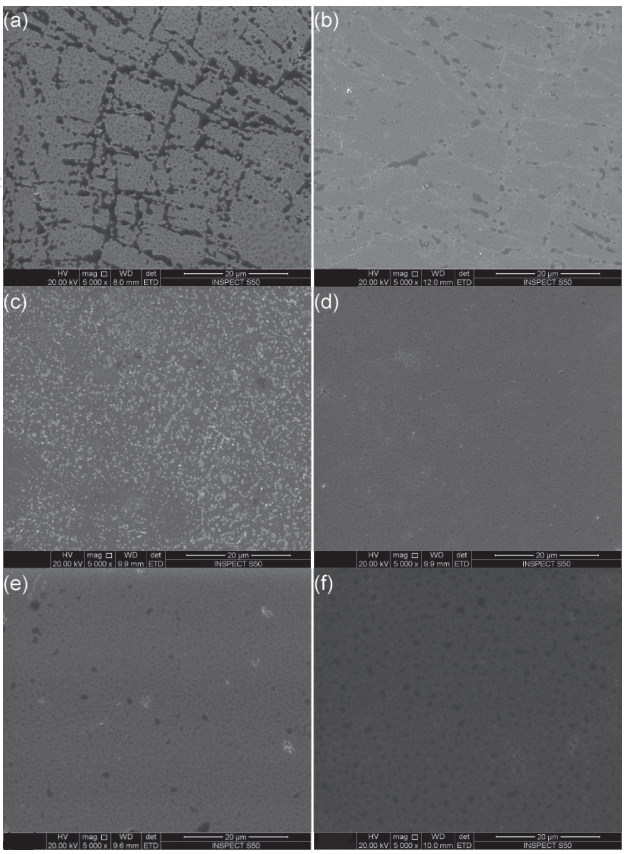

Fig. 7. SEM micrographs of the modified gold-coated Si-chips. Prior to SEM, all electrodes were blocked with poly benzene-1,3-diol using CV and then treated in 1.0 mmol dm^{-3} NaOH caustic solution for: (a) 30 minutes, (b) 60 minutes, (c) 120 minutes, (d) 240 minutes, (e) 300 minutes, and (f) 4320 minutes. Polyaniline was then deposited on the modified electrodes after exposure periods to caustic solutions. SEM analysis was recorded after polyaniline deposition. The scale bars correspond to 20 μm at a magnification of 5 kX.

the current density of the oxidation peak in polyaniline CV is noticed. Furthermore, polyaniline films are classified as conducting polymers and the films are not inherently self-limiting in thickness. This fact is exploited to form protrusions above the poly benzene-1,3-diol so that imaging of the electrode is possible.

3.2. Structural Properties

Figures 7(a)–(f) presents a selection of SEM micrographs of pore development in the modified gold-coated Si-chips that were captured after exposure to caustic solutions followed by polyaniline deposition. All images were captured at same magnification, i.e., 5 kx magnifications to facilitate the comparison among the different samples. Figure 7(a) presents the surface morphology of the modified Si-chips after being exposed to caustic for 30 minutes. Morphological features of the surface revealed that large melted disordered patterns with distinguished faint and dark irregular regions are observed. The observed features were reduced dramatically after 60 minutes of exposure to caustic, becoming less obvious (Fig. 7(b)). We believe that these changes are caused by exposure to caustic solutions that caused some parts of the coated polymer to be removed. The first change observed at 120 minutes is the irregular formation of condensed white particles, which covered and spread out on the entire surface of the modified chip (Fig. 7(c)).

In Figure 7(d), several dots covering the entire surface of the sample were observed after 240 minutes of exposure to caustic. Additionally, the regular well-defined features of the observed dark dots could be characterized as ordered mushroom-like structures. "Mushroom" type structures (where the polyaniline fills the pores and spreads over the surface of the insulating polymer) are formed on the electrode surface. These structures can be imaged more easily than the pores in a poly benzene-1,3-diol film, owing to the nanometre thickness of such films.[31]

The situation is somewhat different for samples in Figures 7(e) and (f). A few dark hole-like structures begin appearing on the surfaces at 300 minutes exposure to caustic. When the exposure to caustic extended up to

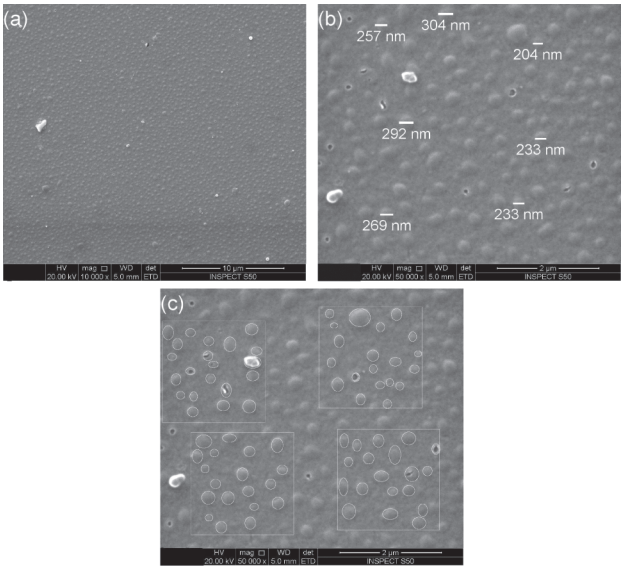

Fig. 8. SEM micrographs of polyaniline bumps on the modified electrodes of Micrux® ED-SE1-Au (a–c). Micrux® modified electrode was exposed to 1.0 mol dm^{-3} NaOH caustic solution for 5 minutes of: (a) Unmarked image at a magnification of 10 kX, (b) same sample with dimensions of bumps marked in at 50 kX, and (c) same sample with four counting squares marked on image 2.0 μm × 2.0 μm per one square at 50 kX.

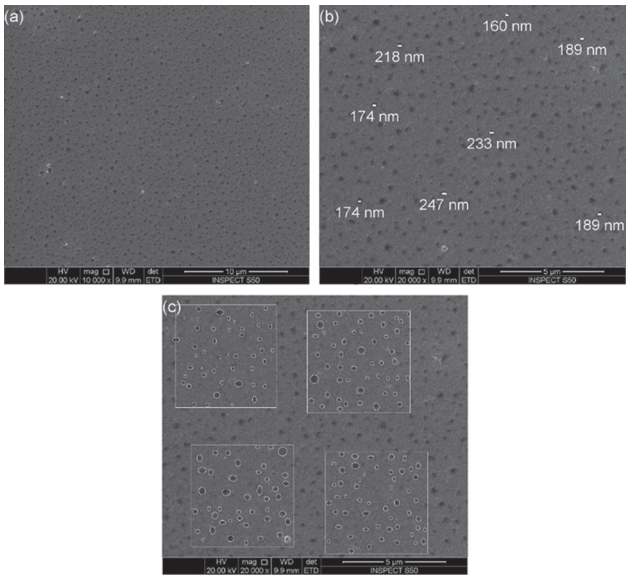

Fig. 9. Comparative SEM micrographs of polyaniline bumps on the modified electrodes of gold-coated Si-chips (a–c). The modified gold-coated Si-chips exposed to 1.0 mmol dm^{-3} NaOH caustic solution for 240 minutes of: (a) unmarked image at a magnification of 10 kX, (b) same sample with dimensions of bumps marked in at 20 kX and (c) same sample with four counting squares marked on image 5.0 μm × 5.0 μm per one square at 20 kX.

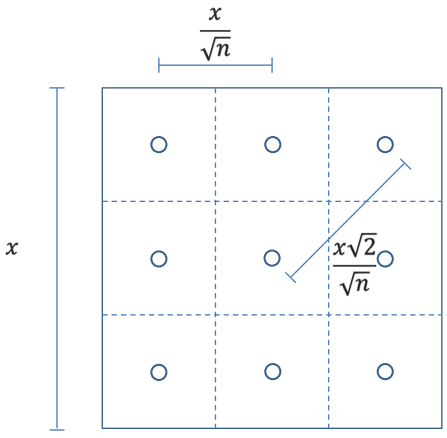

Fig. 10. An image showing the basis for estimating the average distance between the pores.

Table I. Average inter-pore distance expressed in nm calculated from Eq. (1) for the modified Micrux® electrode and gold coated Si-chips.

	Average distance between pores (nm)	
Sample	Modified micrux® electrode	Modified gold coated Si-chips
1	540	890
2	540	840
3	540	860
4	554	850
Average	543	860

4320 minutes, the dark circle features continue developing with an obvious increase in their quantity on the surface as clearly seen in Figure 7(f).

Figures 8(a)–(c) presents SEM micrographs of polyaniline bumps formed on the Micrux® modified electrodes that were exposed to 1.0 mol dm^{-3} NaOH caustic solution up to 5 minutes. Figure 8(a) presents a low magnification image of the irregular bumps on electrode's surface. These bumps are the "mushroom" structures described in previous paragraphs. Each "mushroom" corresponds to a defect in the poly benzene-1,3-diol film, where polymerization of polyaniline was enabled due to the exposure of the underlying gold electrode. Figure 8(b) presents the diameter of the bumps in the order of <400 nm with an average value of approximately 200 nm. Figure 8(c) presents the four squares marked on the image with a 2.0 μm × 2.0 μm per one square at 50 kX of the modified Micrux® electrode surface. Figure 8(c) was also used in the calculations of the average inter-pore distance of the modified electrodes.

A comparative SEM micrograph evaluation of polyaniline features formed on the modified gold-coated Si-chips is presented in Figures 9(a)–(c). Figure 9(a) shows irregular bumps on the surface of the polyaniline modified electrodes of gold-coated Si-chips that were exposed to 1.0 mmol dm^{-3} NaOH caustic solution for 240 minutes. These features are the "mushroom" structures described in previous paragraphs. The diameter of the bumps is shown in Figure 9(b). Figure 9(c) presents the four squares marked on the image with dimensions of 5.0 μm × 5.0 μm per square at 20 kX for the modified gold-coated Si-chips. It was found that the diameter of these bumps was in the order of <300 nm with an average value of approximately 200 nm. Figure 9(c) was also used in the calculations of the average inter-pore distance of the modified electrodes.

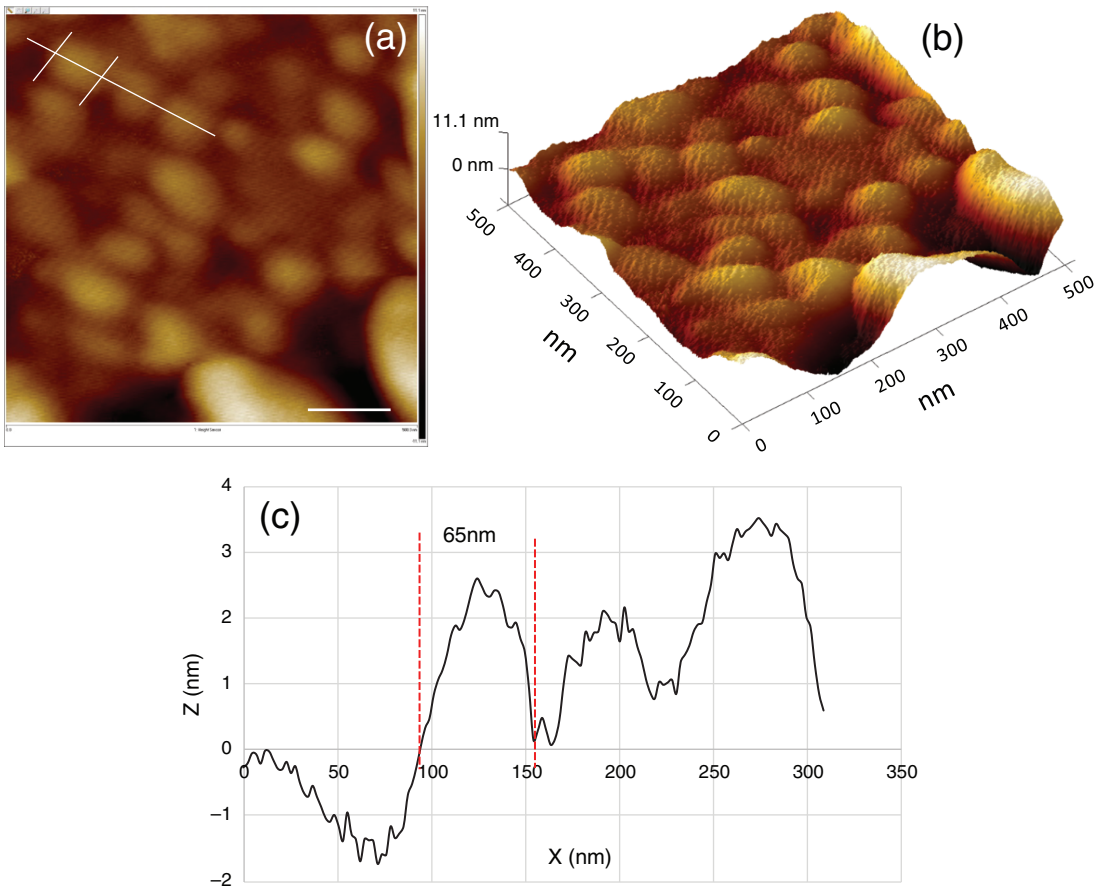

Fig. 11. AFM micrographs of the modified gold-coated Si-chips with polyaniline deposition. AFM was performed on the sample to show the nanoparticles formed at the defects of the coating. (a) 2D image of the surface showing particles of different sizes, (b) 3D image of the same 2D image and (c) line profile taken from the area (white line) shown in the panel (a). The size of the highlighted particles was measured ~65 nm.

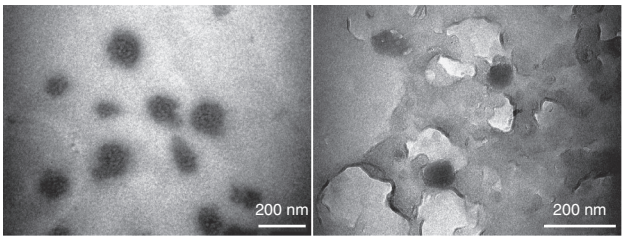

Fig. 12. TEM images of the modified gold-coated Si-chips with polyaniline deposition. TEM was performed on the sample to show the nanoparticles formed at the defects of the coating. Scale bars correspond to 200 nm.

In Figures 8(c) and 9(c), the images have been analyzed to estimate the density of pores in the poly benzene-1,3-diol film. The method used was to count the number of bumps in four 4×10^{-8} cm^2 sections of the Micrux® modified electrode surface (Fig. 8(c)) and in four 25×10^{-8} cm^2 sections of the gold-coated Si-chips surface (Fig. 9(c)). The number density of the bumps was then expressed on per cm^2 basis and found equal to 4.9×10^8 electrodes/cm^2 for Micrux® modified electrode. For gold-coated Si-chips, the number density of the features was equal to 2.0×10^8 electrodes/cm^2. The data was further analyzed to estimate the average distance between adjacent pores. The model used is that of a regularly spaced distribution of pores, as per Figure 10. It can be shown that the average distance (d_{av}) between the pores is given by Eq. (1).

$$d_{av} = (1+\sqrt{2})\frac{x}{2\sqrt{n}} \quad (1)$$

Here, x is the length of the side of the square area containing the pores and n is the number of pores in that area. It is clear that the actual distribution of pores on the electrode surface will be random, but this model provides a useful estimate for the average inter pore distance. The calculated separation is presented in Table I.

AFM micrographs along with line profile of the modified gold-coated Si-chips exposed to 1.0 mmol dm^{-3} NaOH caustic solution for 240 minutes are presented in Figure 11 (the detail of the analyzed sample is given in the Section 2.3). Particles of varied sizes were shown in Figure 11(a). In Figure 11(b), the 3D image shows the topological features of the film with maximum thickness of the polymeric film being about 11.1 nm. The size of the highlighted particles was measured to be approximately 65 nm (Fig. 11(c)). The nano features of the particles were confirmed when the same sample was characterized using TEM (Fig. 12).

4. DISCUSSION

In this work, two types of electrodes were used the Micrux® electrodes and the gold-coated Si chips. Micrux® electrodes are based on a three-electrode system that were fabricated commercially as a thin-film on a glass substrate by means of sputtering. A protective layer of SU-8 resin was placed on the electrodes by the manufacturer enabling the use of a very small sample volume (1–5 μl). The Micrux® electrodes require a surface pre-cleaning before conducting the experiments. The area of the working electrode in Micrux® electrodes is 0.008 cm^2. We examined such commercial electrodes to find out the applicability of producing microelectrode ensembles in an area as small as 0.008 cm^2. It can be clearly seen that microelectrodes ensembles were produced successfully by using Micrux® electrodes from the methods presented in this paper. The concentration of caustic solution and the exposure times have been optimized. This opens the possibility for using such commercial electrodes for sensors in the future.

The second type of electrodes used in this work is the gold-coated Si chips. These are 1.0 cm^2 square chips. These chips were used mainly in SEM tracking of the pores development study upon exposure to caustic solutions. Once again, the concentration of caustic solution and the exposure times have been optimized for these chips.

Kennedy and Cunnane stated that poly 1,3-dihydroxybenzene films deposited on gold electrodes (A = 0.07 cm^2) can be degraded by exposure to 10.0 mmol dm^{-3} caustic solutions and a microelectrode array/ensemble will be formed in eight minutes.[36] In this laboratory, we have examined the same procedure of Kennedy and Cunnane by exposing the blocked gold-coated Si-chips (A = 1.0 cm^2) with poly benzene-1,3-diol in 10.0 mmol dm^{-3} NaOH (data not shown).[36] The sigmoidal voltammogram shape was formed extremely fast and within <20 seconds compared to 8 minutes in their paper. In order to facilitate SEM capturing in the case of the blocked gold-coated Si-chips (A = 1.0 cm^2), caustic concentration was decreased by ten-fold when compared to Kennedy and Cunnane.[36] This was meant to stretch the full process to facilitate SEM capturing at different time intervals.

In the case of blocked Micrux® electrode (A = 0.008 cm^2), weak caustic solutions were not being able to produce the sigmoidal voltammogram shaped even after hours of exposure. Thus, we have tried several caustic concentrations from 0.001 to 0.01 and 1.0 mol dm^{-3} NaOH. The sigmoidal voltammogram shaped has been successfully formed by using 1.0 mol dm^{-3} NaOH after five minutes of exposure to caustic. A point of interest in Micrux® electrode (A = 0.008 cm^2) is that the optimized caustic concentration used to develop the microelectrode ensemble here is 100-fold greater than that used by Kennedy and Cunnane.[36] We believe that the polymer surface area has a significant effect on the degradation of poly benzene-1,3-diol in caustic solutions. When the area is increased for example up to 1.0 cm^2, polymer degradation process was increased significantly. A few seconds was required to remove the polymer from the surface upon using a concentration of caustic solution between 0.01 and 1.0 mol dm^{-3}. Consequently, This work extends the work of Kennedy and

Cunnane.[36] and is the first direct experimental evidence as to the nature of the films deposited on the electrodes. The studies of Kennedy and Cunnane inferred the nature of the films from electrochemical measurements but offered no direct evidence on the nature of the porous films. As such this work is novel and an important investigation in its' own right.

5. CONCLUSION

This paper is focused on the fabrication of microelectrode ensembles on thin-film single electrodes by means of wet chemical etching. The electropolymerized electrodes were treated in caustic solutions for definite time. This was carried out using Micrux® electrodes ($A = 0.008$ cm^2) and gold-coated Si-chips ($A = 1.0$ cm^2). Fabrication of microelectrode ensembles have been successfully achieved and the process parameters were optimized in Micrux® electrodes and gold-coated Si-chips. Microelectrode ensembles would be formed if the caustic concentration and exposure time were properly controlled. SEM analysis revealed the successful formation of regular bumps on the surface of the modified electrodes upon caustic exposure. Moreover, it was found that the area of the electrodes has considerable influence on the entire process of microelectrode ensembles fabrication. As the polymer surface area was decreased up to $A = 0.008$ cm^2, stronger caustic concentration (1.0 mol dm^{-3}) was required to develop the microelectrode ensembles in five minutes. Moreover, the number density of the pores was equal to 4.9×10^8 electrodes/cm^2 for Micrux® modified electrode. For gold-coated Si-chips, the number density of the pores was equal to 2.0×10^8 electrodes/cm^2. This study provides useful information for researchers to fabricate such microelectrode ensembles in direct, accurate and cost-efficient technique. However, exploration of the applications of the current fabricated microelectrode ensembles in analyzing and quantifying chemical or biological species requires further studies.

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ORIGINAL ARTICLE

Identify and prioritize the major influencing causes of automated concrete mixing system for mega construction projects using analytic hierarchy process

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Concrete batch plants;
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Abstract It is clear that most of mega and medium sized projects in Egypt are using ready-mix concrete in their construction work. It is important to improve the actual production rates of batch plant to optimize the usage of their outputs; the use of concrete batch plants by concrete mixers is rapidly increasing in the construction industry. This is an important step in securing high productivity in the industry. Concrete batch plant specialists are well aware of the importance of productivity, and hence, there is a great potential for productivity improvement in batch plant concrete industry, Batch plant of concrete is very essential part in construction process, which is defined as central plant on project site and is transported by transit mixers to projects, this paper attempts to classify, investigate, and sort causes that affect batch plant productivity. To perform that goal, researchers invited experts on this field by answering detailed a questionnaire survey. It was taken brain storming into consideration, through more effective causes was identified in batch plant. Totally, forty five (45) related causes are classified into five (5) major groups. This survey was done with representatives and experts from public and private automated batch plants. All data was analyzed by Analytic Hierarchy Process (AHP), ranking and simple percentages. All ranked causes were demonstrated and mentioned against their most effective causes to the batch plant productivity.

1. Introduction

Construction Projects started to tackle the problem of productivity measurement and improvement it, the batch plants in

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Egypt are facing many problems which affect ready mix concrete quality and productivity. Industry plants number is continuous increasing but industry firms' number had fixed, Lu and Lam [10]. Many construction managers automatically think only of labor when the term "productivity" is mentioned. Others associate capital expenditures is only partly correct. When an individual thinks of the term "productivity", it was usually imagined a worker either working hard or perhaps not working to his capacity. This perception resulted from a widely accepted definition of productivity as the amount of work performed per person hour of work effort. In reality, productivity is a much larger subject than labor effort and it can be improved through various methods that accommodate high labor productivity as well as decisive project designers, and owners, and well-managed contractors that are attentive to planning, scheduling, people management, and job control. Productivity is described as relationship between output and inputs which is provided to get those outputs Lu et al. [11]. Projects that related to construction divisions is most one in the world and very challenging industries due to involved conflicting parties, its unique nature and high risk, Sumanth [19] and Al-Araidah [3].

2. Literature review

The causes that influence construction equipment productivity had studied more researchers. To improve productivity must do focused study on influencing causes that positively or negatively effect, and on other hand if all causes are determined, then easy to forecast equipment productivity Zayed et al. [28]. Zayed and Minkarah [26] classified construction productivity causes affecting into: (1) Administrative causes are related to the construction project management and (2) Technological causes are related to project design. Lu et al. [12] explained distinction between those two groups from a different perspective. Productivity can be measured by change different rates and level Maghrebi et al. [13]. Hence using productivity measures as performance indicator is more accurate than others Zayed and Halpin [25]. Productivity cycles involve four stages: (1) measurement, (2) evaluation, (3) planning, and (4) improvement. Thomas et al. [20] studied masonry productivity similarities in seven countries. Abdel-Razek [2] applied the time study measurement technique for the first time in Egypt to measure the productivity of reinforcement concrete operation on a large construction project. It was reported an improvement of 35% on the formwork output and 11.30% on the reinforced concrete operation. Srichandum and Rujirayanyong [18] conducted a survey with experts in Singapore field to recognize all problems that may affect construction productivity. Diab et al. [7] reported that the common reasons for low productivity in construction sites. Thomas et al. [20] reported that the contract conditions such as project schedule, delay penalty, and payment scheme have a great influence on productivity. Zayed and Halpin [25] predicted production of concrete batch plant by using simulation technique assist related field decision makers. Tian et al. [21] mentioned that possible causes of declining of productivity in US construction sector from 1970 to 2009. Abdel-Monem [1] provided a mathematical model to evaluate construction equipment productivity under certain operating conditions. To achieve this goal, the relation between quantities processed by equipment in cyclic times (dependent variable) and the corresponding affecting independent causes were studied and analyzed. The causes to be recorded against productivity were determined. Fifteen independent causes have been taken into consideration. Six of them are classified as descriptive causes; they are: type of soil, topography, job difficulty, equipment operating system, labor operating system, and project specifications. Nine of them are classified as quantitative causes; they are: grade, temperature, relative humidity, rate of rain, equipment efficiency, equipment age, equipment maximum capacity, labor efficiency, and management efficiency, Videla and Imbarack [22]. Dietz et al. [8] grouped the causes affecting construction productivity in: (1) Internal causes included technology, management and labor. (2) External causes included industry nature, construction client knowledge, weather, and economic level which they are representing firm's management control. Zayed and Nosair [27] proposed batch plant production optimization model for maximizing net profit using a linear programming technique. A transmixer are most important effective production tools for ready mixed concrete plant and its capacities are 4, 6, 8 and 12 m^3. Technology use is most important role for quality of ready mixed concrete production Vikan [23]. Zayed and Nosair [27] focused on measuring concrete batch plant cost and productivity using Artificial Neural Network (ANN) technique. Zayed and Nosair [27] developed some models to get delays effect on unit cost in batch plant by applying stochastic mathematical technique. Yan and Lai [24] evaluate and improving production process in a concrete batching plant using management tools. The tools, which include the five-minute rating, the crew balance charts, the method productivity delay model, and the simulation modeling, have been applied in a case study; the improvement to the process involves several steps: data collection, work analysis, and design improvement. Diab et al. [7] classified causes influencing construction equipment productivity in three groups: (1) Job conditions causes, (2) management efficiency causes, and (3) equipment causes. Sajadieh et al. [17] stated that construction sector productivity had negative development compared with others. Level of innovation within industry is considered by many to be too low. Elazouni and Basha [9] measured at same time operation safety, risk and productivity by using new methodology. Marzouk and Younes [15] applied a modeling simulation technique for concrete batch plants. This model assisted quantify production rate configurations for the study plant. Oglesby et al. [16] illustrated construction industry productivity improvement, to give minimum production cost using four basic steps: (1) concrete transporting; (2) concrete placing; (3) concrete compaction and (4) concrete surface finishing. Al-kass et al. [4] developed mathematical model by two mechanisms: (1) Integer programming and (2) Mixed integer programming. Cheng and Tran [6] developed an optimization framework that integrates multi objective differential evolution with discrete event simulation for determining solutions for batch plant trucks scheduling.

3. Paper objective

This research aimed to: (1) Gathering and identify most effective causes that influencing batch plant productivity; (2) Cate-

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gorize causes in batch plants into five (5) major groups; (3) Quantify the ranking of causes according to most effective causes using Analytic Hierarchy Process (AHP).

4. Research methodology

(1) The research methodology can be summarized in: forty five (45) different causes were identified, categorized into five (5). The collected data was analyzed through Analytic Hierarchy Process (AHP) method.
(2) Questionnaires were developed into five (5) major parts (A, B, C, D and E). Part (A): batch plant Causes, Part (B): Road and Equipment Causes, Part (C): Sites Causes, Part (D): Management Causes and Part (E): Labor Causes.
(3) A survey was conducted through personal interviews in which experts were asked for scoring and ranking these causes against their experience. They were classified into three groups, the first Group batch plant manager, Second Group quality control engineer, Third Group sales engineer and maintenance engineer.

5. Causes affecting batch plant productivity

There are forty five (45) causes and are categorized into five (5) major groups as shown in Table 1, which are used in this paper, as follows: (1) The batch plant arrangement (General location) and easily maneuverable vehicles; (2) The number of truck mixers in the plant; (3) Periodical calibration of scales; (4) Raw materials storage location; (5) The existence of automatic control mixing; (6) Availability of drainage system; (7) Availability of undesired concrete disposal system; (8) Regular maintenance for plant equipment; (9) Plant safety plan efficiency; (10) The plant urban location; (11) The age of Batch Plant; (12) Idle batch plant; (13) The traffic situation on the road to the casting site; (14) The quality of the road to the casting site; (15) Weight average distance between batch & projects; (16) Efficiency of truck mixers; (17) Concrete pump efficiency; (18) Availability ready mix concrete according to project requirements and Easy to transfer; (19) The age of truck mixers; (20) The age of pump; (21) Unexpected work suspension due to idle equipment; (22) The number of sites zone which needs RMC; (23) The types of items that will be cast (raft – col. – slabs – etc.); (24) Existence of the site lighting at night; (25) Weather conditions; (26) Ease of entry and exit from the casting site; (27) The project urbanity; (28) Concrete workability; (29) Concrete transference/pouring method; (30) The relative pouring height; (31) Marketing Plan efficiency; (32) Planning and organization(procurement plan cement, sand, etc.); (33) The Ease and clear for exchange of information and instructions; (34) The effectiveness of site supervision and labor guidance; (35) Efficiency of the batch manager &his ability to distribute tasks (36) The major forces (Manage crises); (37) Efficiency of the batch plant operator; (38) Effect of Education and Culture of labors; (39) The effect of breaks and snacks; (40) The effect of the worker's wages; (41) Drivers' efficiency; (42) Motivation system for plant labors; (43) Concrete pump operator efficiency; (44) Efficiency of Casting Crew in site; (45) Site/plant communication flow.

Table 1 Categorized causes.

Group item	Related factor ID	Total number of group causes
Batch plant related causes group	01:12	12
Roads and transportation related causes group	13:21	09
Sites related causes group	22:30	09
Management related causes group	31:36	06
Labor related causes group	37:45	09
Total	01:45	**45**

6. Questionnaire survey

6.1. Designing questionnaire

Designing questionnaire is main objective for this study with aim to reply all questionnaire questions. Brainstorming was done for performing questionnaire outlines. Experts meetings were done to determine suitable questions that required for presenting clear understanding with special care that was done for answering all questions.

6.2. Questionnaire contents

Questionnaire was classified into five major groups; first section contains general information as: (1) The batch plant arrangement (General location) and easily maneuverable vehicles; (2) The number of truck mixers in the plant; (3) Periodical calibration of scales; (4) Raw materials storage location; (5) The existence of automatic control mixing; (6) Availability of drainage system; (7) Availability of undesired concrete disposal system; (8) Regular maintenance for plant equipment; (9) Plant safety plan efficiency; (10) The plant urban location; (11) The age of Batch Plant; (12) Idle batch plant. Second section contains information for transportation and road; (13) The traffic situation on the road to the casting site; (14) The quality of the road to the casting site; (15) Weight average distance between batch & projects; (16) Efficiency of truck mixers; (17) Concrete pump efficiency; (18) Availability ready mix concrete according to project requirements and Easy to transfer; (19) The age of truck mixers; (20) The age of pump; (21) Unexpected work suspension due to idle equipment. The third section contains information about the Sites such as: (22) The number of sites zone which needs RMC; (23) The types of items that will be cast (raft – col. – slabs – etc.); (24) Existence of the site lighting at night; (25) Weather conditions; (26) Ease of entry and exit from the casting site; (27) The project urbanity; (28) Concrete workability; (29) Concrete transference/pouring method; (30) The relative pouring height. The forth section contains information about the Management such as: (31) Marketing Plan efficiency; (32) Planning and organization (procurement plan cement, sand, etc.); (33) The Ease and clear for exchange of information and instructions; (34) the effectiveness of site supervision and labor guidance; (35) Efficiency of the batch manager &his ability to distribute tasks (36) the major forces (Manage crises). The fifth section

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Table 2 Profession of respondent.

S/N	Professional cadre of Respondents	No of Respondents	Percentage %
1	Batch Plant managers	12	23.08
2	Quality control engineers	24	46.15
3	Sales engineers and maintenance engineers	16	30.77
	Total	52	100%

Table 3 Respondents Years of Experience.

Years of experience	No of respondents	percentage %
1:10 Years	14	28.00
10:20 Years	29	55.00
Above 20 Years	9	17.00
Total	52	100%

contains information about the Labor such as: (37) Efficiency of the batch plant operator; (38) Effect of Education and Culture of labors; (39) The effect of breaks and snacks; (40) The effect of the worker's wages; (41) Drivers' efficiency; (42) Motivation system for plant labors; (43) Concrete pump operator efficiency; (44) Efficiency of Casting Crew in site; (45) Site/-plant communication flow. The questionnaire required from experts to select one scale as "one" is representing Very Strong effect; "two" Strong effect; "three" medium effect; "four" Poor effect and "five" very Poor effect against influence of effective factor in the batch plant productivity.

7. Data gathering

Questionnaires were visit to batch plant and work sites (Batch Plant managers, Quality control engineers, sales engineers and maintenance engineers) data were collected. Standard forms were given to respondents to complete them. These forms gave researcher for exploring most effective causes of batch plant productivity. Over a period of ten (6) months later, the researcher collected Fifty two (52) responses from Sixty three (63) total forms; this means the rate of response was 82.54%. The details of various professional cadres of respondents with their classifications were mentioned in Table 2 for clarifications. The survey presents forty five (45) causes generated from most effective batch plant productivity causes. These causes were classified into five (5) major groups based on previous section by researcher: (1) Batch plant Group; (2) Road and Transportation Group; (3) Sites Group; (4) Management Group; (5) Labor Group (see Table 1). To can measure influence of different participants with different experiences, results were classified using four (4) groups as follow: "group one" for experience of respondents till 10 years; "group two" for respondents' experience above 10 till 20 years and "group three" for respondents' experience above 20, Table 3 depicts these groups. Tables 2 and 3 give more information with classifications of questionnaire's respondents that made the detailed results with full analysis (see Fig. 1).

8. Analytical hierarchy process

After determine problem goal. The first step in Analytical Hierarchy Procedure is to structure hierarchy from up (objectives) through middle levels (criteria) to down level which they conclude alternatives list, the goal in this case was to determine rank of effective causes affecting batch plant productivity Maghrebi et al. [14] (see Table 4).

Where, A are equal to Batch plant manager & Experience > 15 years, B Batch plant manager & Experience ≤ 15 years, C are equal to Quality control engineer & Experience > 10 years, D are equal to Quality control engineer & Experience ≤ 10 years, E are equal to Sales or maintenance engineer & Experience > 10 years, F are equal to Sales or maintenance engineer & Experience ≤ 10 years, weights of each criteria as Cited in Al-Harbi [5].

9. Calculating criteria weight and consistency checking

As Cited in Al-Harbi [5] and determined by using Expert Choice professional soft-ware the weight of each criterion

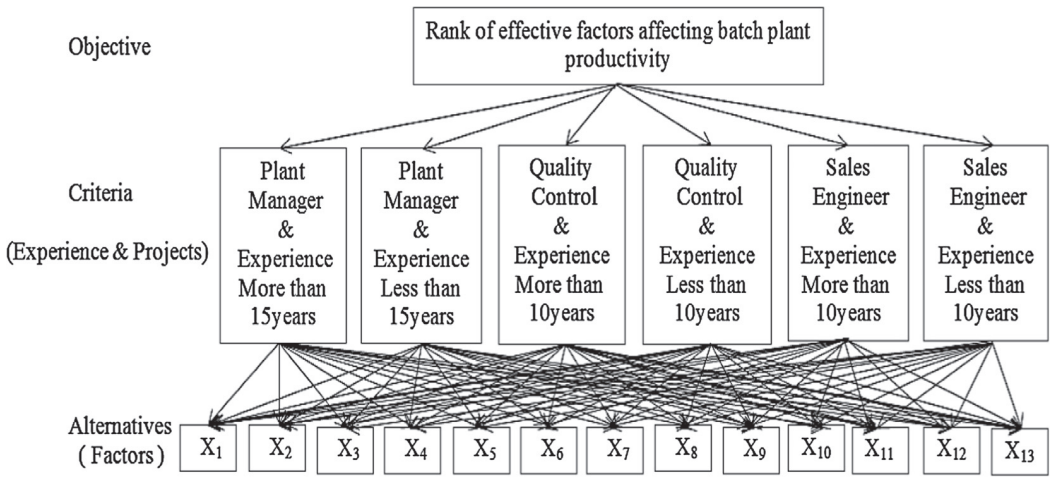

Fig. 1 Hierarchy of AHP process.

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Table 4 Pairwise comparison scale in AHP.

Rating	Preferences Judgments
09	Extremely preferred
08	Very strongly to extremely
07	Very strongly preferred
06	Strongly to very strongly
05	Strongly preferred
04	Moderately to strongly
03	Moderately preferred
02	Equally to moderately
01	Equally preferred

and check CR if it not exceed 0.10, then it is acceptable (see Fig. 2).

10. Analysis and discussions

The causes affecting productivity in batch plants in Egypt will be examined and looked from many views by data which is provided by respondents. The **A**nalytical **H**ierarchy **P**rocess will be calculated as final outlined results. These causes will be grouped and sorted according to their Analytical Hierarchy Process report. Table 5 lists the total results of responses per factor affecting productivity in batch plants in Egypt. Fig. 3 shows Relative importance indices for forty fife (45) causes according to weighted average and ranked the "Efficiency of the batch manager &his ability to distribute tasks" factor as the most effective causes of productivity of batch plant in construction projects in Egypt at this Group, with a rank equals to 0.04. This factor is ranked in first large effect on productivity of batch plant in construction projects in Egypt.

Fig. 4 shows Relative importance indices for forty fife (45) causes according to confidence causes and ranked the "Efficiency of the batch manager &his ability to distribute tasks" factor as the most effective Causes of productivity of batch plant in construction projects in Egypt at this Group, with a rank equals to 0.042. This is the first ranked factor in its effect, which indicates impact on batch plant productivity in construction projects in Egypt.

Table 5 Projects and experience pair-wise comparison matrix sample.

EXP.	A	B	C	D	E	F
A	01	02	03	05	05	07
B		01	03	04	04	06
C			01	02	03	05
D				01	03	04
E					01	02
F						01

Table 6 declared Ranking of effective Causes of productivity according to weighted average and ranked the "Efficiency of the batch manager &his ability to distribute tasks" factor as the most effective Causes of productivity of batch plant in construction projects in Egypt at this Group, with a rank equals to 0.04.

Table 7 declared Ranking of effective Causes of productivity according to weighted average and ranked the "Efficiency of the batch manager &his ability to distribute tasks" factor as the most effective Causes of productivity of batch plant in construction projects in Egypt at this Group, with a rank equals to 0.042.

10.1. Batch plant related causes group

Relative importance indices for twelve (12) causes are ranked that they are classified inside "Batch plant Related Causes Group" are shown in Table 8. The surveyed Batch Plant managers, Quality control engineers, sales engineers and maintenance engineers ranked the "Periodical calibration of scales" factor as the most effective Causes of productivity batch plant in construction projects in Egypt at this Group, with a rank equals to 0.035. This factor is ranked in second large effect on productivity of batch plant in construction projects in Egypt.

10.2. Roads and transportation related causes group

Relative importance indices for nine (9) causes are ranked that they are classified inside "Roads and transportation Related

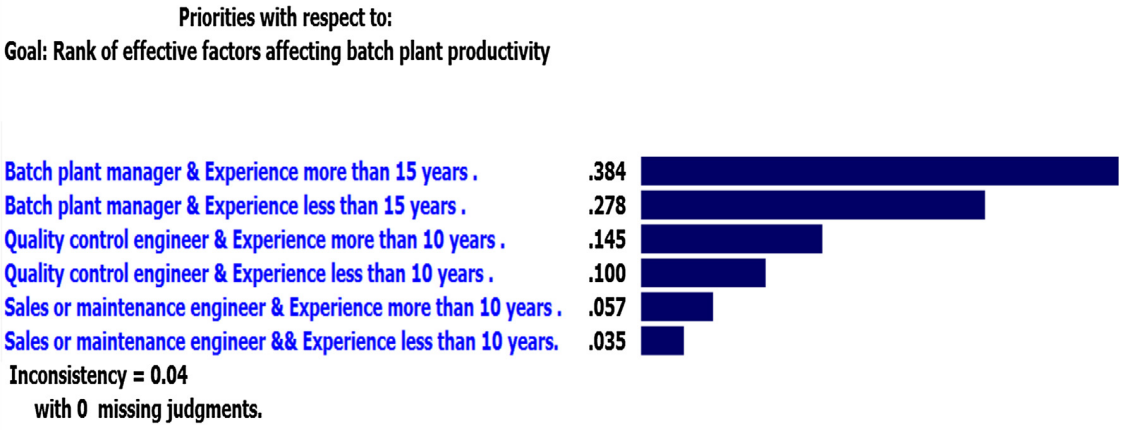

Fig. 2 Weights of each criterion.

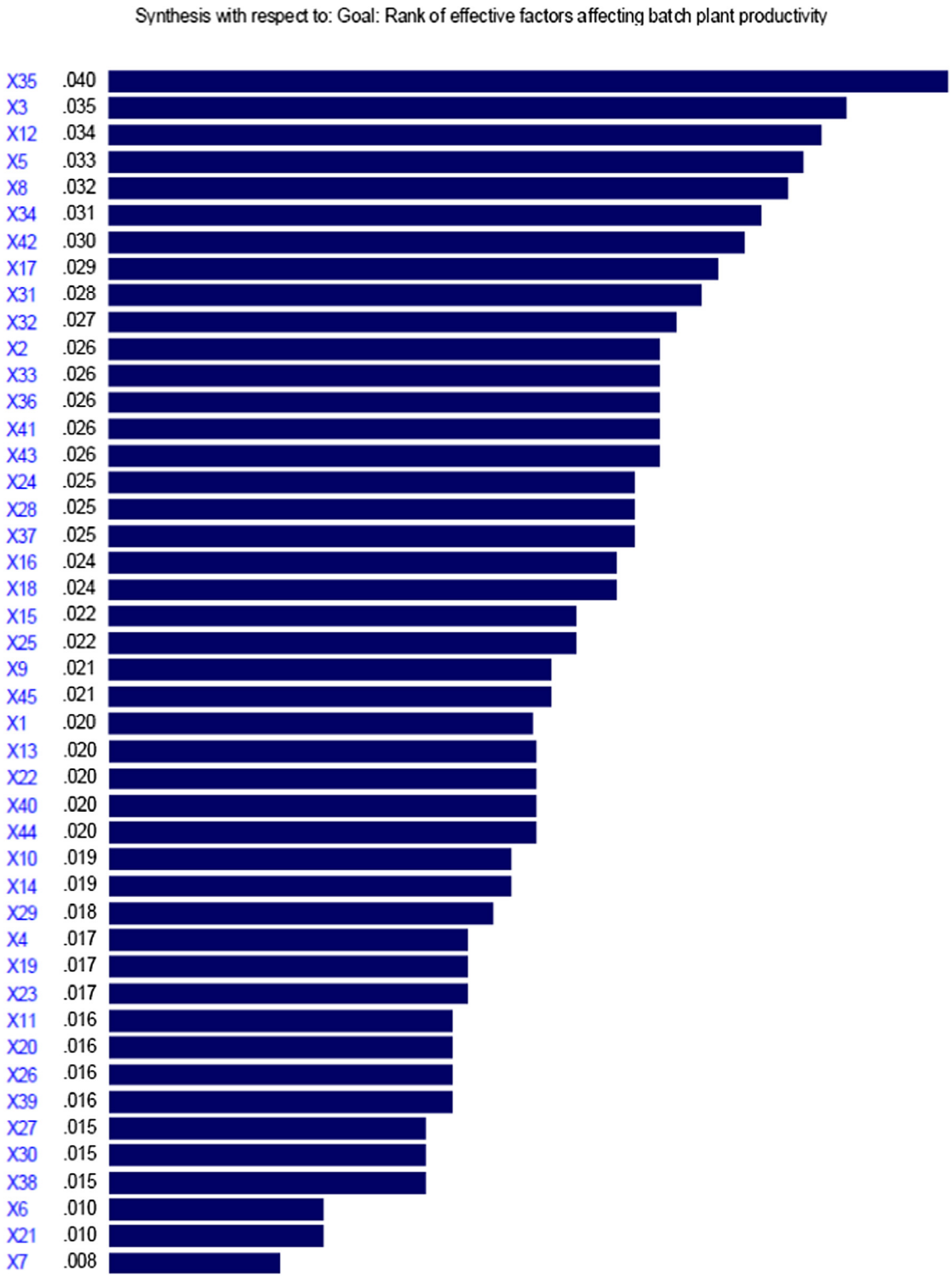

Fig. 3 Ranking according to weighted average.

Causes Group" are shown in Table 9. The surveyed Batch Plant managers, Quality control engineers, sales engineers and maintenance engineers ranked the "Concrete pump efficiency" factor as the most effective Causes of productivity batch plant in construction projects in Egypt at this Group, with a rank equals to 0.032. This factor is ranked in sixth large effect on productivity of batch plant in construction projects in Egypt.

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Table 6 Overall ranking of effective causes of productivity according to weighted average.

Rank	ID	Factor Description	Related Group Item	Rank
01	35	Efficiency of the batch manager &his ability to distribute tasks	Management	0.04
02	03	Periodical calibration of scales	Plant	0.035
03	12	Idle batch plant	Plant	0.034
04	05	The existence of automatic control mixing	Plant	0.033
05	08	Regular maintenance for plant equipment	Plant	0.032
06	34	The effectiveness of site supervision and labor guidance	Management	0.031
07	42	Motivation system for plant labors	Labor	0.03
08	17	Concrete pump efficiency	Road &Transportation	0.029
09	31	Marketing Plan efficiency	Management	0.028
10	32	Planning and organization (procurement plan cement, sand, etc.)	Management	0.027
11	02	The number of truck mixers in the plant	Plant	0.026
12	33	The Ease and clear for exchange of information and instructions	Management	0.026
13	36	The major forces (manage crises)	Management	0.026
14	41	Drivers' efficiency	Labor	0.026
15	43	Concrete pump operator efficiency	Labor	0.026
16	24	Existence of the site lighting at night	Site	0.025
17	28	Concrete workability	Site	0.025
18	37	Efficiency of the batch plant operator	Labor	0.025
19	16	Efficiency of truck mixers	Road &Transportation	0.024
20	18	Availability ready mix concrete according to project requirements Easy to transfer	Road &Transportation	0.024
21	15	Weight average distance between batch & projects	Road &Transportation	0.022
22	25	Weather conditions	Site	0.022
23	09	Plant safety plan efficiency	Plant	0.021
24	45	Site/plant communication flow	Labor	0.021
25	01	The batch plant arrangement (General location) and easily maneuverable vehicles	Plant	0.02
26	13	The traffic situation on the road to the casting site	Road &Transportation	0.02
27	22	The number of sites zone which needs RMC	Site	0.02
28	40	The effect of the worker's wages	Labor	0.02
29	44	Efficiency of Casting Crew in site	Labor	0.02
30	10	The plant urban location	Plant	0.019
31	14	The quality of the road to the casting site (bumpy - earthy - slopes)	Road &Transportation	0.019
32	29	Concrete transference/pouring method	Site	0.018
33	04	Raw materials storage location	Plant	0.017
34	19	The age of truck mixers	Road &Transportation	0.017
35	23	The types of items that will be cast (raft – col. – slabs – etc.)	Site	0.017
36	11	The age of Batch Plant	Plant	0.016
37	20	The age of pump	Road &Transportation	0.016
38	26	Ease of entry and exit from the casting site	Site	0.016
39	39	The effect of breaks and snacks	Labor	0.016
40	27	The project urbanity	Site	0.015
41	30	The relative pouring height	Site	0.015
42	38	Effect of Education and Culture of labors	Labor	0.015
43	06	Availability of drainage system	Plant	0.01
44	21	Unexpected work suspension due to idle equipment	Road &Transportation	0.01
45	07	Availability of undesired concrete disposal system	Plant	0.008

10.3. Sites related causes group

Relative importance indices for nine (9) causes are ranked that they are classified inside "Sites Related Causes Group" are shown in Table 10. The surveyed Batch Plant managers, Quality control engineers, sales engineers and maintenance engineers ranked the "Existence of the site lighting at night" factor as the most effective Causes of productivity batch plant in construction projects in Egypt at this Group, with a rank equals to 0.024. This factor is ranked in nineteenth large effect on productivity of batch plant in construction projects in Egypt.

10.4. Management related causes group

Relative importance indices for six (6) causes are ranked that they are classified inside "Management Related Causes Group" are shown in Table 11. The surveyed Batch Plant managers, Quality control engineers, sales engineers and maintenance engineers ranked the "Efficiency of the batch manager &his ability to distribute tasks" factor as the most effective Causes of productivity batch plant in construction projects in Egypt at this Group, with a rank equals to 0.042. This factor is ranked in first large effect on productivity of batch plant in construction projects in Egypt.

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Table 7 Overall ranking of effective causes of productivity according to confidence causes.

Rank	ID	Delay factor description	Related group item	Rank
01	35	Efficiency of the batch manager &his ability to distribute tasks	Management	0.042
02	03	Periodical calibration of scales	Plant	0.036
03	05	The existence of automatic control mixing	Plant	0.034
04	12	Idle batch plant	Plant	0.033
05	42	Motivation system for plant labors	Labor	0.033
06	17	Concrete pump efficiency	Road &Transportation	0.032
07	31	Marketing Plan efficiency	Management	0.032
08	34	The effectiveness of site supervision and labor guidance	Management	0.031
09	08	Regular maintenance for plant equipment	Plant	0.028
10	33	The Ease and clear for exchange of information and instructions	Management	0.028
11	43	Concrete pump operator efficiency	Labor	0.028
12	02	The number of truck mixers in the plant	Plant	0.027
13	37	Efficiency of the batch plant operator	Labor	0.027
14	41	Drivers' efficiency	Labor	0.027
15	16	Efficiency of truck mixers	Road &Transportation	0.025
16	32	Planning and organization (procurement plan cement, sand, etc.)	Management	0.025
17	36	The major forces (manage crises)	Management	0.025
18	15	Weight average distance between batch & projects	Road &Transportation	0.024
19	24	Existence of the site lighting at night	Site	0.024
20	18	Availability ready mix concrete according to project requirements Easy to transfer	Road &Transportation	0.023
21	28	Concrete workability	Site	0.023
22	14	The quality of the road to the casting site (bumpy - earthy - slopes)	Road &Transportation	0.021
23	22	The number of sites zone which needs RMC	Site	0.021
24	25	Weather conditions	Site	0.021
25	01	The batch plant arrangement (General location) and easily maneuverable vehicles	Plant	0.02
26	40	The effect of the worker's wages	Labor	0.02
27	19	The age of truck mixers	Road &Transportation	0.019
28	44	Efficiency of Casting Crew in site	Labor	0.019
29	45	Site/plant communication flow	Labor	0.019
30	13	The traffic situation on the road to the casting site	Road &Transportation	0.018
31	20	The age of pump	Road &Transportation	0.018
32	39	The effect of breaks and snacks	Labor	0.018
33	09	Plant safety plan efficiency	Plant	0.017
34	11	The age of Batch Plant	Plant	0.017
35	23	The types of items that will be cast (raft – col. – slabs – etc.)	Site	0.016
36	29	Concrete transference/pouring method	Site	0.016
37	04	Raw materials storage location	Plant	0.015
38	10	The plant urban location	Plant	0.015
39	38	Effect of Education and Culture of labors	Labor	0.015
40	26	Ease of entry and exit from the casting site	Site	0.014
41	27	The project urbanity	Site	0.013
42	30	The relative pouring height	Site	0.013
43	21	Unexpected work suspension due to idle equipment	Road &Transportation	0.01
44	06	Availability of drainage system	Plant	0.009
45	07	Availability of undesired concrete disposal system	Plant	0.007

10.5. Labor related causes group

Relative importance indices for nine (9) causes are ranked that they are classified inside "Labor Related Causes Group" are shown in Table 12. The surveyed Batch Plant managers, Quality control engineers, sales engineers and maintenance engineers ranked the "Motivation system for plant labors" factor as the most effective Causes of productivity batch plant in construction projects in Egypt at this Group, with a rank equals to 0.033. This factor is ranked in fifth large effect on productivity of batch plant in construction projects in Egypt.

11. Research results

Based on the effective Causes ranking in Table 5, the ranking of all groups indicates degree of impact batch plant productivity in Egyptian construction projects. The most effective Causes of productivity of batch plants in construction projects in Egypt are classified into five (5) major groups (A) Batch plant Related Causes Group; This was mainly due to the causes "Periodical calibration of scales (R = 0.036)", "The existence of automatic control mixing (R = 0.034)", "Idle batch plant (R = 0.033)", "Regular maintenance for plant equipment (R = 0.028)", "The number of truck mixers in

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Table 8 Ranking of causes related to batch plant group.

Priority	Rank	ID	Factor description	Rank
12	01	03	Periodical calibration of scales	0.036
11	02	05	The existence of automatic control mixing	0.034
10	03	12	Idle batch plant	0.033
09	04	08	Regular maintenance for plant equipment	0.028
08	05	02	The number of truck mixers in the plant	0.027
07	06	01	The batch plant arrangement (General location) and easily maneuverable vehicles	0.02
06	07	09	Plant safety plan efficiency	0.017
05	08	11	The age of Batch Plant	0.017
04	09	04	Raw materials storage location	0.015
03	10	10	The plant urban location	0.015
02	11	06	Availability of drainage system	0.009
01	12	07	Availability of undesired concrete disposal system	0.007

Table 9 Ranking of causes related to roads and transportation group.

Priority	Rank	ID	Factor Description	Rank
09	01	17	Concrete pump efficiency	0.032
08	02	16	Efficiency of truck mixers	0.025
07	03	15	Weight average distance between batch & projects	0.024
06	04	18	Availability ready mix concrete according to project requirements and Easy to transfer	0.023
05	05	14	The quality of the road to the casting site (bumpy - earthy - slopes)	0.021
04	06	19	The age of truck mixers	0.019
03	07	13	The traffic situation on the road to the casting site	0.018
02	08	20	The age of pump	0.018
01	09	21	Unexpected work suspension due to idle equipment	0.01

Table 10 Ranking of causes related to sites group.

Priority	Rank	ID	Factor Description	Rank
09	01	24	Existence of the site lighting at night	0.024
08	02	28	Concrete workability	0.023
07	03	22	The number of sites zone which needs RMC	0.021
06	04	25	Weather conditions	0.021
05	05	23	The types of items that will be cast (raft – col. – slabs – etc.)	0.016
04	06	29	Concrete transference/pouring method	0.016
03	07	26	Ease of entry and exit from the casting site	0.014
02	08	27	The project urbanity	0.013
01	09	30	The relative pouring height	0.013

Table 11 Ranking of causes related to management group.

Priority	Rank	ID	Factor Description	Rank
06	01	35	Efficiency of the batch manager &his ability to distribute tasks	0.042
05	02	31	Marketing Plan efficiency	0.032
04	03	34	The effectiveness of site supervision and labor guidance	0.031
03	04	33	The Ease and clear for exchange of information and instructions.	0.028
02	05	32	Planning and organization (procurement plan cement, sand, etc.)	0.025
01	06	36	The major forces (political disorders)	0.025

the plant (R = 0.027)", "The batch plant arrangement (General location) and easily maneuverable vehicles. (R = 0.02)", "Plant safety plan efficiency (R = 0.017)", "The age of Batch Plant (R = 0.017)", "Raw materials storage location (R = 0.015)", "The plant urban location (R = 0.015)", "Availability of drainage system (R = 0.009)", "Availability of undesired concrete disposal system (R = 0.007)", (B) Road and transportation Related Causes Group; This was mainly due to the causes "Concrete pump efficiency (R = 0.032)", "Efficiency of truck mixers (R = 0.025)", "Weight average

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Table 12 Ranking of causes related to labor group.

Priority	Rank	ID	Factor Description	Rank
09	01	42	Motivation system for plant labors	0.033
08	02	43	Concrete pump operator efficiency	0.028
07	03	37	Efficiency of the batch plant operator	0.027
06	04	41	Drivers' efficiency	0.027
05	05	40	The effect of the worker's wages	0.02
04	06	44	Efficiency of Casting Crew in site	0.019
03	07	45	Site/plant communication flow	0.019
02	08	39	The effect of breaks and snacks	0.018
01	09	38	Effect of Education and Culture of labors	0.015

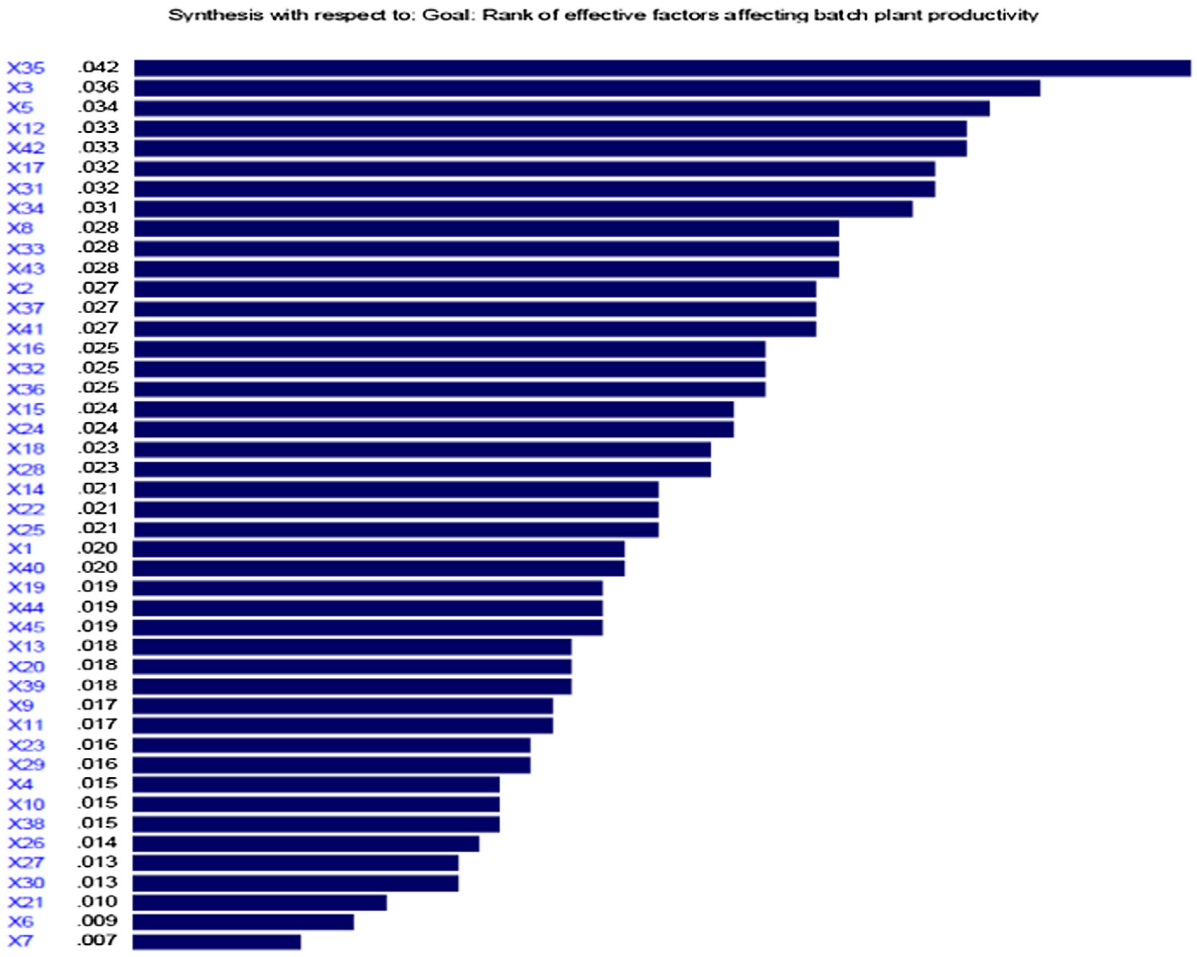

Fig. 4 Ranking according to confidence causes.

distance between batch & projects (R = 0.024)", "Availability ready mix concrete according to project requirements and Easy to transfer (R = 0.023)", "The quality of the road to the casting site (bumpy - earthy - slopes) (R = 0.021)", "The age of truck mixers (R = 0.019)", "The traffic situation on the road to the casting site (R = 0.018)", "The age of pump (R = 0.018)", "Unexpected work suspension due to idle equipment (R = 0.01)", (C) Sites Related Causes; This was mainly due to the causes "Existence of the site lighting at night (R = 0.024)", "Concrete workability (R = 0.023)", "The number of sites zone which needs RMC (R = 0.021)", "Weather conditions (R = 0.021)", "The types of items that will be cast (raft – col. – slabs – etc.) (R = 0.016)", "Concrete transference/pouring method (R = 0.016)", "Ease of entry and exit from the casting site (R = 0.014)", "The project urbanity (R = 0.013)", "The relative pouring height (R = 0.013)", (D) Management Related Causes Group; This was mainly due to the causes "Efficiency of the batch manager &his ability to distribute tasks (R = 0.042)", "Marketing Plan efficiency (R = 0.032)", "The effectiveness of site supervision and labor guidance (R = 0.031)", "The Ease and clear for exchange of information and instructions (R = 0.028)", "Planning and organization (procurement plan cement, sand, etc.) (R = 0.025)", "The major forces (Manage crises)

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(R = 0.025)", (E) Labor Related Causes Group; This was mainly due to the causes "Motivation system for plant labors (R = 0.033)", "Concrete pump operator efficiency (R = 0.028)", "Efficiency of the batch plant operator (R = 0.027)", "Drivers' efficiency (R = 0.027)", "The effect of the worker's wages (R = 0.02)", "Efficiency of Casting Crew in site (R = 0.019)", "Site/plant communication flow (R = 0.019)", "The effect of breaks and snacks (R = 0.018)", "Effect of Education and Culture of labors (R = 0.015)".

12. Conclusion

To improve productivity of automated concrete mixing system for mega construction projects in Egypt; the influence of the main causes affecting it must be identified and recognized. This paper had determined influence ranks and had quantified relative importance indices for forty five (45) causes that affecting batch plant productivity in Egypt. The explored causes were grouped into five (5) primary groups: (1) Batch plant; (2) Roads and transportation; (3) Sites Related; (4) Management; (5) Labor. To can study participants' experience effect on the obtained results, all questionnaire answers are grouped under participants experience and their professional cadre. The results were compared by studying all participants to cope with affecting causes on Egyptian batch plant productivity. This paper is quantified the relative importance indices of productivity related causes in batch plant and is demonstrated these causes ranking based on their productivity importance level. This goal was completed by interview analysis out comings. All causes and groups were ranked. The least and large important groups and causes were analyzed by ranking of results using AHP.

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Impact of permanent magnet stirring on dendrite growth and elastic properties of Sn–Bi alloys revealed by pulse echo overlap method

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ABSTRACT

Studying and understanding the dendritic growth process is a challenging topic related to liquid-solid phase transition, as it helps to predict the final microstructure controlling the solder properties. In a specific case of the design of Sn-Bi and Sn-Bi-Cu alloys, the solidification microstructures and corresponding electrical and elastic properties were studied with and without permanent magnetic stirring (PMS), as their influence on the growth morphology of dendrites is not yet fully assessed to date. We use pulse echo overlap (PEO) method for measuring the polycrystalline bulk modulus *K*, Young's modulus *E*, shear modulus *G*, Poisson ratio υ and hardness *H*. The PMS-driven flow caused a disruption of the columnar β-Sn dendrites and columnar-to-equiaxed transition (CET). Such behavior is believed to evolve from dendrite fragmentation, arises through complex hyper-branched morphologies at the origin of Lorentz force and Seebeck effect that acting on the melt. Both the hardness and elastic modulus are increased as the Poisson's ratio decreased. Moreover, the Pugh ratio clarified the ductility behavior of the alloy samples, while Poisson's ratio and electrical resistivity display slight decrease in the ionic contribution with applying PMS and/or Cu content. These results open new ways to predict the final microstructure controlling the dendritic growth in metallic alloys.

1. Introduction

With the increased global environmental concerns of lead in solder alloys, the development of lead-free solder alloys is documented as a vital and urgent task in electronic industry. To date, numerous lead-free solder alloys, such as Sn–Ag–Cu, Sn–Ag, Sn–Bi, Sn–Cu and Sn–Zn, have been developed extensively and selected as potential replacements of Sn–Pb solder. With a further decrease of solder joint sizes, the reliability of Pb-free solder joints will be more crucial to the performance of electronic products [1,2]. One of the key factors that affect the solder joint reliability is the formation and growth of IMC layer, which are dependent on the type of solder ball and surface finish used in printed circuit board (PCB) [3]. Recently, numerous qualitative studies of bulk solders to find an appropriate Pb-free surface finish on a printed circuit were found in literature [4]. Among them the most promising one is undoubtedly Sn-Ag-Cu(SAC) ternary alloys, which have advantages of good wetting property, superior interfacial properties, high creep resistance and low available melting temperature. Yet, the major challenge with high Ag content SAC solders are the undesirable formation of thick Ag_3Sn IMCs at surface finish, which adversely affect the thermal fatigue life of solder joints [5].

Because of its unique characteristics, such as low melting temperature of 139 °C, good tensile strength, and wettability, the eutectic Sn-Bi alloy has become a promising candidate solder in multi-step assembly process [6,7]. Nevertheless, Sn-58Bi has some disadvantages, such as the microstructure coarsening of Bi phase during thermal aging that deteriorates the tensile strength and ductility. Many efforts have been made to address these issues with the addition of alloying elements and nanoparticles [8]. However, full implementation of the new generation of lead-free solders requires detailed knowledge on microstructure coarsening of IMCs and dendritic growth process, as it helps to provide valuable insights for predicting the final microstructure that controls the alloy properties. Therefore, describing and understanding precisely the complexity of dendrites morphology is a challenging topic at the heart of many research in metallic alloys [9]. Practically, without alloying element additions as a grain refinement, fragmentation is the prime source of equiaxed grains, which under reasonable

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delimited growth conditions, can block the columnar growth and originate a columnar-to-equiaxed transition (CET), which impacts the alloy properties. But a little work has been performed on CET in solder alloy systems. Recently, the effects of physical fields including ultrasonic field [10], electromagnetic field [11] and electric current pulse on the solidification process of metals and alloys have been studied and discussed [12]. For example, there have been many different views regarding the mechanisms of ultrasonic grain refinement. One mechanism to promote the nucleation is a cavitation bubbles, and another is the fragmentation of dendrite arms in columnar zone caused by a strong circulating convection [13]. However, the most prominent realization of these physical fields is the rotating magnetic stirring. Since the flow intensity can be controlled definitely with applying various processing parameters, the magnetic field and electromagnetic vibrations have gained attention as their completely contactless could influence the melt flow adjacent to liquid-solid interface [14]. Direct imposition of magnetic field on molten metal during solidification allows grain refinement in microstructure. Researchers have achieved grain refinement in Sn-Pb alloys by applying permanent magnetic stirring (PMS), and have proposed several mechanisms for grain refinement [15]. The beneficial effect of rotating magnetic stirring is to induce fragmentation of columnar dendrites owing to the transport of hot liquid towards the solidification front, which in turn endorses re-melting of dendrite arms. PMS also can entirely eliminate the gravity induced macro-segregation and modify the solute diffusion velocity. However, the detailed mechanisms of PMS during the solidification process are still unclear. Considerable progress has been made recently, in particular with PMS-driven fluid flow, by employing specific model experiments of low-melting-point Sn-20Bi alloys and adapted their processing parameters [16]. Materials and processing design of Sn-Bi solders and Sn-based solders have been conducted to improve the comprehensive performance of alloy solder joints [17]. For instance, the addition of Sb into Sn-8Zn-3Bi solder alloy resulted in an extra nucleation sites, stimulating the solidification process and the microstructure was refined [18]. Although the inherent brittleness of Bi element in eutectic Sn-58Bi alloys could result in insufficient ductility, and cause high risk of brittle fracture under mechanical shock or drop conditions, the reasonable method to enhance the Sn-Bi solder joints was to suppress the relative concentration of Bi-rich phase and adding other additive elements as Cu element. PMS also was found to be an effective technique to reduce the columnar dendrite primary β-Sn phase, which allows direct enhancement of mechanical properties and nucleation undercooling of β-Sn [19,20].

Since the classic mechanical tests are generally performed using traditional experimental procedures and specific devices, their accuracy seems to be mightily dependent on experimental settings and data analysis procedures. Therefore, pulse echo overlap method is rather performed providing a local and non-destructive technique (NDT) for inspection means. Analytical and predictions of the whole elastic–plastic response and local damage mechanisms in Sn-20Bi and Sn-20Bi-0.4Cu solders are very complex problem, since the microstructural aspects of solders play an important roles in deformation behavior. Therefore, the present study aims to introduce an intense PMS-driven melt flow to entirely alter the solidification structure of Sn-20Bi and Sn-20Bi-0.4Cu alloys. The mechanism of formation of regular equiaxed microstructure of primary β-Sn phase during solidification under PMS is discussed. Also, the longitudinal and shear ultrasound wave velocities as well as elastic properties have been evaluated using pulse echo overlap method. Besides, the electrical resistivity of Sn-Bi and Sn-Bi-Cu alloys will be examined. As well, an attempt has been made to correlate between the changes in solidification structure due to PMS and elastic properties.

2. Experimental procedures

2.1. Alloy design and preparation

The Sn - 20 wt % Bi and Sn - 20 Bi - 0.4 wt % Cu alloys were prepared from pure Sn (99.9%), Bi (99.9%), and Cu (99.99%) metals by melting in a quartz tube 25 mm in diameter and 50 mm in height. The alloys were initially molten in a box furnace under protection of an anti-oxidizing flux (KCl + LiCl (1.3:1)) at 600 °C for 60 min. The molten obtained from the experiments was subjected to rotating permanent magnets during the whole solidification process with a nature cooling at room temperature. The details of experimental set-up of RMF can be found elsewhere [16]. The magnetic field was fabricated by a coupled of disc-shaped NdFeB permanent magnets of 0.5 T with their N, S poles face to face. The interval between the two faces was 40 mm. The rotating permanent magnets were controlled by an adjustable speed motor connected to a power supply system, which permits precise rotation speed ω of 120 r/min. The rotation speed was elected being definitely small to neglect any impacts arising from skin effect. The microstructure was investigated near the bottom surfaces of ingots to detect the gravity influence of alloy phases before and after applying PMS. The obtained alloy samples were examined in the polished and etched conditions by an optical microscopy (OM). Grain sizes were measured using linear intercept method. The details of microstructure were examined by Scanning Electron Microscopy (SEM) (FE-SEM, model: S-4800, HITACHI) in backscattered electron (BSE) mode. Different phases were conducted by Energy Dispersive X-ray Spectrometry (EDS).

2.2. Ultrasonic velocity and resistivity measurements

Ultrasonic pulse echo overlap (PEO) method shown in Fig. 1, as a non-destructive technique, was employed to measure the mechanical wave velocity in the alloy specimens. The alloy samples were polished with 0.5 μm Al_2O_3 particles. The polished specimens are cylindrical in shape with diameter of 10 mm and length of 6 mm. Plane parallelism between opposite faces was checked using a surface plate and its accuracy was ±25 μm. The ultrasonic velocities (UV) were obtained by measuring the transit time between the initiation and the receipt pulse appearing on the screen of a flaw detector (USIP20-Kraütkramer) using a standard electronic circuit (Hewlett Packard 54615 B). The wave velocity was calculated by dividing the round trip distance (twice the thickness of specimen, $2x$) by elapsed time Δt with the relation: $V = 2x/\Delta t$. Two samples have been tested for each alloy composition and the average value was measured. The density (ρ) of each alloy specimens was measured by applying Archimedes principle at 25 °C using toluene as an immersion liquid. For isotropic crystal materials, there are a number of empirical relationships to correlate the elastic coefficients. The detailed procedures for evaluating the elastic coefficients such as; shear modulus, Young's modulus, bulk modulus, hardness and Poisson's ratio were reported elsewhere [20]. The room temperature resistivity measurement of alloy solders was measured by four-point probe method [21]. Five measurements were registered and the average value was considered. The advantage of using four-point probe method is the possibility of measuring the sample's resistance without any interruption from the contact resistance at probe contacts.

3. Experimental results and discussion

3.1. Solidification microstructure

The dendrite morphologies observed during solidification of Sn-Bi and Sn-Bi-Cu alloys without and with PMS are displayed in Figs. 2

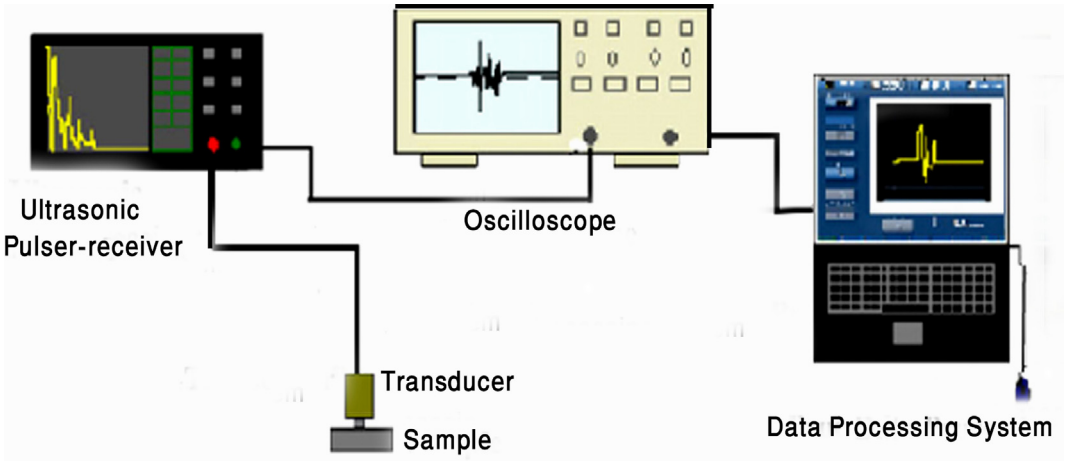

Fig. 1. Schematic representation of pulse echo overlaps (PEO) method.

and 3. In the absence of PMS, the OM microstructure exhibits columnar zones at the less surface quality caused by appearance of small pinholes near the surface of ingots. As can be seen, the β-Sn crystals of Sn-Bi alloy are structured into large regular dendrite β-Sn grains of 40–400 μm with high aspect ratio and average size of ~80 μm (Fig. 2a). The remarkably rapid growth of β-Sn phase could result in its significant undercooling (~30–50 °C) [22], which limit the nucleation and growth of other phases. For Sn-Bi-Cu alloy, the OM microstructure consists of a primary Cu_6Sn_5 phase, Bi and columnar dendrite β-Sn phases, which are consistent with the phase diagram and previous work [19,23,24] (Fig. 2b). The columnar dendrite growth is the main solidification mode in both alloys although its average size is reduced to ~55 μm in case of Sn-Bi-Cu alloy due to Cu content. With the presence of Cu_6Sn_5 as nucleant particles inside the bulk Sn-Bi-Cu solder, the nucleation events are expected to be increased, which are likely to be the key factor for suppression the large columnar dendrite β-Sn grains shown in Fig. 2b. However, when PMS was not performed, the porosity and pinholes are already visible in solidifying microstructure samples. The inset was a magnified section showing the porosity and pinholes in both solders. On the other hand, it is interesting to note that the morphology of dendrite β-Sn phase in Sn-Bi-Cu alloy is still columnar dendritic and not affected by the addition of Cu in the ternary alloy. The direction of β-Sn columnar growth could induce specific symmetry and uniformity in the growth patterns.

It is well known that when PMS is performed during solidification of alloys, the magnetic field B tends to rotate the easy magnetic axis of β-Sn crystals to its lowest energy state [25]. The driving force is given by the anisotropic magnetic energy $E_m(\theta, B)$ of grains, where θ is the angle between the magnetic field and grain axis. Then, the preferred growth direction of dendrite β-Sn crystal

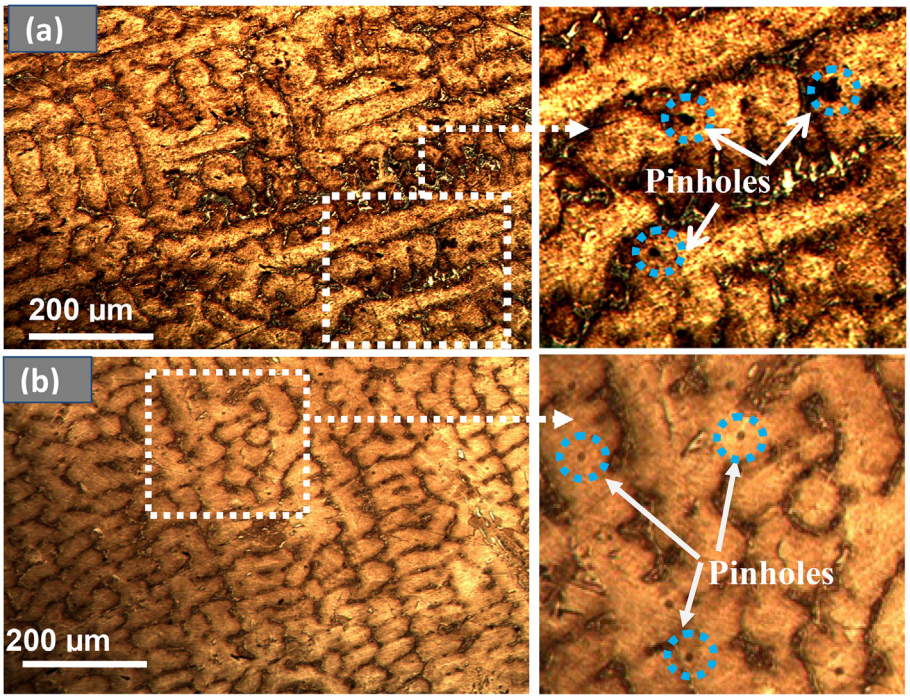

Fig. 2. OM microstructures of solidified (a) Sn-20Bi and (b) Sn-20Bi-0.4Cu alloys before applying PMS.

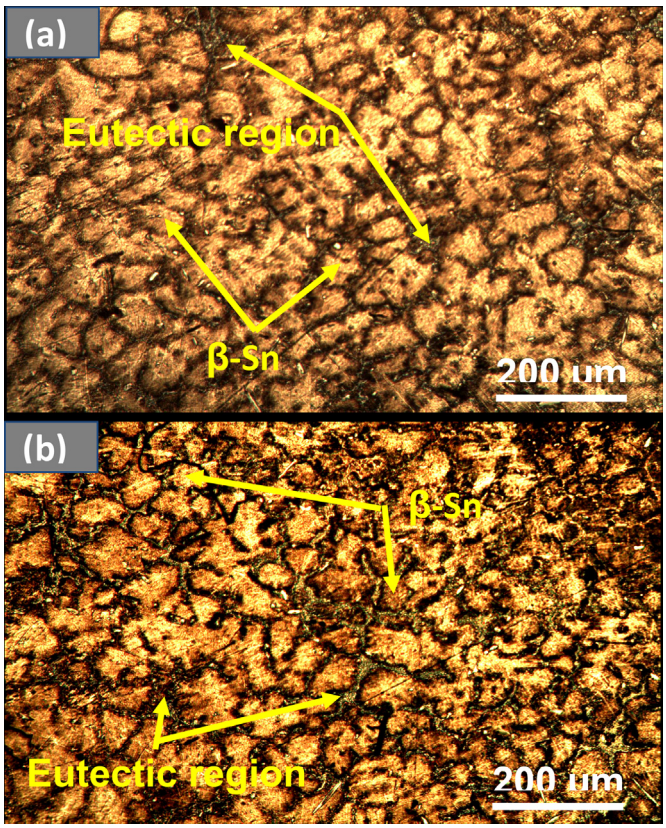

Fig. 3. OM microstructures of solidified (a) Sn-20Bi and (b) Sn-20Bi-0.4Cu alloys after applying PMS.

could deviate from its preferred direction gradually leading to dendrite-free grain structure. For that reason, the orientation of β-Sn crystals should be ascribed to the rotation of β-Sn grains caused by the induced magnetic field as well as the angle between the solidification and magnetic field directions. Hence, the effects of stirring and convection could induce instability at the liquid-solid interface of primary phases. As a result, the long β-Sn dendrite phase is fragmented into smaller ones and they appear to be more equiaxed rather than the more collective columnar shape under the effect of induced Lorentz force F acting on the melt, where $F = J_{ind} \times B$, J_{ind} is the induced current and B is the applied magnetic field. At that point, it was specified that the elimination of existing β-Sn dendrites has been occurred. The melt is homogenized and the columnar-to-equiaxed transition (CET) processes take place. Besides, the size of equiaxed grains is slightly decreased to about to ~53 μm with low aspect ratio, and the residual porosity defects in solder alloys are diminished as seen in Fig. 3a and b. Although seemingly straightforward, this CET can produce large variety of solidification microstructures. The fragment particles caused by PMS could be a source of equiaxed grains for secondary nucleation, and this currently appears to be the primary source of equiaxed grains in non-grain refined cast alloys. Likewise, the solid-liquid interface also contributes to fragmentation. Modifying the number and spatial distribution of β-Sn heterogeneities in the melt leads to significant influence on the morphology of dendrites growing in such media. Branching events of long β-Sn dendrite are then more frequent when the field of fragment particles is better dispersed by performing PMS, leading to the hyper-branched structure shown in Fig. 3. In conclusion, the experimental results indicate that the magnetic field could affect the morphology, size and orientation of the β-Sn phase.

Apart from the morphological change of β-Sn dendrite phase, a prominent variation of the distribution of eutectic phases also was observed after applying PMS. Figs. 4 and 5 show the FE-SEM images of near bottom section of samples of Sn-Bi and Sn-Bi-Cu alloys with and without PMS. Without PMS, the FE-SEM image of binary alloy will be characterized by typical heterogeneous white gray discrete particles, coarse and fine lamellae structure of Bi-rich phase within the dark matrix β-Sn phase and binary eutectic (Fig. 4a). With applying PMS, the microstructure of Sn-Bi solder shows significantly finer and uniformly distributed Bi particles (Fig. 4b). The finer microstructure is likely to be caused by the transport of hot liquid towards the solidification front, which in turn endorses remelting of dendrite arms. Besides, the inter-lamellar spacing is decreased after applying PMS. The present results are correlated well with the decreased inter-lamellar spacing according to the eutectic growth theory [26]: $k^2V =$ constant, where k is the lamellar spacing and V is the growth rate. These features are controlled by the growth kinetics, like dissipation of heat at the solid/liquid interface and cooling rate under PMS during the solidification process. In Fig. 5, the predicted solidification structure of Sn-20Bi-0.4Cu solder without PMS starts with the formation of primary Cu_6Sn_5phase and finished with the eutectic phase of fine dot Bi-rich particles and β-Sn phase. The presence of those Cu_6Sn_5 particles may reduce the reliability of solder owing to their brittleness and weakness. According to Fig. 6, the solidification process of Sn-20Bi-0.4Cu alloy can elucidated as follows: L (liquid phase)/L (primary Cu_6Sn_5)/L (primary Cu_6Sn_5) (primary Sn-rich)/L(primary Cu_6Sn_5)(-primary Sn rich Bi precipitates)/(primary Cu_6Sn_5)(primary Sn-rich Bi precipitates) ternary eutectic [(Sn) (Bi) Cu_6Sn_5]. Without applying PMS, the eutectic mixture of Sn-20Bi-0.4Cu solder is characterized by complex arrangements of fine gray and white regions represent β-Sn and Bi phases respectively, while the large dark ribbons represent the Cu_6Sn_5 IMC particles, which are heavily concentrated in the Sn-rich phase. With applying PMS, the Cu_6Sn_5 particles are refined and randomly distributed throughout the microstructure. In this case, such fine Cu_6Sn_5particles have been predicted as part of a ternary eutectic formed by Sn + Bi + Cu_6Sn_5. Similarly, the refinement of Bi particles in binary Sn-20Bi alloy after applying PMS could result in improving the binary eutectic (Sn + Bi) structure as seen in Fig. 4. The SEM-EDX results in Table 1 also indicate that these three phases have compositions close to Sn, Bi and Cu_6Sn_5 phases. It is likely that primary Cu_6Sn_5 particles contribute to the fine dot Bi nucleation, since the presence of Cu_6Sn_5 particles had significant influence on the nucleation of Bi-rich particles and there are no fiber-like or coarse lamellas of Bi-rich particles in the cross-sectional area. Microstructural analysis in Fig. 5 also revealed a lot of multiple polymorphs Cu_6Sn_5 phase. These polymorphs Cu_6Sn_5 particles were evenly broadcasted throughout the cross-section. It seems likely that the Cu_6Sn_5 particles are correlated with the high-temperature hexagonal η-Cu_6Sn_5 phase and could attribute to different forms of superstructure ordering and consequential decrease in its symmetry [27,28]. These Cu_6Sn_5 particles are settled under gravity without PMS as seen in Fig. 5a. However, the Cu_6Sn_5 particles were significantly reduced after applying PMS due to the homogeneous distribution of these particles in the alloy matrix, showing that the PMS holding technique was successful for eliminating the gravity of denser particles at the bottom of the melt (Fig. 5b). Moreover, the fine dot Bi-rich particles formed with the denser Cu_6Sn_5 particles are transformed into fiber-like Bi-rich phase with a large inter-lamellar spacing due to the decreased number of Cu_6Sn_5 particles after applying PMS. However, the anisotropy of free energy at solid/liquid interface, resulting from the crystalline anisotropy of Sn-rich phase, is responsible for the shape of phases and effectively controls the details of emerging morphological patterns [29].

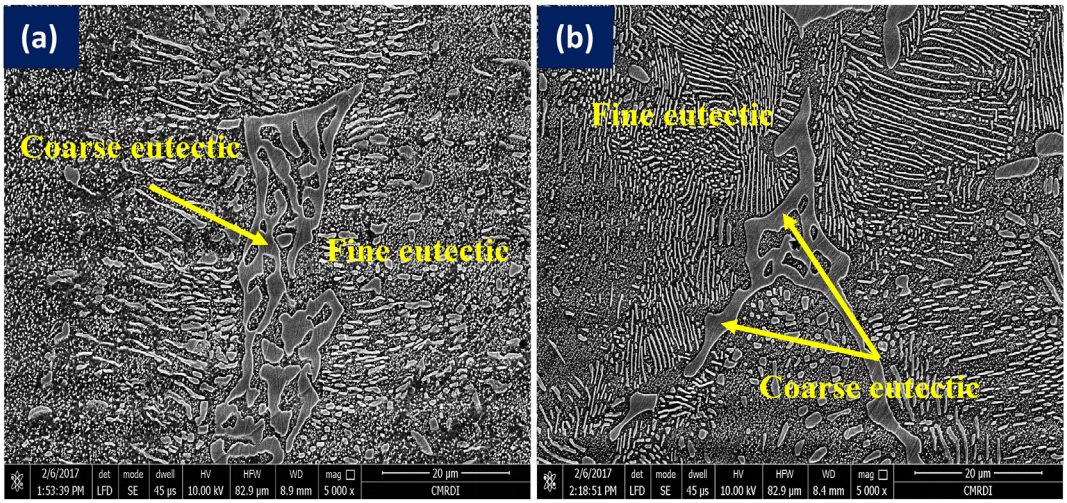

Fig. 4. FE-SEM microstructures of Sn-20Bi alloys: (a) without applying PMS, (b) with applying PMS.

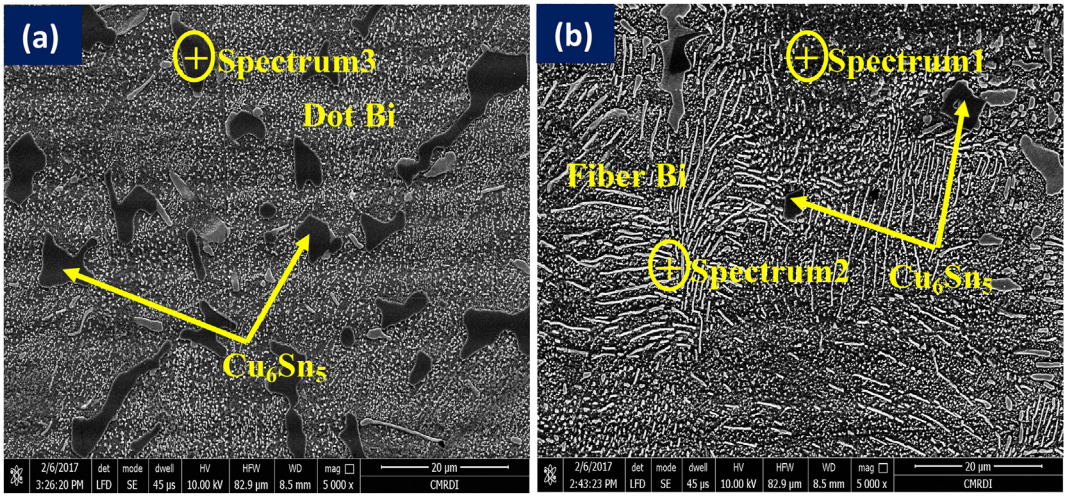

Fig. 5. FE-SEM microstructures of Sn-20Bi-0.4Cu alloys: (a) without applying PMS, (b) with applying PMS.

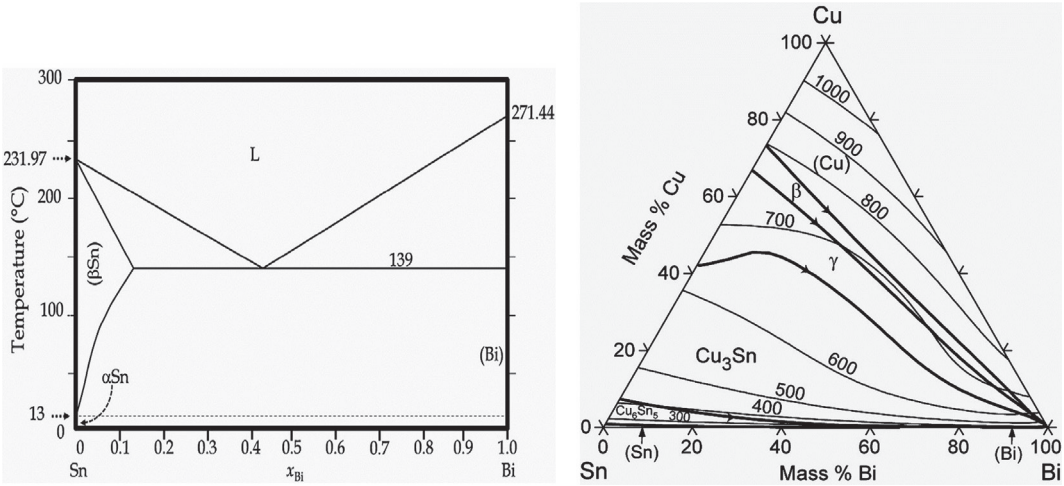

Fig. 6. Binary and Ternary phase diagrams of Sn-20Bi and Sn-20Bi-0.4Cu alloys [23,24].

Table 1
EDX analysis of different phases.

Phase	Spectrum	Sn (At. %)	Bi (At. %)	Cu (At. %)
Sn	1	95.73	4.27	–
Bi	2	4.78	95.22	–
η-Cu_6Sn_5	3	52.56	–	47.44

Additionally, the thermo-electrical properties at the interface between the two bulk phases in equilibrium could result in the fact that the atoms are located at different environment at the interface than inside the bulk phases. Thus, the interface is associated with free energy and entropy that reflect the local atomistic scale structure of the patterns. Fig. 7 shows the elemental SEM-EDS mapping of Sn-20Bi-0.4Cu alloy. As seen, Sn contrast (in yellow) is higher in the alloy matrix, while its intensity is decreased in the Cu_6Sn_5 IMC regions. Bi (in blue) is concentrated in the eutectic mixture and dispersed in the Sn-rich matrix. These results also indicate that Cu (in red) was consumed in the formation of Cu_6Sn_5 IMC. This is befitting with the stoichiometry of these IMCs. SEM images depict that Cu_6Sn_5 particles are either including the β-Sn matrix or within the eutectic mixture, giving rise to the ternary [(Sn) (Bi) Cu_6Sn_5] eutectic, which appeared as isolated "islands" between the predominant binary eutectic [(Sn) (Bi)] and β-Sn rich phase.

To inspect the underlying mechanism, microstructure of Sn-20Bi-0.4Cu solder solidified under the effect magnetic fields was observed in Fig. 8. The primary Cu_6Sn_5 phase was firstly precipitated from liquid melt during the solidification process [23]. Then, the fiber-like Bi particles are arranged at the tip of interface between the primary $Cu_6Sn_5$and eutectic phases. It should be noted that this swirl is remarkably localized at tip of Cu_6Sn_5 particles and does not extend into the bulk of Cu_6Sn_5 IMC particles. The orientation of fiber-like Bi particle should be ascribed to the rotation of Bi particles caused by two major magnetic effects inspire the solidification structures: First effect is the magnetic moment E_m arising from the magnetic crystalline anisotropy, which is described by: $E_m = mLB \sin\theta$, where m is the pole intensity, L is the grain size, B is the applied magnetic field, θ is the angle between B and the easy magnetization axis of β-Sn grain [27]. This moment tends to align the eutectic lamellar along the magnetic field ahead of the liquid–solid interface as seen in Fig. 8. It should be noted that the magnetic moment on the dendrite array is eliminated when θ is zero. At these conditions, the modification of microstructure during solidification under magnetic field can be ascribed to the second effect, which is the Seebeck effect [27]. Due to the transport of hot liquid towards the solidification front, the thermoelectric current will be created at the liquid–solid interface and at the tip of Cu_6Sn_5 interface [30]. The interaction between the induced thermoelectric current and magnetic field will generate a thermoelectric magnetic force, which may induce a torque that disturbs the dendrite and rotate of the dendrite fragments ahead of the liquid–solid interface. Fragments of destroyed β-Sn dendrites may act as solidification sites. A comparison between the present study and the previous numerical simulations for thermoelectric magnetic force acting on the primary ε-Cu_5Zn phase was performed. Fig. 8a-c highlights the morphological similarities between the present experimental results and the results obtained by Li et al. [27] based on finite element method (FEM) simulation commercial code. Numerical simulation for the distribution of thermoelectric current streamlines near the interface and thermoelectric power is speculated in Fig. 8(b and c). Although the simulation models support several

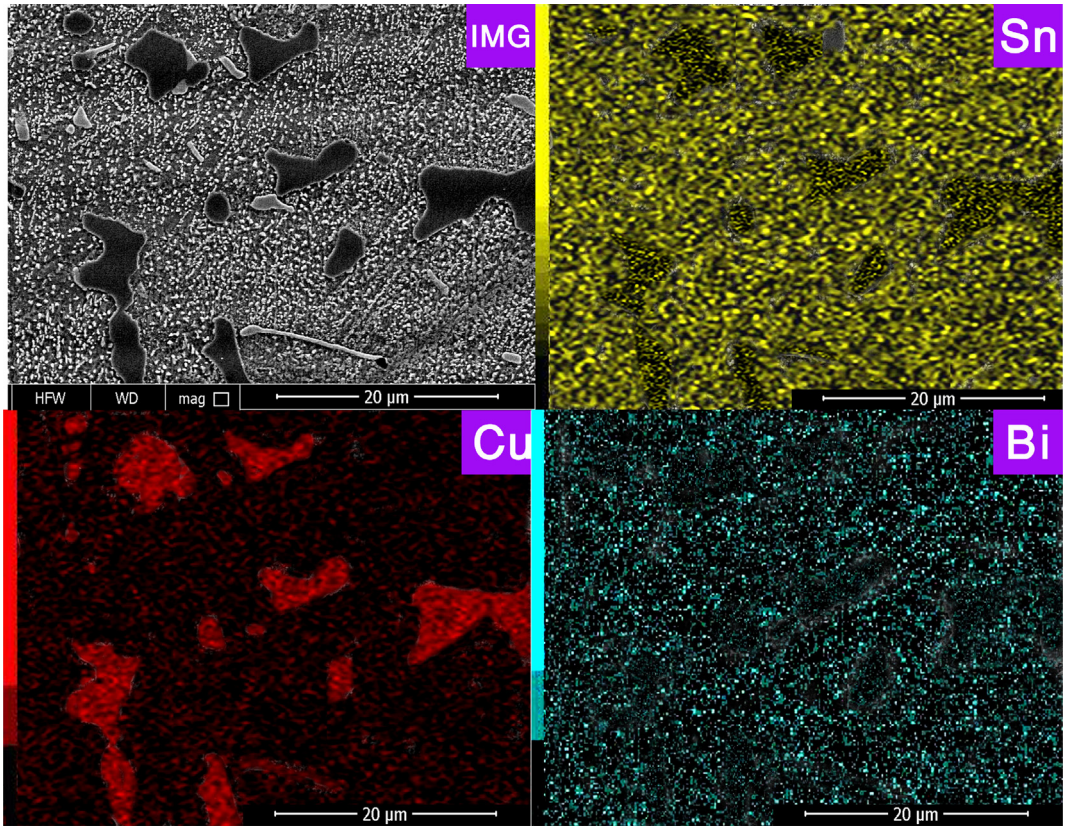

Fig. 7. Microstructure and element mapping of the Sn-Bi-Cu solder bulk.

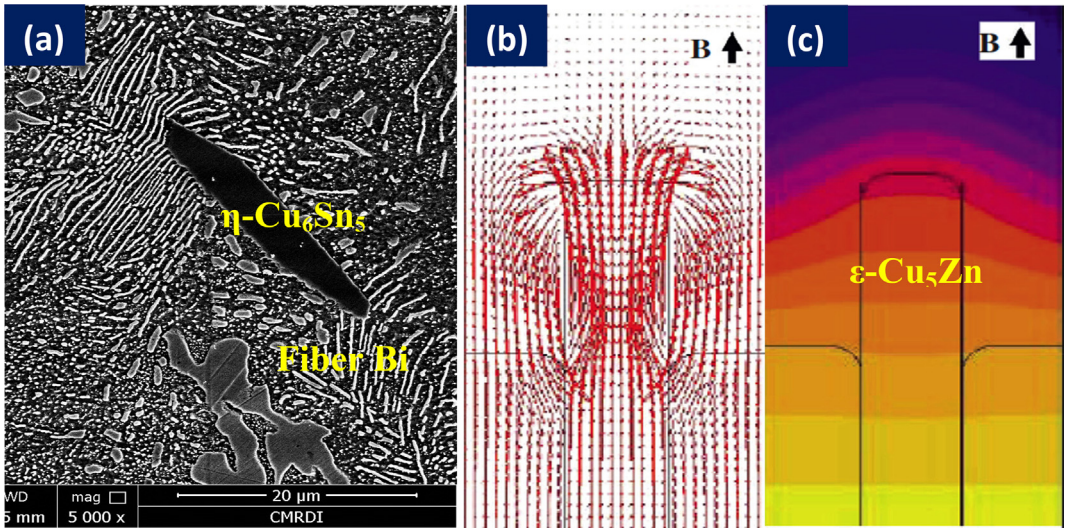

Fig. 8. Comparison between the microstructure of present study and the previously computed thermoelectric effects around the modeled liquid–solid interface during directional solidification of ε-Cu_5Zn phase: (a) typical distribution of Bi particles around the liquid–solid interface of Sn-20Bi-0.4Cu solder during solidification under a 0.5 T magnetic field; (b and c) are the thermoelectric current streamlines near the interface (in Am^{-1}) and thermoelectric power (in V) obtained for Zn–Cu alloys under a 1.0 T, supporting the present experimental evidences and reprinted from Ref. [27] with permission, Copyright 2014, Elsevier.

mechanisms but this time the mechanism was obtained experimentally in the present work of Sn-20Bi-0.4Cu melt alloys.

3.2. Elastic properties

The prediction of overall elastic response and local damage mechanisms in alloy materials, in particular lead-free solders, is very complex problem, since the microstructural aspects of solder play important roles in the deformation behavior. Hence, the response of alloy crystals to external applied force, as characterized by Young's modulus (*E*), shear modulus (*G*), bulk modulus (*K*), hardness (*H*), attenuation coefficient(α) and Poisson's ratio (υ), could play a vital role in determining its mechanical properties.

3.2.1. Effect of solidification microstructure on ultrasonic velocities and density

Experimental values of density and ultrasonic wave velocities (longitudinal & shear) propagating in [1 0 0] and [1 1 1] directions are listed in Fig. 9 and Table 2. It can be seen for Sn-20Bi and Sn-20Bi-0.4Cu alloys without PMS that the longitudinal velocities were 3157 ± 4 and 3160 ± 4 m/s, whereas the shear velocities were 1432 ± 11 and 1519 ± 11 m/s, respectively. It is interesting to note that, the shear velocity is more affected than the longitudinal velocity by the Cu addition due to the microstructural variation and formation of Cu_6Sn_5 IMC in the ternary alloy. This indicates that the error in shear velocity measurement is less than that of longitudinal velocity, since the transient time of shear velocity is about double of that of longitudinal velocity for the same thickness of specimen. Similar remarks were obtained by Stella et al. [31] who established that the conventional ultrasonic longitudinal velocity measurements do not allow precisely estimation of any microstructural change between AISI 304 stainless steel materials with different degrees of sensitization. The obtained results indicate that shear velocity is better parameter for detecting the microstructural change as compared to longitudinal velocity. Additionally, the PEO method is sensible and reliable for evaluating the elastic properties.

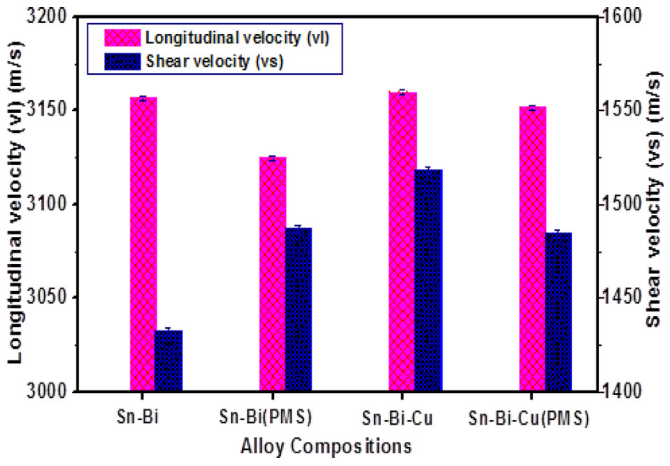

Fig. 9. Variation of ultrasonic wave velocities (longitudinal V_l and shear V_S) with alloy composition.

With performing PMS on both alloys during solidification, longitudinal velocities were 3125 ± 4 and 3152 ± 4 m/s, whereas the shear velocities were 1487 ± 11 and 1485 ± 11 m/s, respectively. As seen, no visible change in the shear velocities or longitudinal velocities was observed due to the similarity of microstructure of both alloys when PMS was performed (see Fig. 3). In other words, there was little difference in the longitudinal or shear velocities between Sn-20Bi and Sn-20Bi-0.4Cu alloys with applying PMS. Conversely, the observed increase or decrease of the density values should not be correlated only with the distribution and volume fraction of the newly developed phases in solder alloys, but also with their axial ratio and porosity content of these solders.

Table 2
Ultrasonic wave velocities (longitudinal Vl and shear Vs) and density(ρ) of the alloys.

Alloy	Vl (m/s)	Vs (m/s)	ρ (Kg/m^3)
SnBi	3157 ± 4	1432 ± 11	7609.5 ± 5
SnBi(M)	3125 ± 4	1487 ± 11	7645.0 ± 5
SnBi-0.4Cu	3160 ± 4	1519 ± 11	7651.8 ± 5
SnBi-0.4Cu (M)	3152 ± 4	1485 ± 11	7608.8 ± 5

3.2.2. Effect of solidification microstructure on hardness (H) attenuation and coefficient (α)

Hardness plays an important role in solder materials to provide a measure of alloy resistance against plastic deformation. Hence, all factors that affect the dislocation mobility may influence the hardness value of Sn-20Bi and Sn-20Bi-0.4Cu alloys. The results in Fig. 10 and Table 3 illustrate that the *H* value of Sn-20Bi was increased from 1.3479 ± 0.1to 1.6481 ± 0.1 (~22%) after applying PMS during solidification. For a given solder, applying PMS leads to small inter-particle spacing of Bi fibers that act as hard inclusions in a soft matrix, and results in higher stresses for dislocation mobility through the matrix and high hardness value (Fig. 4). On the contrary, for Sn-20Bi-0.4Cu alloy the *H* value was decreased from 1.7697 ± 0.1to 1.5978 ± 0.1 (~11%) after performing PMS. The fine dot Bi phase in eutectic structure and increasing the initial status of Cu_6Sn_5 IMCs precipitates could result in greater solder matrix hardness of Sn-20Bi-0.4Cu alloy before applying PMS compared to the Sn-20Bi-0.4Cu sample after performing PMS, as shown in Fig. 5a. As the fine dot Bi phase transformed into wide Bi fibers in addition to the Cu_6Sn_5 IMCs precipitates are reduced with the PMS (Fig. 5b), the solder hardness is decreased accordingly. Similar observations were also obtained in literature data by Tan et al. [32], in which smaller β-Sn phase and finer eutectic structure resulted in greater solder matrix hardness.

The calculated results of attenuation coefficient α in Fig. 10 illustrate that the α-value of Sn-20Bi was increased from 0.97 to 1.81 dB/m (the enhanced effect on α was ~87%), while decreased from 1.71 to 0.59 dB/m (the diminished effect on α was ~290%) for Sn-20Bi-0.4Cu alloy after applying PMS during solidification. The results summarized in Figs. 2–5 confirm the hypothesis that the attenuation coefficient arises in Sn-20Bi and decreases in Sn-20Bi-0.4Cu specimens after applying PMS not only due to the microstructural component size of each alloy, but also through multiple modifications that befall simultaneously as a result of applying PMS. The intensity reduction of ultrasonic wave through the whole sample is therefore not established from the scattering wave caused by a variation of alloy composition. After applying PMS on the binary and ternary alloys, both the precipitation of Bi particles and other microstructural changes of Cu_6Sn_5 IMCs are expected to affect the intensity reduction of ultrasonic wave, especially the modification of inter-particle spacing and average particle size. It can also reduce the opportunity of fillet lifting phenomena in Sn-20Bi specimen and the affinity towards porosity as well as hot tearing caused by the influence of alloy shrinkage [33].

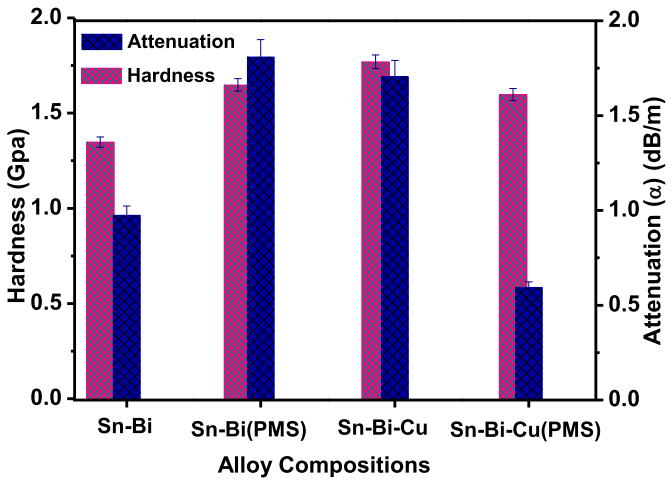

Fig. 10. Attenuation coefficient (α) and Hardness value (*H*) for Sn-20Bi and Sn-20Bi-0.4Cu alloys with and without PMS.

3.2.3. Effect of solidification microstructure on Poisson's ratio and elastic moduli

Young's modulus *Y* and Poisson's ratio *ν* are important parameters for technological applications. They can resolve the response of crystalline material to external forces, and realize the relationship between structural characteristics and associated mechanical properties. The first one provides a global macroscopic view of material stiffness, since it defines the inter-atomic bonding energies and connectivity [34]. The second, the Poisson's ratio quantifies the material's resistance to dilatation and shearing depending on the compressibility of solders. It has a value of between 0 and + 0.5. The larger the value of *ν* is, the more ductile the alloy becomes [20]. As a result, these investigations will offer a valuable guidance for analysis and alloy design. Figs. 11 and 12 show the results of elastic moduli and Poisson's ratio of Sn-20Bi and Sn-20Bi-0.4Cu alloys with and without PMS. Young's modulus of pure Bi and Sn, with modulus of 25.89 GPa [35] and 44.62 GPa [36] respectively, are employed for comparison. With applying PMS, the Young's modulus increased from 42.7725 ± 0.1to 45.7483 ± 0.1 GPa for Sn-20Bi alloy, while it decreased from 47.6711 ± 0.1to45.5746 ± 0.1 GPa for the Sn-20Bi-0.4Cu alloy. However, the Sn-20Bi-0.4Cu system without PMS showed greater elastic modulus than Sn-20Bi solder due to the formation of Cu_6Sn_5 IMCs in the ternary alloy. After applying PMS, Young's modulus was the same for both alloys (~45.5746 ± 0.1 GPa). It infers that any increase or decrease of Young modulus with/without PMS should be an intrinsic property of the shape, size and distribution of phases owing to the characteristics of inter-atomic force and the connectivity of these components. Therefore, it can be decided that the origin of elastic modulus in both solders was related to the microstructural changes induced by PMS.

As well, the bulk modulus (52.1145 ± 0.3 GPa) of Sn-20Bi alloy with PMS is fairly smaller than 55.0198 ± 0.3 GPa without PMS of the same alloy. It implies that the incompressibility of Sn-20Bi alloy was reduced with applying PMS, although it slightly increased for Sn-20Bi-0.4Cu with applying PMS. However, in Table 3, it is interesting to note that the elastic constants are decreased with increasing Poisson's ratio, and they were a minimum when Poisson's ratio was maximum. Poisson's ratio also can quantify the structural stability of solder against shear. The calculated results denoted that Sn-20Bi-0.4Cu without PMS showed the lowest tenacity due to the smallest value of Poisson's ratio. The variation feature of Poisson's ratio for Sn-20Bi alloy system with Cu content or effect of PMS in the present calculation were in agreement with the experimental values of these solders [19]. For Sn-20Bi solder, the average Poisson's ratio is identical to the Sn-20Bi-0.4Cu system when PMS was performed, although it was decreased from 0.3704 to 0.3496 when Cu was added to Sn-20Bi solder. This infers that a higher ionic contribution in the inter-atomic bonding for these solders should be expected [20].

The ratio of G/B introduced by Pugh is of high interest [20], as it can point to the path to engineering alloy design and predict its brittleness and ductility behavior. It has been supposed that the critical value separating ductility from brittleness is about 0.571. i.e., if G/K is more than 0.571, the alloy behaves in a brittle manner; otherwise the alloy behaves in a ductile manner. The calculated results of Table 3 showed that the entire solders are behaves in a ductile manner, although Sn-20Bi without PMS had better ductility and Sn-20Bi-0.4Cu without PMS had the lower one.

3.3. Electrical resistivity of solder alloys

The variation of electrical resistivity of plain Sn-20Bi solder with Cu addition and/or applying PMS is shown in Fig. 13. The resistivity value of Sn-20Bi solder was firstly increased from 13.5 μΩ.cm to

Table 3
Experimental values of hardness (H), Young's modulus(Y), Poisson's ratio (υ), shear modulus (G), Attenuation coefficient (α) and bulk modulus (K).

Alloy	H (Hardness) (GPa)	Attenuation (α) (dB/m)	Y (Young modulus) (GPa)	υ (Poisson's ratio)	G (Shear modulus) (GPa)	K (Bulk modulus) (GPa)	(G/K) ratio
SnBi	1.3479 ± 0.1	0.97	42.7725 ± 0.1	0.3704	15.6055 ± 0.1	55.0198 ± 0.3	0.2836 ± 0.008
SnBi(M)	1.6481 ± 0.1	1.81	45.7483 ± 0.1	0.3536	16.8976 ± 0.1	52.1145 ± 0.3	0.3242 ± 0.008
SnBi-0.4Cu	1.7697 ± 0.1	1.71	47.6711 ± 0.1	0.3496	17.6601 ± 0.1	52.8563 ± 0.3	0.3341 ± 0.008
SnBi-0.4Cu (M)	1.5978 ± 0.1	0.59	45.5746 ± 0.1	0.3572	16.7894 ± 0.1	53.2076 ± 0.3	0.3155 ± 0.008
Bi	–	–	25.89 GPa [35]				
Sn	0.145	–	44.62 GPa [36]				
Sn–9Zn–0.5Ag–0.7Cu	–	–	43.66 GPa [36]				

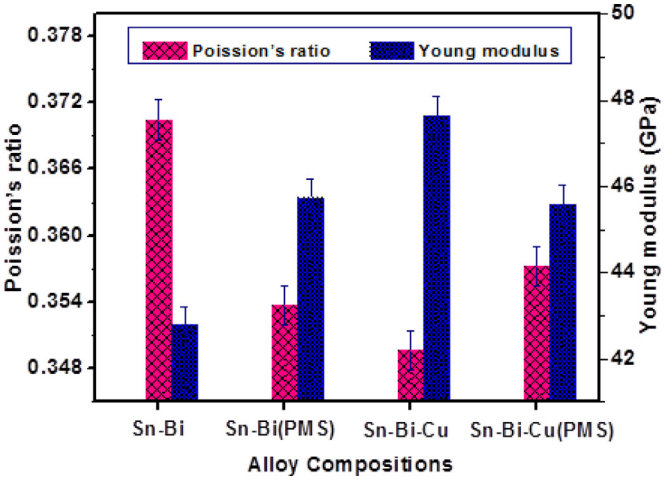

Fig. 11. Poisson's ratio (ν) and Young modulus (E) for Sn-20Bi and Sn-20Bi-0.4Cu alloys with and without PMS.

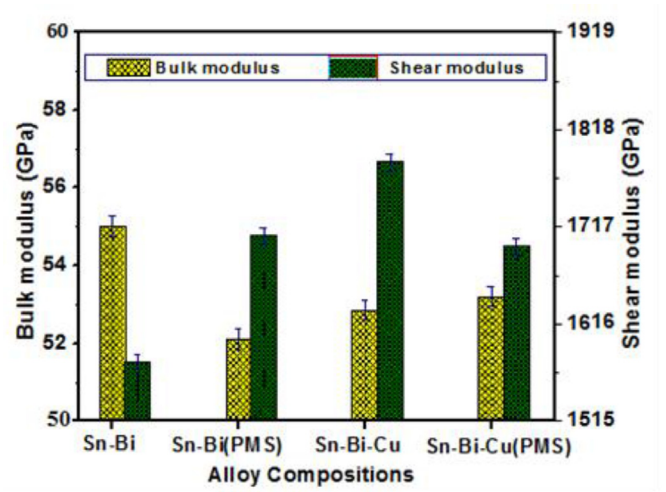

Fig. 12. Bulk modulus (K) and Shear modulus (G) for Sn-20Bi and Sn-20Bi-0.4Cu alloys with and without PMS.

18.2 μΩ.cm with addition of 0.4 wt% Cu, but it slightly increased to 15.8 μΩ.cm with applying PMS. In solder alloys, the electrical resistivity are affected by a combination of several issues consistent with Matthiessen's rule; (i) impurity atoms, (ii) formation of IMC particles, (iii) shape, type and size of IMC particle, (iv) volume fraction of IMCs and (v) solubility limit of solute phases. Alloying elements such as Cu, for instance, could induce an additional lattice-stain scattering in Sn-20Bi-0.4Cu solder due to formation of Cu_6Sn_5 IMC particles [36]. But the degree at which the lattice-strain

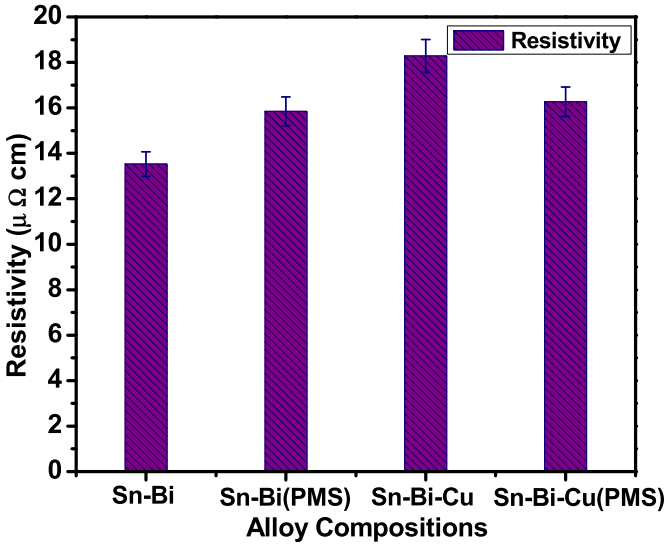

Fig. 13. Electrical resistivity values (ρ) for Sn-20Bi and Sn-20Bi-0.4Cu alloys with and without PMS.

scattering could affect the resistivity value depends on the shape and size of Cu_6Sn_5 particles. Hence, the observed increase of resistivity with Cu addition could be correlated with the increase in the size of Cu_6Sn_5 particles, which has higher electrical resistivity value (17.5 μΩ cm) than that of Sn-matrix (12 μΩ cm) [36]. According to the Norbury-Linde rule [37], the residual resistivity initiated by the lattice-strain scattering is proportional to the square of the valence electron difference between solute and solvent, $(\Delta VE)^2$. In case of Sn-20Bi-0.4Cu solder, the magnitude of $(\Delta VE)^2$ is 1 for Bi and 9 for Cu. Hence, to a first approximation, a 0.4Cu substitution in β-Sn matrix would be energetic to increase the bulk resistivity of ternary alloy sample, whereas a great amount of Bi would ensure a small effect even though the pure Bi has a resistivity value of 129 μΩ cm [38].

Alternatively, with applying PMS the observed refinement of Bi particles in Fig. 3 could result in slightly increase of resistivity value of binary Sn-20Bi solder whereas, the resistivity value of ternary Sn-20Bi-0.4Cu solder is decreased to 16.2 Ω cm after applying PMS since the increased number of fine-dot Bi particles is transformed into fiber-like Bi particles with large inter-particle spacing (Fig. 5). The large number of fine-dot Bi particles leads to a large number of scattering centers for conduction electrons, which in turn diminishes the mean free path and hinders the motion of conduction electrons, and hereafter raises the resistivity value. The results also showed that the electrical resistivity of the bulk Sn-20Bi solder (13.5 μΩ.cm) was slightly higher than that of pure Sn (12.0 μΩ.cm), which contributes to the high solubility limit of Bi atoms. However, the present results also indicated that the electrical resistivity of the entire solders was comparable to the published value of SAC solders (13.2 μΩ.cm) and Sn–Ag solder (15.4 μΩ.cm) [35,39].

4. Conclusions

The following conclusions can be drawn from the present experimental investigation:

The results established that the addition of 0.4 wt %Cu alloying element dramatically reduces the dendrite grain size but not alters the columnar dendrite behavior of β-Sn phase in Sn-20Bi solder alloys and produced novel polymorphs Cu_6Sn_5 IMC phase. On contrary, the PMS-driven flow applied played a key role in controlling the final length scale of solidification microstructures via its impact on nucleation and growth process during solidification. For the compositions studied, fragmentation and CET of β-Sn dendrites occurs due to the forced melt convection, which facilitates the increased number of nuclei from broken dendrites. Consequently, the PMS induced Lorentz force and magnetic moment E_m arising from the magnetic crystalline anisotropy. Equally, the thermoelectric current will be created at the liquid–solid interface and at the tip of Cu_6Sn_5 interface. The interaction between the induced thermoelectric current and magnetic field will generate a thermoelectric magnetic force, which may induce a torque that disturbs the dendrite and rotate of the dendrite fragments ahead of the liquid–solid interface. In contrast to Sn-20Bi-0.4Cu solder, both the hardness and elastic modulus are increased as the Poisson's ratio decreased for Sn-20Bi solder with PMS. Moreover, the Pugh ratio clarified the ductility behavior of the alloy samples, while Poisson's ratio and electrical resistivity display slight decrease in the ionic contribution with applying PMS and/or Cu content.

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Intelligent decision system for responsive crisis management

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Abstract: Disaster mitigation of severe catastrophic events depend heavily on effective decisions that are made by officials. The goal of disaster management is to make decisions that properly reallocate and redistribute the scarce resources produced by the available interconnected-critical infrastructures (CI's). This paper investigates the application of Monte Carlo (MC)-based policy estimation in reinforcement learning (RL) to mount up experience from

a massive number of simulations. This method, in conjunction with an optimised set of RL parameters, will help the RL agent to explore and exploit those trajectories that lead to an optimum result in a reasonable time. It shows that a learning agent using MC estimation policy, through interactions with an environment of simulated disastrous scenarios (i2Sim-infrastrucuture interdependency simulator) is capable of making informed decisions for complex systems in a timely manner.

Keywords: artificial intelligence; critical infrastructure; disaster management; i2Sim real-time simulator; reinforcement-learning agent; responsive crisis management; Monte Carlo policy estimation; decision support system; agent based modelling; machine learning.

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1 Introduction and overview

1.1 Introduction

The ability to utilise the available limited resources of any urban community during disaster is crucial for human lives and economy. Therefore, optimal decisions that are taken by executives at similar situations will strongly affect the mitigation of any catastrophic event. In this paper, we describe an intelligent decision system (IDS) that consists of an integration of the reinforcement learning (RL) and the infrastructure-interdependency simulator (i2Sim). The integrated system is capable of assisting the emergency responders to make informed decisions in an effective time. It does so, by sensing the surrounding environment and performing actions that effectively reallocate the available resources with a goal of optimising some output, which in the case of disasters is the total number of discharged patients (DPs) from emergency units.

Previous work shows that system output was optimised using a RL agent called DAARTS. DAARTS was modelled using a temporal difference (TD) learning mechanism for learning a policy in RL. Nevertheless, in this work, the optimisation method is done using other RL mechanism called Monte Carlo (MC). The RL agent IDS uses MC to optimise a modelled output that is the total number of DPs. It is observed that, within our architecture, IDS provides a significant advantage over DAARTS in terms of computation time. This improvement is attained in conjunction with proper

selection strategies of RL learning parameters. Such advancement aimed in effectively mitigating devastation within a desirable time span.

1.2 Response crisis management framework

The horrific consequences on the national economy and security caused by, for examples, Haiti earthquake in 2010, Great Eastern Japan earthquake in 2011, Hurricane Sandy, USA in 2012 and Typhoon Haiyan, Philippines in 2013 are disastrous events in the human history. These deadly incidents reveal the need for an efficient planning and coordination at every level of the crisis response management process and particularly at the decision-making level (David Rubens Association, 2011). Therefore, effective decisions to properly allocate the scarce resources within the available interconnected critical infrastructures (CIs) systems are required for disaster mitigation.

Chosen decisions that are made on the basis of sound knowledge and experience in the context of interconnected CIs are vital. The reallocation activities of the available limited resources can strongly influence in death mitigation and disaster devastation following a disaster. Luckily, the worldwide frequency of such situations is low. The probability of the same command and control personnel encountering similar scenarios over and over again is slim. Therefore, a compounded experience is always appreciated and needed in such cases. This is the premise of this study and we maintain that such decisions need to be closely studied and pre-measured prior to implementation. Additionally, these decisions need to be monitored and modified as the situation evolves.

In this paper, we propose an IDS that is controlled by an experienced agent who is able to interact continuously with a simulated environment. This interaction is defined in the form of sensing the physical operability [physical mode (PM)] and the resources availability [resource mode (RM)] of the CIs and then learning to perform those actions that would lead to the best-case desired outcome (total number of DPs from emergency units). The agent behaviour is trained using the RL (Barto and Sutton, 1998). The core function of RL is to discover a policy that optimises a long-term reward, which here is the total number of DPs. i2Sim is used to simulate the environment that RL agent is going to interact with. Although, we used i2Sim to study and analyse the consequences of a fast-evolving catastrophe, i2Sim is designed to simulate the slow scenarios as well, similar to those described in (Calida and Katina, 2012).

1.3 Literature review

The history of RL is full of real applications. A list of these applications is presented in a chronicle order as follows. Probably, the most famous one is Backgammon (the board game). In this case, Tesauro (1992) applied TD learning mechanism on this board game. O'Neil et al. (2010) presented a residential demand response application to reduce power energy cost and smooth its usage. Yu et al. (2012) demonstrated a distributed multi-step learning (DQ(λ)L) algorithm for solving a large-scale multi objective optimal power flow problem. Wiering and Dorigo (1998) presented a framework of an intelligent system to allow the decision makers to mitigate the consequences of any natural or human made disaster (e.g., forest fires). Abdolmaleki et al. (2011) suggested an approach to find the optimal policy of fire extinguishing task for fire brigade using TD learning. Thapa et al.

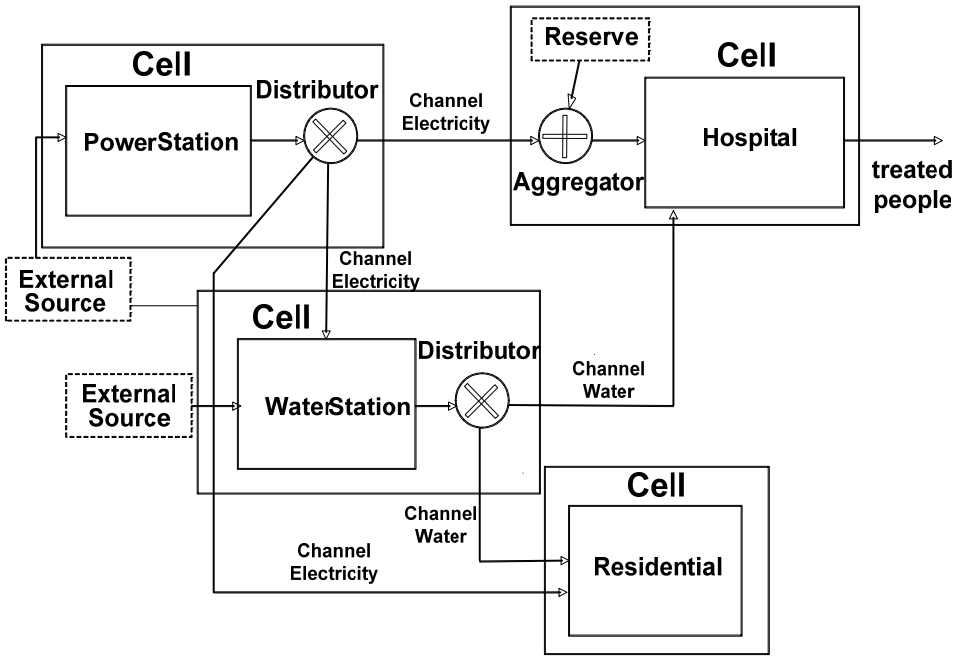
(2005) proposed an agent-based model for patients in emergency circumstances used to offer an accurate diagnosis and exact treatment in appropriate time for high-risk patient during emergency. Martínez et al. (2006) proposed an evolutionary reinforcement-learning model for search and rescue tasks used to support the decision-making of a central agent on a complex victim rescue problem. Su et al. (2011) proposed a path selection algorithm for disaster response management in which disaster responders were able to discover the fastest and the shortest path to the targeted locations. Khouj et al. (2014) used TD in RL platform in conjunction with i2Sim to simulate the impacts of a major disruption, earthquake, on the modelled CIs.

2 System description

2.1 IDS framework

The IDS platform consists of two parts in which the learning system in conjunction with a simulated interdependent CI environment is integrated. A real-world scenario based on a city scale model of Downtown Vancouver is considered and represented using i2Sim (a MATLAB/Simulink-based CIs simulator). The learning agent is developed using JAVA. Both the learning agent and i2Sim models are connected through a platform interface to form the IDS. This system interacts with a modelled environment that is disrupted by a major catastrophic event, which in this case is an earthquake. Accordingly, number of consequences will be experienced and captured as the scenario progress.

Figure 1 Example of i2Sim modelling elements



i2Sim is a hybrid discrete-time simulator that combines agent-based modelling with input-output production models through designated channels as shown in Figure 1. The simulator can model and play out scenarios involving interdependent systems and is able to model interdependencies between critical facilities. i2Sim is designed as a real-time simulator that can also serve as a decision support tool while a disaster is occurring. The simulation capability of i2Sim enables decision makers to evaluate the predicted consequences of suggested actions before the actions are taken (Marti et al., 2008a).

In i2Sim, each cell performs a function. A function relates the outputs to a number of possible operating states (PM and RM) of the system. At every operating point along the event timeline, the idealised i2Sim description corresponds to a system of discrete time equations called the transportation matrix (Figure 2). This matrix conceptualises the interdependencies existing between the simulated quantities (Marti et al., 2008b).

Figure 2 An example of a system transportation matrix showing interdependencies among infrastructures

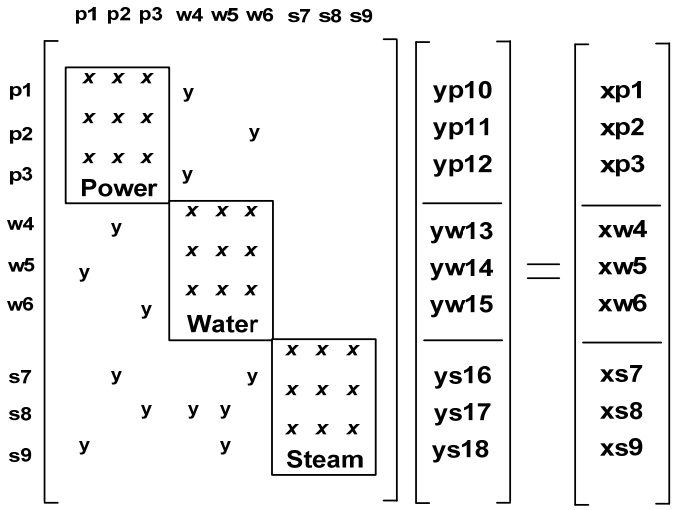
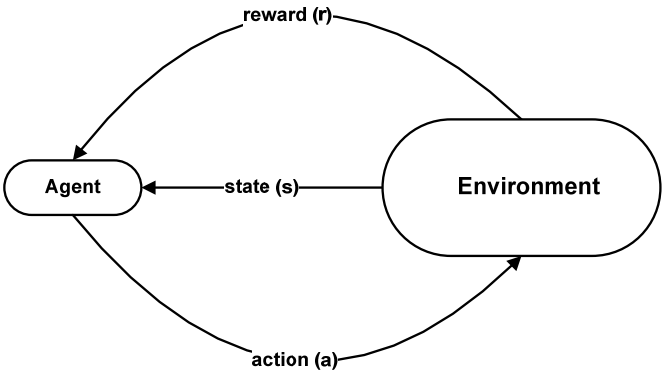


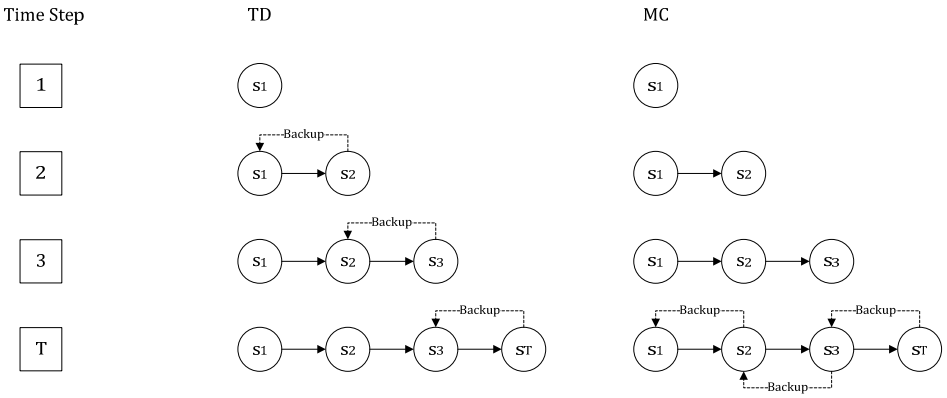
Figure 3 Structure of the learning



The learning agent is constructed using RL. RL is a machine-learning technique based on interactions between an agent and its surrounding environment (Barto and Sutton, 1998). These interactions help an RL agent to maximise a time delayed goal in the presence of uncertainties. The principle underlying RL is that it learns through accumulation of experience, in which it gets developed based on a feedback signal that the RL agent receives. This signal defines a performed action at a given state (policy) based on a return (reward) (Figure 3). The state transitions in RL are typically modelled as a finite Markov decision process (Nissen, 2007). The goal of RL is to determine the policy using an action-value function through the acquired experience that leads to the best long-term reward, which corresponds to the best trajectory using DPs, TD or MC.

In this paper, we apply MC for policy estimation. It is the trajectory that identifies actions, which best mitigate casualties. This recursive-learning algorithm uses incremental episode-by-episode back-ups to solve the Bellman equation (Barto and Sutton, 1998). As opposed to TD, in which back-ups are step-by-step (Figure 4). When applied within the architecture of our platform, MC helps to reduce the communication between JAVA (where the RL agent) and MATLAB (where the i2Sim environment) components of the learning system. The action-value function estimation can be implemented as a look up table (LUT). This table presents the estimation of the action-value function that is assigned to each state, action pair and gets updated as the learning proceeds. As a result, significant computational improvement is observed.

Figure 4 Backup processes in TD and MC

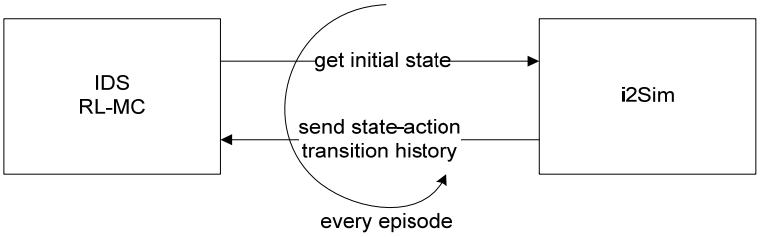


The originality of this research work lies on the fact of addressing the problem of decision-making in the context of problems involving *interconnected* and *interdependent* CIs in a reasonable time (opposes to RL-TD). Here, the objective of the RL-MC is to reduce the communication of the exchangeable information between the two-modelled systems. It is possible since RL-MC is less harmed by the violation of Markov property (does not perform bootstrapping). Having mentioned that, not only it is expected to speed up the computational process but also the ability to extend the modelled system to include more system variables. From a decision-making point of view, such improvements will generate the same optimum precise decisions but in shorter time.

In the RL-MC, the problem has been formulated as follows: the operating mode (PM and RM) of each modelled infrastructure unit represents the state of the targeted system.

The distribution ratio represents the actions that the agent will perform at any visited state. Both state-action pair is represented by a state-action value that estimates the probability of performing action 'a' at state 's'. It is the estimate that is determined by using average sampling return. Here, the return is the expected number of DPs at the end of each episode. It is applied only upon reaching the terminal state as depicted in Figure 5.

Figure 5 Systems interactions in IDS



The learning agent (IDS) is implemented in JAVA and communicates with the i2Sim environment realised in MATLAB. The communication is conducted via the MATLAB-JAVA interface, where the required information states (from i2Sim) and actions (from IDS) are exchanged. From i2Sim, IDS recognises the physical operability (PM) and the resource availability (RM) of the modelled CIs (state). Accordingly, from JAVA, IDS picks the best distribution ratios (action) that maximise the total number of DPs. In RL-MC approach each episode last about 3.25 minutes. This results in 1.9 times computational advantage over RL-TD, especially advantageous when more complex systems are observed.

2.2 IDS application

The Downtown Vancouver model consists of nine interdependent CI cells (Figure 6). These cells are modelled and connected to each other through channels (underground cable, transmission line, water pipes, road, etc.). The resources that are generated from different cells get aggregated or distributed to other interconnected cells by control elements called aggregators and distributors. A pre-defined scenario of an earthquake caused severe damage to the transmission lines towers is simulated. The capacity and the operating parameters (input variables) of the modelled entities such as production cells are obtained either from the available public domains or directly from the CIs managers.

The power infrastructure modelled as power stations is presented by four production cells CSQ, DGR, SPG and MUR in i2Sim using human readable table (HRT). HRT is a table that represents the operating modes of the substation transformers based on the input that comes from the high voltage feeders that are connected to the substation (Table 1 and Table 2). The stations are physically separated and geographically apart. Each one of the power substation supplies a specific amount of power to its interconnected CIs. For example, DGR and MUR are 336 MW and 586 MW two power substations presented in this model. Both substations supply the power to CIs that are connected to them.

Table 1 HRT and power distribution table of the MUR power substation production cell

Physical mode #1					
RM	*Output*			*Input*	
	Electricity [MW]			*Electricity [MW]*	
1	586.00			586.00	
2	439.50			439.50	
3	293.00			293.00	
4	146.50			146.50	
5	0			0	
Power distribution table					
Power action #	*VGH*	*Water station*	*GM*	*DGR*	*Residential*
1	100%	0%	0%	0%	0%
2	1.12%	1.82%	2.1%	57.34%	37.62%
3	1.12%	1.28%	2.1%	57.34%	38.16%
4	0%	100%	0%	0%	0%
5	0.84%	1.82%	2.1%	57.34%	37.80%
6	1.12%	1.82%	1.58%	43.00%	52.48%
7	0%	0%	0%	100%	0%
8	0.56%	1.28%	1.58%	43.00%	53.58%
9	0.28%	0.85%	1.58%	28.67%	68.62%
10	0%	0%	0%	0%	100%

Power supplied by power substations are distributed among the interconnected infrastructures such as hospitals, water pumping station and venues. The distribution mode of the available generated power depends on the switching arrangement of the power substations, the capacity of the outgoing feeders and the topology of the power distribution network. The power distribution tables (Table 1 and Table 2) used here by the power distributors is provided by the power distribution company. The 'distributor' component in i2Sim is assumed to operate instantaneously. This chosen decision (performed action) of which distribution mode is used, made by a decision maker (IDS in this case).

The distributed power is transmitted through the electrical 'channels'. Channels designated for power distribution are an abstraction of the real power mediums such as transmission lines or underground cables. No delay is incurred with electrical channels since electricity is carried at the speed of light.

Similarly, the water pumping station provides pumped water to the connected hospitals (VGH and SPH). The water station receives power from MUR power substation and water from an external source. The output of this modelled cell is high pressure pumped water that goes to a water distributor. The operation modes (PM and RM) of the water pumping station cell and the distribution ratios are indicated in the HRT tables (Table 3).

Table 2 HRT and power distribution table of the DGR power substation production cell

Physical mode #1			
RM	*Output*		*Input*
	Electricity [MW]		*Electricity [MW]*
1	336.00		336.00
2	210.00		210.00
3	105.00		105.00
4	84.00		84.00
5	0		0
Power distribution table			
Power action #	*BC*	*SPH*	*Residential*
1	2.98%	2.98%	94.05%
2	100%	0%	0%
3	0%	2.98%	97.02%
4	0%	100%	0%
5	2.98%	0%	97.02%

Figure 6 Downtown Vancouver model (see online version for colours)

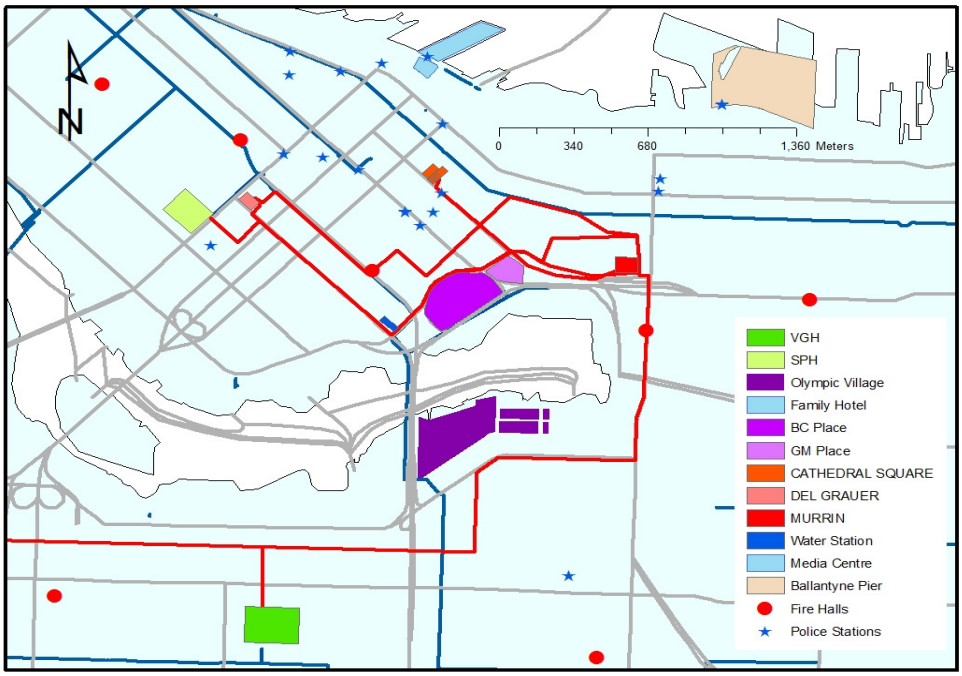


Table 3 HRT and distribution table of the water pumping station

Physical mode #1			
RM	*Output*	*Inputs*	
	Water [KL/hour]	*Electricity [MW/hour]*	*Water [KL/hour]*
1	103	0.01	103
2	77	0.008	77
3	52	0.005	52
4	26	0.003	26
5	0	0	0
Water distribution table			
Water action #	*VGH*	*SPH*	
1	100%	0%	
2	90%	10%	
3	80%	20%	
4	70%	30%	
5	60%	40%	
6	50%	50%	
7	40%	60%	
8	30%	70%	
9	20%	80%	
10	10%	90%	
11	0%	100%	

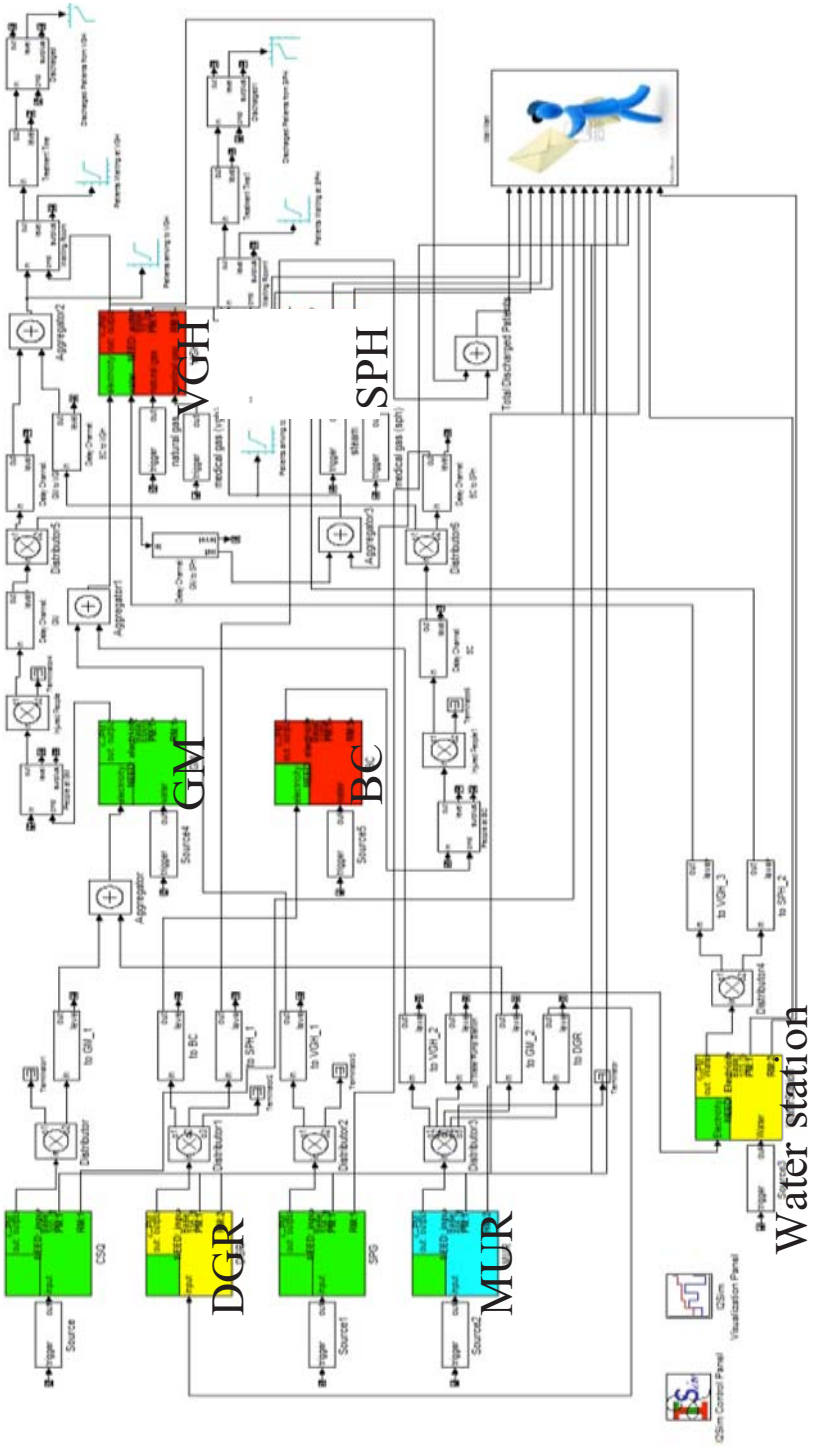
The simulated earthquake (Figure 7) caused severe damage to the towers that carry the power transmission lines. These transmission lines are the mediums that transmit the power to the MUR electrical power substation. Although, the PM of MUR was not affected however the RM was reduced due to this damage. Subsequently, because of the reduced electrical power, the water facility was not able to operate at full capacity and the amount of power delivered to the DGR electrical power substation was also compromised.

IDS will mentor three production cells DGR, MUR and the water pumping station. This extended system caused IDS' LUT size to grow drastically. Therefore, it is expected that IDS will need more time to discover the optimal trajectory.

The emergency units, at both VGH and SPH, were asked to continue to function under this compromised situation due to the limited water and power supplies. Here, the objective of IDS was to experience this scenario and to find a way to mitigate the impact to the emergency units at the hospitals.

IDS evaluates the environment and finds the best distribution settings of the three modelled distributors for power and water to the interconnected cells. Thus, IDS eventually optimise the total number of DPs from both medical units at the two hospitals.

Figure 7 i2Sim Downtown Vancouver mode (see online version for colours)



IDS implements the tabular form of the RL algorithm using MC policy estimation. The LUT is used to determine the action described by variable (α) shown in equation (1) that is adequate for the next state of the modelled environment. This action decides how to set the three distributors (MUR, DGR and water pumping station) based on the scaler (p_i and w_i) that are selected by the RL agent. Given an initially untrained LUT, the goal of the learning system is to find the optimal action to perform in each state (optimum trajectory). If available, real world experience could be used to initialise the LUT as a staring estimate of the optimum schedule.

$$a = \begin{bmatrix} p_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & p_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & p_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & p_4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & p_5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & p_6 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & p_7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & p_8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & w_1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & w_2 \end{bmatrix} X \begin{bmatrix} DGR_{distributor_{BC}} \\ DGR_{distributor_{SPH}} \\ DGR_{distributor_{Others}} \\ MUR_{distributor_{YGH}} \\ MUR_{distributor_{Water}} \\ MUR_{distributor_{GM}} \\ MUR_{distributor_{DGR}} \\ MUR_{distributor_{Others}} \\ Water_{distributor_{YGH}} \\ Water_{distributor_{SPH}} \end{bmatrix} \quad (1)$$

The state of the environment is a vector representing the PM's and RM's of the production cells at any given time shown in equation (2).

$$S = \begin{bmatrix} PM_1RM_{1_{DGR}} & PM_1RM_{1_{MUR}} & PM_1RM_{1_{Water}} & a_1 \\ PM_1RM_{1_{DGR}} & PM_1RM_{1_{MUR}} & PM_1RM_{1_{Water}} & a_2 \\ \vdots & \vdots & \vdots & \vdots \\ PM_1RM_{1_{DGR}} & PM_1RM_{1_{MUR}} & PM_1RM_{1_{Water}} & a_{10} \\ PM_1RM_{1_{DGR}} & PM_1RM_{1_{MUR}} & PM_1RM_{1_{Water}} & a_{11} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ PM_1RM_{1_{DGR}} & PM_1RM_{1_{MUR}} & PM_1RM_{1_{Water}} & a_{550} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ PM_1RM_{1_{DGR}} & PM_1RM_{1_{MUR}} & PM_1RM_{1_{Water}} & a_{550} \end{bmatrix} \quad (2)$$

According to proposed model, a set of chosen action will be initialised by IDS. It is a list that determines what action to encounter at every state within an episode. This list will be sent through the interface to i2Sim. In i2Sim environment, these actions are then applied on the distributors that are connected to the mentored cells. At the end of every episode, an informative list of the environment will be forwarded to IDS. This list defines the states of the modelled environment, the chosen actions at these states and the total number of DPs associated with these performed actions. IDS will use this list to create LUT. There will be multiple (state, action) entries that apply (same state but each with a

different action). Then IDS will employ a greedy policy, i.e., IDS will choose the (state, action) that corresponds to the largest value of the action-value function or pick it randomly if performing exploratory learning. The largest value represents the action that is likely to lead to the most optimal trajectory, which leads to long-term average sampling reward. Then IDS will take the corresponding action and determine the reward. Here, the reward is a function of the number of patients discharged and in this model terminal and immediate reward are computed. The immediate reward is applied at every time step by determining the difference of DPs between the current and previous states. For the terminal reward, it is calculated and applied at the final time step only (terminal state) based on the total number of DPs from both emergency units. Finally, IDS updates the previous action-value function accordingly.

A test of 100 episodes was used to train IDS. Each episode represented a 10-hour period following a catastrophic event. Such event caused sudden changes on the PM's of the targeted cells. It is the change that determines the deterioration in the PM's values with respect to its nominal conditions. Following the event, no further changes were made in the state of damage of the modelled CIs. However, the associated RM's are altered as the situation evolves. These frequent changes in the operating modes of the interconnected CIs and the corresponding reallocation decisions of the available resources are captured by the LUT. As learning proceeds, the contents of LUT are updated as IDS converges towards an optimal policy.

2.3 Learning parameter selection using ordinal optimisation

The ordinal optimisation (OO) approach was demonstrated using OO. Here, the learning parameters' selection is treated as an optimisation problem where the objective is to find a set of parameters with the best learning performance. The effectiveness of the learning operation is controlled by three parameters, learning rate α, discount factor γ and exploration rate (ε). It is suggested that these values have to be carefully selected for best convergence.

Since simulation is the only way to evaluate the performance of each parameter set, a simulation-based optimisation technique, OO, is selected. OO is an optimisation technique for solving discrete event simulation problems with huge search space (Ho et al., 2008). OO uses a probabilistic approach to identify a set of good enough solutions with a given level of confidence. It has various applications in different disciplines such as resources allocation in manufacturing systems (Hsieh et al., 2001), parallel distributed computing (Chen et al., 2000), and power systems (Guan et al., 2001). OO deals with problems that have exponential growth in search space and computational complexity in simulation models. The learning parameter selection process has such properties. This is because the search space of the parameters is huge, and it requires an extensive computational effort to evaluate the performance of each parameter set.

OO is based on two main concepts:

1 Order comparison: it is easier to determine order than value, i.e., determining A > B is easier than calculating A – B.

2 Goal softening: we look for good enough solutions with high probability instead of looking for the best for sure.

The application of OO for the learning parameters' selection is shown in Figure 8. In the OO algorithm, a crude model is used to evaluate the performance of each learning set. The idea here is to 'order' the learning sets based on their performance using an estimate model with less computational effort than the actual simulation environment. A Java version of i2Sim was used as a crude model in this step. Learning sets were evaluated and ordered according to the following performance function:

$$P = w_1 * E_p + w_2 TS \tag{3}$$

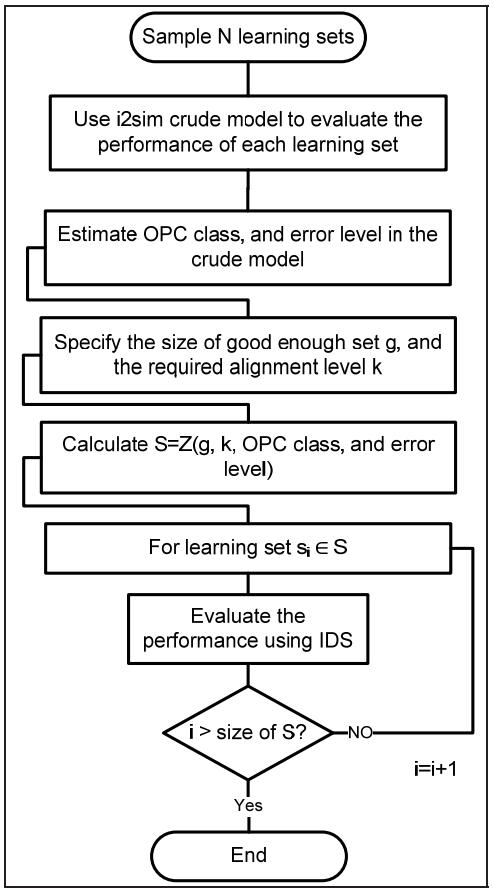
where

E_p is the episode number where the modelled patients are fully discharged

TS is the time step number required to discharge the whole patients within the E_p

w_1 and w_2 are weights, chosen to be 0.75 and 0.25 respectively for better normalisation.

Figure 8 OO algorithm for selecting learning parameters



After estimating the performance of the learning parameters, the ordered performance curve (OPC), shown in Figure 9, is generated. OPC is a conceptual plot of the solutions as a function of their ordered performance. The shape of the OPC plot contains

knowledge about how solutions are distributed in the search space. There are five classes of OPC curves: flat, steep, bell, U-shaped, and neutral (Ho et al., 2008). After identifying the OPC class, the size of the selected set $S = Z(k, g)$, which will be evaluated using the actual simulation environment, is determined using the following equation:

$$Z(k, g) = e^{Z_1} k^{Z_2} g^{Z_3} + Z_4 \tag{4}$$

where

Z_1, Z_2, Z_3 and Z_4 are constants of regression

k is the required alignment level

g is the size of the good enough set

k and g are OO parameters that are chosen to tune the search space of the problem.

Once the size of the selected set S is calculated, the top S solutions from the crude model evaluations will be selected and then evaluated by the actual model. The OO parameters used in this optimisation problem and the results are shown in Table 4.

Figure 9 OPC for the learning parameters (see online version for colours)

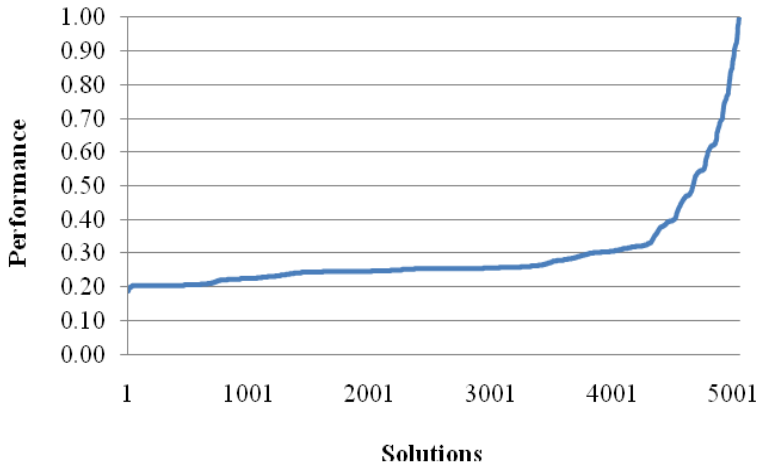


Table 4 OO parameters and results

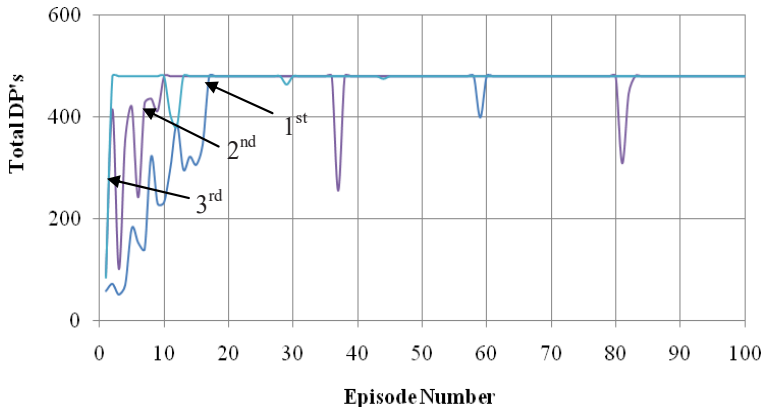
OPC class	Bell
Crude model error level	Low
Z_1	8.1998
Z_2	1.9164
Z_3	–2.025
Z_4	10
g	10
k	1
S	44
Result (α, γ, ε)	0.5, 0.6, 52

2.4 Model results

In this section, the learning behaviour of IDS was observed and analysed for two consecutive test cases. In the first case, IDS was asked to interact with an i2Sim environment. Then, IDS was introduced to an extended city scale model named Downtown Vancouver. The state of this modelled system is estimated to be 15 times larger than the first test case as described below.

For IDS, the RL agent is asked to interact with the i2Sim environment described in (Khouj et al., 2014). The goal of IDS is to find the optimum trajectory that leads to the optimum goal using RL-MC. Our expectation is that this approach will show an ability to converge towards the maximum number of DPs much faster. This is because, as determined earlier, each episode in RL-MC last about 3.25 minutes. In Figure 10, for three consecutive trials (initialised independently) IDS was able to converge to the optimum solution in less than 20 episodes. The total time required, to discover the optimum trajectory using the same-based computer, was estimated to be 65 minutes.

Figure 10 IDS learning behaviour using RL-MC (see online version for colours)



Both Figure 11 and Figure 12 show the behaviour of IDS before and after learning. In the first episode, as expected, a random behaviour was depicted by IDS in attempt to explore the surrounding environment. This was done by reallocating the available resources randomly. IDS realised that more patients were discharged from VGH. This explains why IDS diverted more resources to VGH over SPH. Such actions have improved the RM of VGH to RM_{VGH} = 2, which means higher DPs rate as per i2Sim VGH HRT. This improvement resulted in IDS discharging all patients from VGH in less than 60-time steps. Moreover, the decisions from IDS enabled SPH to continue its service with fewer resources. It should be stressed that both IDS and DAARTS used a set of RL learning parameters that was heuristically determined.

The previous results illustrate the potential of IDS as an assistance tool for CI managers. This is because IDS is able to complete the simulation in much faster than DAARTS (Khouj et al., 2014). A 10-hour simulation can be completed in about half the time of DAARTS. We are encouraged by these results and attempt to apply IDS to an extended city scale model such as Downtown Vancouver (Figure 13). The extensions of the Downtown Vancouver model are mathematically derived and explained in Table 5.

Figure 11 VGH RM profile (see online version for colours)

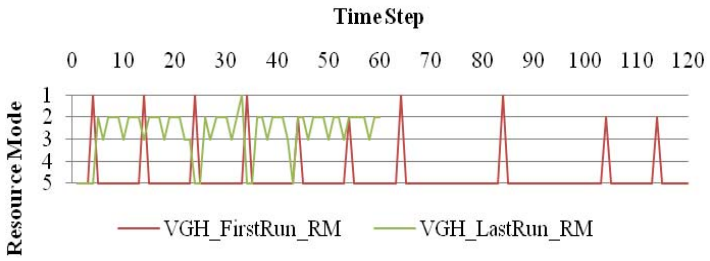


Figure 12 SPH RM profile (see online version for colours)

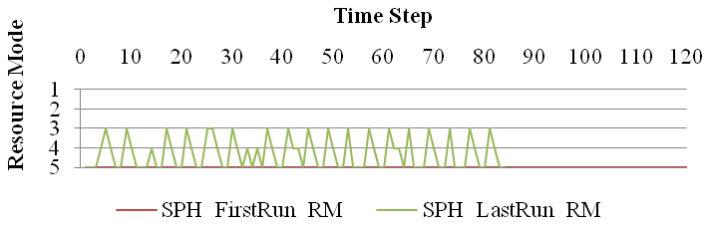


Figure 13 IDS within i2Sim Downtown Vancouver model (see online version for colours)

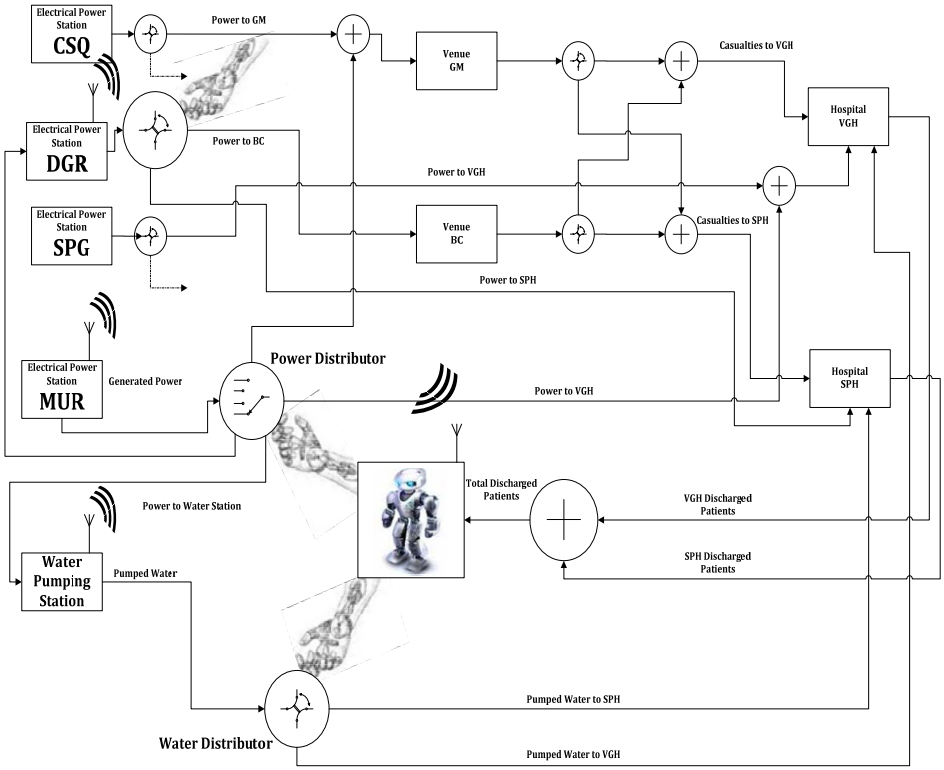


Table 5 IDS and DAARTS state space system comparison

System elements	*DAARTS*	*IDS*
State	$num_{states} = x^y = 15^2 = 225$	$num_{states} = x^y = 15^3 = 3{,}375$
Action	$num_{actions} = d_{MUR} * d_{Water} = 10 \times 11 = 110$	$num_{actions} = d_{DGR} * d_{MUR} * d_{Water} = 5 \times 10 \times 11 = 550$
LUT size	$num_{rows} = num_{states} * num_{actions} = 225 \times 110 = 24{,}750$	$num_{rows} = num_{states} * num_{actions} = 3{,}375 \times 550 = 1{,}856{,}250$
Time per episode	6.21 minutes	3.25 minutes

where

state represents the total number of states (PM's and associated RM's) of the modelled system

action represents the total number of combined actions of the controlled distributors

x represents the maximum possible number of RMs associated with each PM per production cell

y represents the number of production cells that are mentored by the RL agent

d_{DGR} represents the number of distribution ratios of the DGR power substation distributor

d_{MUR} represents the number of distribution ratios of the MUR power substation distributor

d_{Water} represents the number of distribution ratios of the water pumping station distributor.

The states and actions suggest a theoretical maximum size for the LUT of 1,856,250 rows. Each row of the table represents a state-action pair and the associated long-term average sampling return. It defines the state-action value for taking that action at that state. These state-action values get updated in every episode and ultimately get optimised for a policy. It is the optimised policy that distinguishes the ordinary from the optimum trajectories. Table 6 is a sample of the LUT being used for this model.

Table 6 Sample of IDS' LUT

(<State>, <Action>)	*Q(s, a)*
(<PM_{DGR}, RM_{DGR}, PM_{MUR}, RM_{MUR}, PM_{Water}, RM_{Water}>, <Dis_{DGR}, Dis_{MUR}, Dis_{Water}>)	
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---	---
---	---

where

PM_{DGR} represents the DGR electrical power station PM (state)

RM_{DGR} represents the DGR electrical power station RM (state)

PM_{MUR} represents the MUR electrical power station PM (state)

RM_{MUR} represents the MUR electrical power station RM (state)

PM_{Water} represents the Water Pumping station PM (state)

RM_{Water} represents the Water Pumping station RM (state)

$Distributor_{DGR}$ represents the DGR electrical power station distributor (action)

$Distributor_{MUR}$ represents the MUR electrical power station distributor (action)

$Distributor_{Water}$ represents the Water Pumping station distributor (action).

The formulation here is used in conjunction with a proper selection of RL parameters. These parameters were estimated off-line using OO approach in contrast to those learning parameters obtained using heuristic search (HS) approach. The goal here is to advance the learning behaviour of IDS, in terms of total DPs and number of episodes per learning set (100 episodes), by exploring OO approach when applied on the modelled environment. As described earlier both immediate and terminal rewards are considered. The immediate rewards and terminal rewards were computed as follows:

$$r_{immediate} = \left(num_{VGH} + num_{SPH}\right)_{cureent} - \left(num_{VGH} + num_{SPH}\right)_{previous} \quad (5)$$

$$r_{terminal} = num_{VGH} + num_{SPH} \quad (6)$$

where

num_{VGH} total number of DPs from VGH

num_{SPH} total number of DPs from SPH.

IDS was asked to optimise the total number of DPs from both emergency units using RL parameters that were estimated heuristically. The goal is defined as the ability to discharge all injured people (maximum of 480) from both units within simulation time (ten hours). The scenario was initialised to reflect a disaster in which the RM of MUR was set to operate at 75% capacity (RM_{MUR} = 2). The actions that IDS will perform, will reallocate the available limited resources among the interconnected infrastructure using the predefined distribution ratios as per Table 1, Table 2 and Table 3.

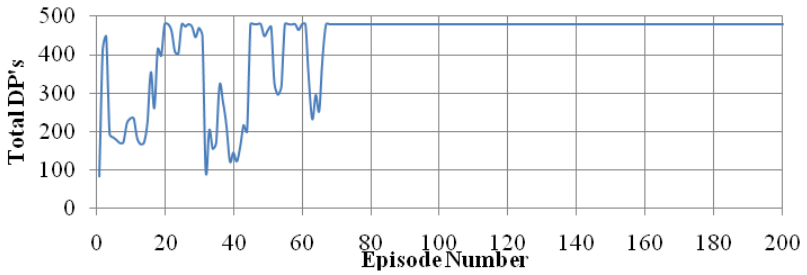
An indication of good learning is when all the patients are discharged within 10 hours simulation time. Such achievement is obtained with the presence of a LUT that is 75 times larger than the LUT that was used in Khouj et al. (2012). Table 7 summarises the results and shows the improvement in IDS performance upon learning completion.

Table 7 IDS learning performance comparisons between first and last run

	Total discharged patients
First run	83
Last run	480

Figure 14 shows IDS behaviour over a single 10-hour scenario at the start of training. It is consistent with the expectation that, with no experience IDS' ability to discharge patients is effectively random as shown in the first 66 episodes. It took 214.5 minutes (≈ 3.5 hours, simulation time) for IDS to discover the optimum trajectory. It is the trajectory the leads to the maximum number of DPs. Because it is the optimum trajectory, IDS had retained to it from episode number 67 and after.

Figure 14 Total numbers of DPs from both hospitals using HS (see online version for colours)



For the same scenario, IDS was asked to optimise the total number of DPs from both emergency units for the second time. In this trial, a different set of learning parameters was proposed to IDS. This set of learning parameters is estimated and optimised using OO and are listed hereafter:

- $\alpha = 0.5$, $\gamma = 0.6$ and $\varepsilon = 52$ (one exploratory movement every 260 minutes, simulation time).

Similarly, IDS has to sense the state of the modelled environment and perform an action for better reallocation of the available resources (power and water). The immediate rewards and terminal rewards were computed using equations (5) and (6). The learning here is processed using a learning set that was estimated using OO. It is expected that the learning behaviour of IDS will get improved comparing to the previous trial, which means faster convergence. A good sign for such improvement is the ability to optimise the total number of DPs in a number of episodes that is much less to what have obtained by IDS using the heuristic technique.

The behaviour of IDS over a single 10-hour simulation time scenario, for 200 episodes, is presented in Figure 15. Considerably, the total time to discover the optimum trajectory by IDS using OO was estimated to be 9.3 times faster than what observed by IDS using HS (Table 8). Despite the exploration activity that was performed every 52 time steps, as seen in Figure 12, this helped IDS to explore other possible trajectories toward better optimality if exist.

Table 8 IDS learning performance comparisons between HS and OO

	Total DPs using OO observed in	*Optimality reaching time (min.)*	*Total DPs using HS observed in*	*Optimality reaching time (min.)*
Episode number	7	22.75	66	214.5

The optimum trajectory that IDS discovered is the trajectory that connects the most visited states to the best performed actions that leads to the optimum number of DPs. From Figure 16, the observed trajectory denotes that state number 243 had been visited 77 times and action number 26 was the most performed action at that particular state (other actions are randomly selected as explained before). It is interesting to look at what actions IDS has learned to pick. The most favoured action is the action that distributes the DGR and MUR power, and the water pumping station as seen in Table 9.

Figure 15 Total numbers of DPs from both hospitals using OO (see online version for colours)

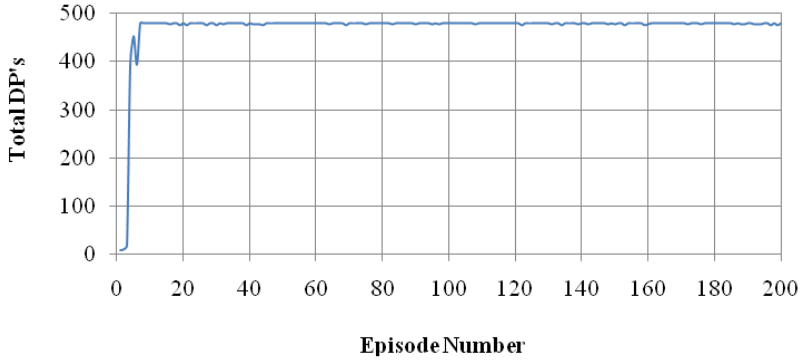
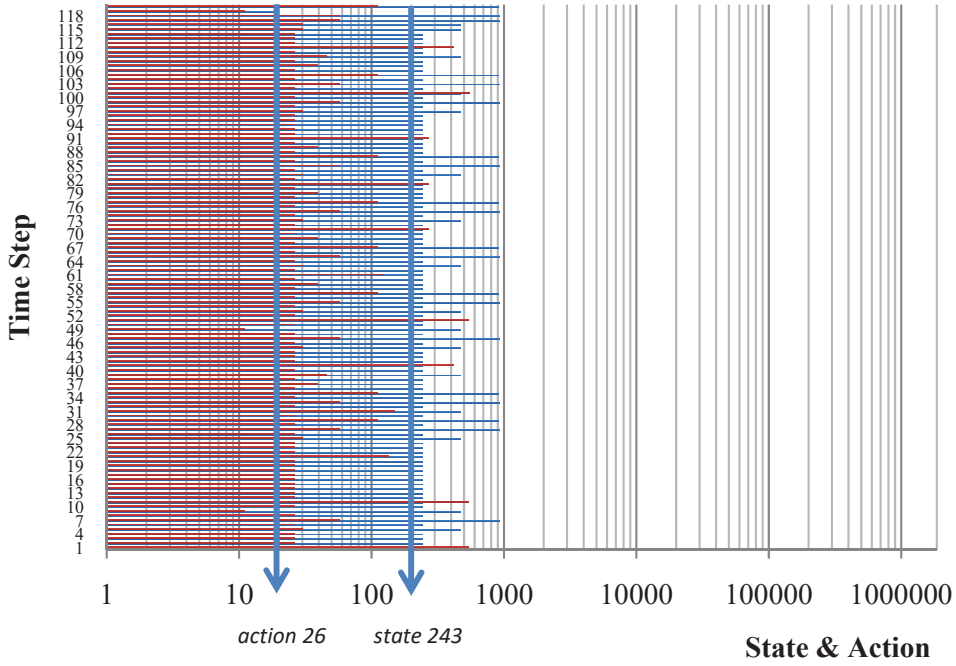


Figure 16 State-action visits of the last episode (see online version for colours)



IDS realised the reduction in the supplied power of MUR because of the disruption. That is why all the correspondent actions should be made with respect to the available power. The 439.5 MW of power was distributed in away to satisfy the demands of the interconnected CIs. For example, DGR received around 252 MW of power that helps to function BC and SPH. It is the same action that delivered 5.63 MW to the water pumping station. Because of the limited amount of water that is available for both VGH and SPH, IDS decided to distribute 70% and 30% of water respectively. IDS favoured VGH over SPH since more patients are admitted to VGH.

Table 9 Actions correspond to the most visited state-action pair of the last run

DGR distribution table					
Power action #	*BC*		*SPH*	*Terminated*	
1	2.98%		2.98%	94.05%	
Water distribution table					
Water action #	*VGH*		*SPH*		
4	70%		30%		
MUR distribution table					
Power action #	*VGH*	*Water station*	*GM*	*DGR*	*Terminated*
3	1.12%	1.28%	2.1%	57.34%	38.16%

Surprisingly, IDS was able to recognise the needs of reallocating the available resources without squandering them. IDS reallocated the resources based on the minimum requirements that help to achieve the optimum goal. For example, IDS assigned 36.4 KL/hours of water to VGH because there is no need to send more water if less electrical power is supplied to VGH. Through experience, IDS is able to observe this and learn there is no advantage in diverting large supply of water when the target CI is already compromised in terms of power. That is IDS through LUT is able to observe the average sampling long-term reward (total DPs) that linked to the optimum trajectory, which saves human lives and natural resources in the context of a fully interdependent CI.

3 Conclusions

In this research, an intelligent disaster management system trained using RL was applied to a simulation of a natural disaster. This study aimed to assist officials in decision-making during the presence of a critical event. In particular, the study highlighted the difference in computation time between policy evaluation performed in an incremental episode-by-episode manner, typical of MC methods, and that performed by TD methods that learn step-by-step. This learning system when used in conjunction with i2Sim is shown to provide effective informed decisions in a timely fashion. Further the MC-based agent was found when applied in the architecture of IDS, due to resulting more efficient communication within the system, to show a substantial computational improvement over a similar TD-based agent (DAARTS). The decisions taken by the agent are consistent with those that would optimise the system output, which in this case is the total number of DPs from medical units.

Real world RL applications using discrete representations of an action-value function are typically restricted in their ability to model environments of increasing complexity. The ability of IDS to run about two times faster than DAARTS, enabled us to model a simulation of significantly greater realism than that selected for DAARTS while still using a LUT-based utility function. Here, the estimation of this utility function was conducted using an optimised set of RL parameters for faster convergence. The results indicate that an optimised learning parameter using OO approach is able to converge in about 9 times faster than the learning set optimised using HS approach. Ultimately, to

support increasingly real-world scenarios, LUT-based approaches become impractical and must be replaced in favour of function approximation techniques.

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ORIGINAL ARTICLE

Linear programming applications in construction sites

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Linear programming;
Construction management;
Cost optimization;
Tendering strategy;
Optimization model;
Contractor selection and decision making

Abstract More issues in construction management were found especially for decision making that related to the Arabian construction management office requirements. Operation research especially linear programming models considered one of the most important tool used in optimization applications at many fields of production engineering and mass production, also linear programming applications was developed to construction engineering field. This paper presents a linear programming technique to spotlight decision making application for optimizing competitive bidding strategy to select best tender as shown in real case study. Therefore, project manager or decision maker can use this concept for getting the best project cost. This paper give linear programming concepts that are reviewed to describe recent linear programming component which had large focus on related time-cost and time problems for studied project. Linear programming models are formulated to solve various cost and time problems by using LINDO software. The developed models had many limitations and restrictions for studied project. Construction managers can use it to explore more possible opportunities to predict influence of decision for construction to facilitate preferred different management objectives. Linear programming implementation shows the practice of wide variety for construction problems especially cost with time issues and it is more applicable to generate a shortest computational effort and time with low cost.

1. Introduction

Linear programming method is the recent method during Second World War. The Applications of Linear Programming models includes for example but not limited to: (1) The Diet Problem; (2) Portfolio Optimization; (3) Crew Scheduling; (4) Manufacturing and Transportation; (5) Telecommunications; and (6) Traveling Salesman Problem. At linear programming model which is optimized is called objective function. The services, products and projects are sharing by limited resources which are named variables. The resources limitations are shown as inequalities which they are named constraints. Linear programming problem formulation as a mathematical function using following steps: (1) Define decision variables to be express and determined them as symbols such as x_i; (2) Define all constraints as function of defined decision variables;

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and (3) Define objective function that is optimized as a function of decision variables (maximized or minimized). (See-Fig. 1., Fig. 2.)

2. Literature review

Many Scholars has researched and dealt with the Linear Programming and they have studied many applications of Linear Programming and Operation Research in several field [1]. presented a simplified linear programming model having many management restrictions and it was formulated to solve construction problems using LINDO software. The model developed represents of this project [2]. considered rectilinear distance location problem, which yields to capacitated facilities location, to decrease total project cost. The problem is reformulated as linear mixed integer problem related to linear programming relaxation [3]. applied mathematical programming methods by recognized widely limitations. This researcher proposed multi-mode technique depends on linear and/or integer programming for improving project cost and time. More modules were used for this study: (1) Duration, (2) Reduction, and (3) adjustment models [4]. reviewed linear programming as mathematical procedures that needed to obtain variables, constraints and feasible solutions [5]. presented workforce planning and operations research applications to explore general potential modeling. Operations research was applied four major techniques: (1) Simulation models, (2) Supply chain models (3) Optimization models and (4) Markov models,. It concerned with important theory that provides integer programming with optimizing decisions mechanism for complex systems [6]. was concerned with cost or/and time which are major criteria that must considered carefully for construction scheduling with pricing. Construction managers should trying to find optimal project duration corresponding with minimum project cost that is solved by LINGO 12.0 [7]. Proposed a new optimum technique especially in fuzzy environment cost and time trade-off problems. For goal programming problems, it was developed new solution technique [8]. got and analyzed linear programming problems that were solved by original simplex algorithm [9]. presented a simplex algorithm that gives more solutions and taking advantage of minimizing construction operations based upon rational arithmetic [10]. mentioned project important factors to provide skilled labor related to its requirements. Linear programming was done to achieve optimized solution [11]. Linear algorithms in linear programming are presented and they are applicable for other problems as quadratic programming [12]. applied fuzzy theory for more construction fields, and presented more new solving fuzzy methods for construction by linear ranking function [13]. solving nonlinear problems complexity were reduced by transformations actions from nonlinear to integer linear programming [14]. investigated a new teaching process which it will be considered by two different methods: (1) quadratic programming problems by linear models are solved and formulated by statistical methods; and (2) linear regression model solution with constraints can be use quadratic and linear programming by simplex techniques [15]. Concentrated on simplistic approach for real construction problems within multiple objectives and is high practice of operation research [16]. Focused on human resource planning and their needs that facing leaders and managers.

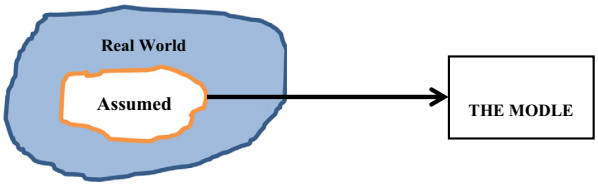

Fig. 1 Levels of abstraction in model development [17].

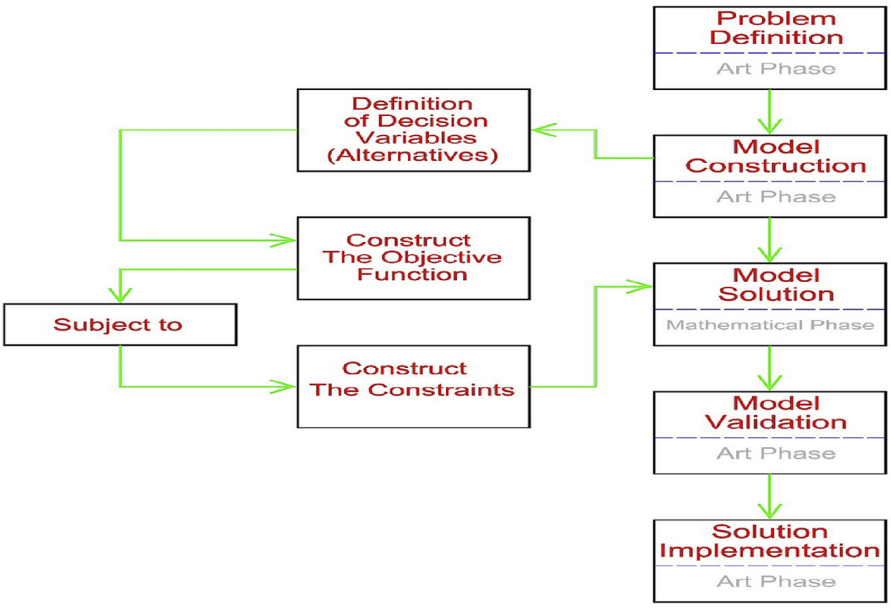

Fig. 2 Flow Chart illustrates Construction of Operation Research Model.

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3. Research scope

The primary research scope is to review solving method of The Linear Programming Models (Graphical Solution, Simplex Method, and Binary Variable) and discuss The Applications of The Linear Programming in The Project Management Office (PMO) to provide useful information for establishing data. Therefore, this study constitutes a wide review of literature including more cases of studies.

4. Methodology

This Research presents realistic Linear Programming models that define the variables and problem constraints also objective function for construction which are not straightforward. Firstly, it should understand what is Operation Research and Linear Programming where that it's Mathematical modeling is a cornerstone to solve more Problems and making a decision before a final decision can be reached. All techniques include the following: (1) Non-Linear Programming (2) Dynamic Programming, (3) Network Programming, finally (4) Integer Programming. They are trying to find functional relationships between all variables and defining real World boundaries [17], The principal phases for the implementation of operation research model in practice include the following: (1) Definition, (2) Construction, (3) Solution, (4) Validation and (5) Solution Implementation.

5. Linear programming applications

Ready mix produces two types of paints, first one is interior paint and second one is exterior paint. They are produced from two raw materials. Following table give all limitations of problem:

Interior paint maximum demand per day is equal to 2 tons. Also, interior paint daily demand cannot exceed by 1 ton than exterior paint. Ready mix wants to get optimal product mix from exterior and interior products that increase daily profit. The studied model had three items: (1) Decision variables, (2) Constraints and (3) Objective (maximize or minimize).

It must be to get optimal feasible solution that maximizes the total profit and must be locate the optimum solution.

5.1. Graphical method

- Feasible area can be founded in Fig. 3. First, account the non-negativity constraints $X_1 \leq 0$ and $X_2 \leq 0$. Two axis x_1 and x_2 represent two variables. To plot all constraints, replace inequality to equation and plot it into graph. Any point inside or border of ABCDEF area is feasible solution.
- Determination of Optimum Solution as shown in Fig. 3. Any point on area boundary of ABCDEF may one of them to can find optimum solution by solve profit function $z = 5\ X_1 + 4$ for maximizing objective function.
- Optimum solution can be found at point C, X_1 and X_2 values corresponding to point C were calculating equations: $5.0\ X_1 + 4.0\ X_2 = 24.0$ and $1.0\ X_1 + 2.0\ X_2 = 6.0$.
- The solution of point C (3, 1.5) give daily profit is equal to $21,000.
- The benefit of optimum solution that is located at corner point only. (See Fig. 4).

Properties of the linear programming model: (1) Proportionality: it requires every decision variable contribution in constraints and objective function which directly proportional to variable value. (2) Additivity: it requires all variables contribution constraints and objective function which directly each variable individual contributions summation. (3) Certainty: Linear Programming model constraint coefficients and objective were deterministic.

5.2. Software solution (TORA)

(See-Fig. 5., Fig. 6.).

5.3. Simplex method and sensitivity analysis

Simplex technique was invented to solve problems that related to linear programming [18]. This technique had developed to solve complex problems using more variables with limitations and constraints. Simplex method begin from origin then moves from next corner point and so on for increasing objective function value, simplex method is used to optimize linear programming associated with complex problems using more decision variables number, it will be restricted the use of problems with

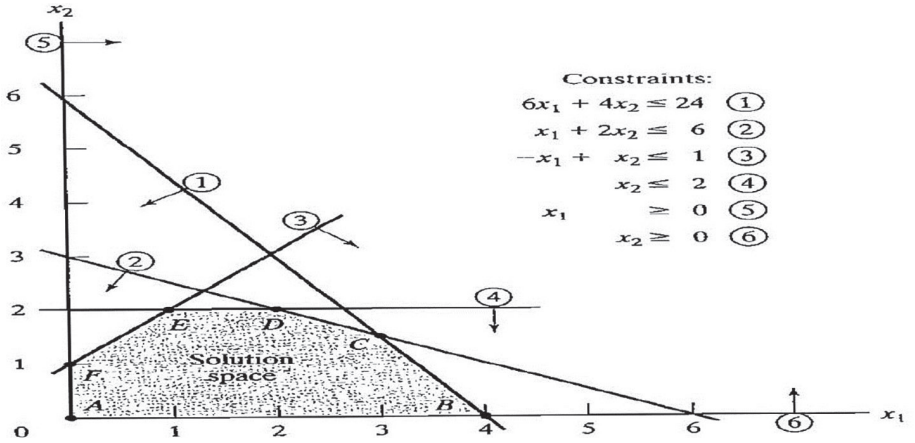

Fig. 3 Feasible Space of The Ready mix Model.

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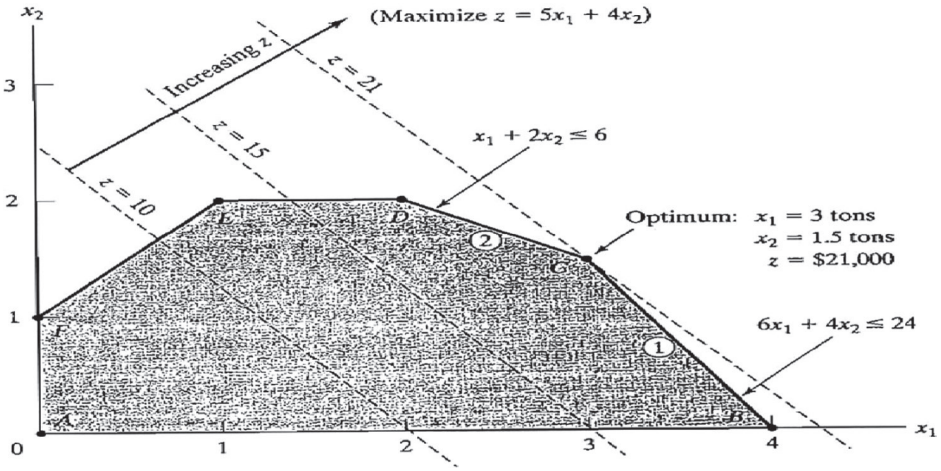
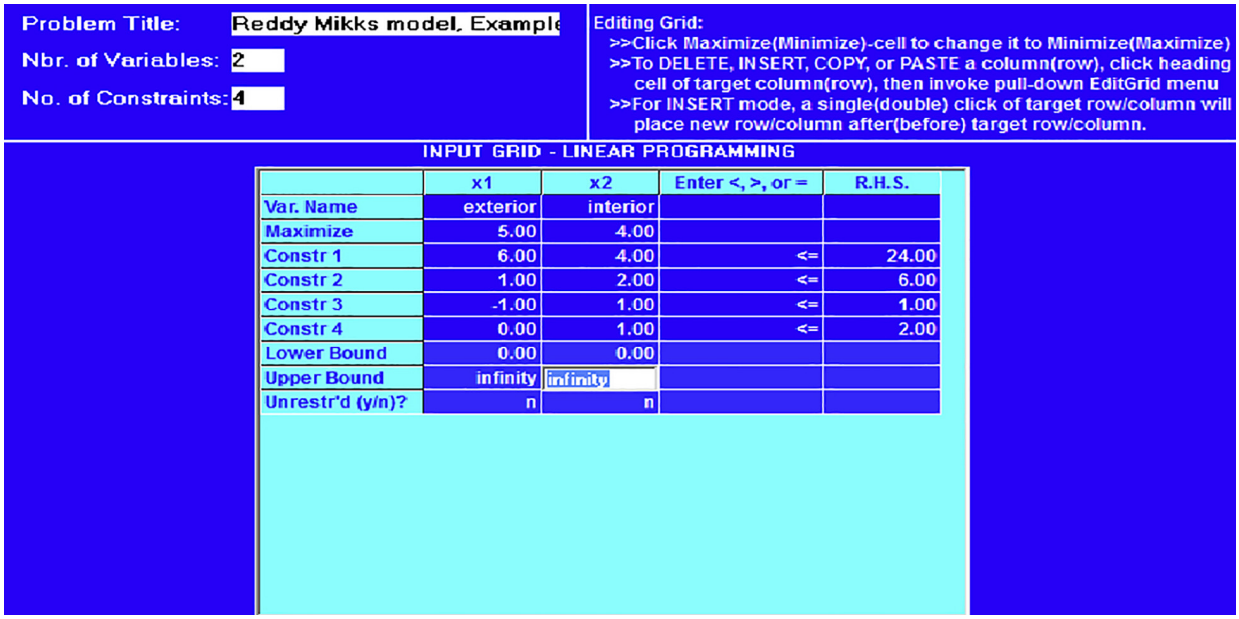


Fig. 4 Optimum Solution of the Ready mix Model.



	x1	x2	Enter <, >, or =	R.H.S.
Var. Name	exterior	interior		
Maximize	5.00	4.00		
Constr 1	6.00	4.00	<=	24.00
Constr 2	1.00	2.00	<=	6.00
Constr 3	-1.00	1.00	<=	1.00
Constr 4	0.00	1.00	<=	2.00
Lower Bound	0.00	0.00		
Upper Bound	infinity	infinity		
Unrestr'd (y/n)?	n	n		

Fig. 5 Detailed Solution by TORA software.

four variables or less based on sensitivity analysis to optimize project cost.

5.3.1. Simplex method Form

Two requirements must be done as: (1) Variables are non-negative. (2) Constraints are presented as equations.

5.3.2. Converting inequalities to equations

In less than or equal constraints, right-hand side present resource availability by using of model. To convert less than or equal inequality constrain into simplified equation, it must be add non-negative slack variable at constraint left-hand side. As shown in Table 1, it will be solved the illustrative example by using simplex method, then Table 4 shows the simplex equation forms. (See-Table 2., Table 3.)

Three equations with five unknowns (X_1, X_2, S_1, S_2 and S_3). If unknowns number more than equations number, there will be many solutions available at this model. It can be represented the initial Simplex Table as shown in Table 5.

Table 6 was designed to specify Basic and Non-basic Variables and to provide at the origin (X_1, X_2) = (0, 0) starting iteration solution as (1) Non-basic variables: (X_1, X_2), 2) and Basic vars. are S_1 & S_2 & S_3 and S_4. In case of non-basic vars. are $X_1 = 0.0$ and $X_2 = 0.0$ then $Z = 0.0$ & $S_1 = 24.0$ & $S_2 = 6.0$ & $S_3 = 1.0$ and $S_4 = 2.0$. Objective function $Z = 5.0\ X_1 + 4.0\ X_2$ presents that any result can increase in case of increasing X_1 or/and X_2. While X_1 is better than X_2 because of its high positive coefficient inside objective function and it is selected as entering variable, then it will assigned to high negative coefficient at new objective function optimality

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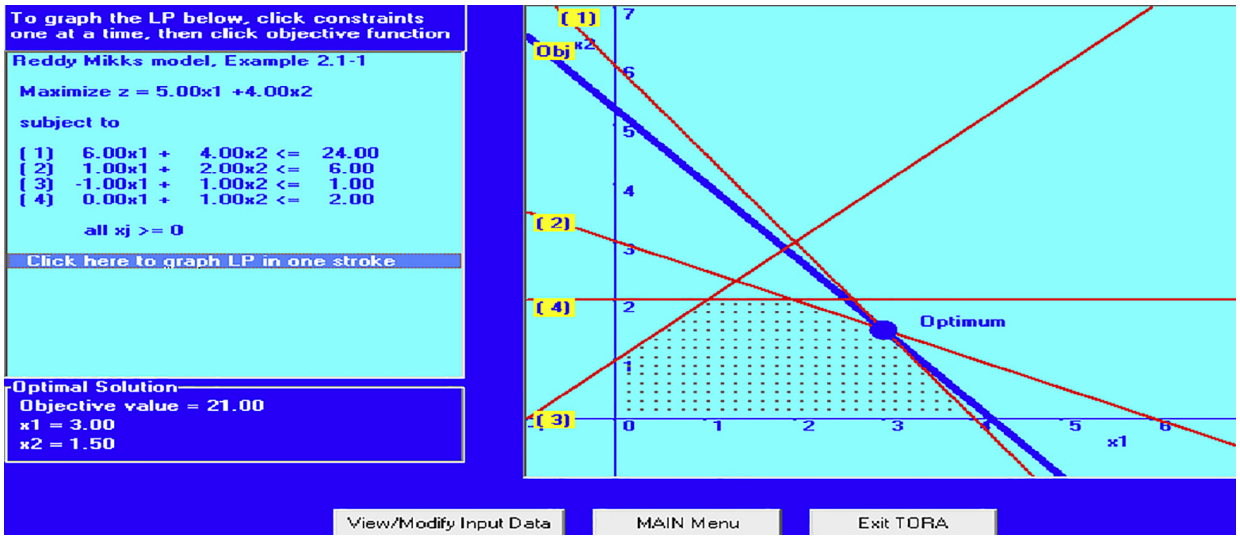

Fig. 6 Graphical Solution by TORA software.

Table 1 Basic data for ready mix application.

	Raw matl.	Tons per ton of	Maximum Availability (tons per day)
	Ext. paint	Int. paint	
First raw matl. M_1	6.0	4.0	24.0
Second raw matl. M_2	1.0	2.0	6.0
Profit per ton ($1000.0)	5.0	4.0	

Table 2 LP model for ready mix application.

1- Decision variables:

X_1 = daily exterior paint production per tons
X_2 = daily interior paint production per tons

2- Objective function:

Maximize $Z = 5.0\ X_1 + 4.0\ X_2$

3- Constraint:

$6.0\ X_1 + 4.0\ X_2 \geq 24.0$
$1.0\ X_1 + 2.0\ X_2 \geq 6.0$
$-1.0\ X_1 + 2.0\ X_2 \geq 1.0$
$1.0\ X_2 \geq 2.0$
$X_1, X_2 = <0$ (The non-negativity Constraints)

Table 4 LP Model Equation Form.

1- Decision variables:

X_1 = daily exterior paint production per tons
X_2 = daily interior paint production per tons

2- Objective function:

Maximize $Z = 5.0\ X_1 + 4.0\ X_2$

3- Convert objective function.:

Maximize $Z - 5.0\ X_1 - 4.0\ X_2 = 0$

4- Constraints:

$6.0\ X_1 + 4.0\ X_2 \geq 24.0$
$1.0\ X_1 + 2.0\ X_2 \geq 6.0$
$-1.0\ X_1 + 2.0\ X_2 \geq 1.0$
$1.0\ X_2 \geq 2.0$
$X_1, X_2 \leq 0$ (The non-negativity Constraints)

5- Convert each constrain inequality into equation:

$6.0\ X_1 + 4.0\ X_2 + 1.0\ S_1 = 24.0$ where Slack Variable $S_1 \leq 0$
$1.0\ X_1 + 2.0\ X_2 + 1.0\ S_2 = 6.0$ where Slack Variable $S_2 \leq 0$
$-1.0\ X_1 + 2.0\ X_2 + 1.0\ S_3 = 1.0$ where Slack Variable $S_3 \leq 0$
$1.0\ X_2 + 1.0\ S_4 = 2.0$ where Slack Variable $S_4 \leq 0$
$X_1, X_2, S_1, S_2, S_3, S_4 \leq 0$

condition rule $1.0\ Z - 5.0\ X_1 + 4.0\ X_2 = 0$, (all vars. are switched to L.H.S). Leaving variable determining mechanics from simplex table calls computing equations right-hand side

Table 3 LP Model Algebraic Method.

	The Corner Point		The Objective Function (in dollar)
Code	X_1	X_2	$Z = 5.0\ X_1 + 4.0\ X_2$
A	0.0	0.0	00.0
B	4.0	0.0	20.0
C	3.0	1.5	21.0
D	2.0	2.0	18.0
E	1.0	2.0	13.0
F	0.0	1.0	04.0

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Table 5 LP Model Initial Simplex Coefficients.

Basic	Z	X_1	X_2	S_1	S_2	S_3	S4	Solution	
Z	1.0	-5.0	-4.0	0.0	0.0	0.0	0.0	0.0	Objective Function
S_1	0.0	6.0	4.0	1.0	0.0	0.0	0.0	24.0	Constraint - 01
S_2	0.0	1.0	2.0	0.0	1.0	0.0	0.0	6.0	Constraint - 02
S_3	0.0	-1.0	1.0	0.0	0.0	1.0	0.0	1.0	Constraint - 03
S_4	0.0	0.0	1.0	0.0	0.0	0.0	1.0	2.0	Constraint - 04

Table 6 Simplex Optimality Condition.

Basic	Entering X_1	Solution	Ratio (or intercept)	
S_1	6.0	24.0	$X_1 = 24/6 = 4.0$	Min.
S_2	1.0	6.0	$X_1 = 6/1 = 6.0$	Not Ok
S_3	-1.0	1.0	$X_1 = 1/-1 = -1.0$	Ignore.
S_4	0.0	2.0	$X_1 = 2/0 = \infty$	Ignore.

nonnegative ratios (Solution column) to corresponding coefficients of constraint under use of entering variable, X_1, as the following Table 6.

The minimum non-negative ratio automatically will convert leaving var. S_1 with entering var. X_1 with corresponding new value. Fig. 7. shows computed ratios using intercepts of constraints and entering variable (X_1) axis. It can be produce following sets for Non-basic and basic variables: (1) Non-basic variables: (S_1, X_2), 2) Basic variables: (X_1, S_2, S_3, S_4). Basically it must be to determine column of entering var. as pivot column and row of leaving var. as pivot row. Intersection between pivot column with pivot row is named aspivot element. Table 7 shows starting table with its pivot row and column highlighted.

It is important to generate new basic solution which it include: (1) Pivot row: switch leaving var. at basic column with entering var. by new pivot row isequal to current pivot row divided by pivot element as shown in next calculations. (2) All next new rows and Z row as New Row is equal to current row minus its pivot column coefficient multiply to new pivot row [19,20]. (See-Fig. 8.)

These calculations are used to as following steps:

1- Replace S_1 in the Basic column with X_1. New X_1-row = Current S_1-row ÷ 6
= 1/6 (0 6 4 1 0 0 0 24) = (0 1 2/3 3/6 0 0 0 4)

2- New $Z_{\text{-row}}$ = Current $Z_{\text{-row}}$ - (-5) × New $X_{1\text{-row}}$
= (1–5 -4 0 0 0 0 0) - (-5) × (0 1 2/3 1/6 0 0 0 4) = (1 0–2/3 5/6 0 0 0 20)

3- New $S_{2\text{-row}}$ = Current $S_{2\text{-row}}$ - (1) × New $X_{1\text{-row}}$
= (0 1 2 0 1 0 0 6) - (1) × (0 1 2/3 1/6 0 0 0 4) = (0 0 4/3–1/6 1 0 0 2)

4- New $S_{3\text{-row}}$ = Current $S_{3\text{-row}}$ - (-1) × New $X_{1\text{-row}}$
= (0–1 1 0 0 1 0 1) - (1) × (0 1 2/3 1/6 0 0 0 4) = (0 0 5/3 1/6 0 1 0 5)

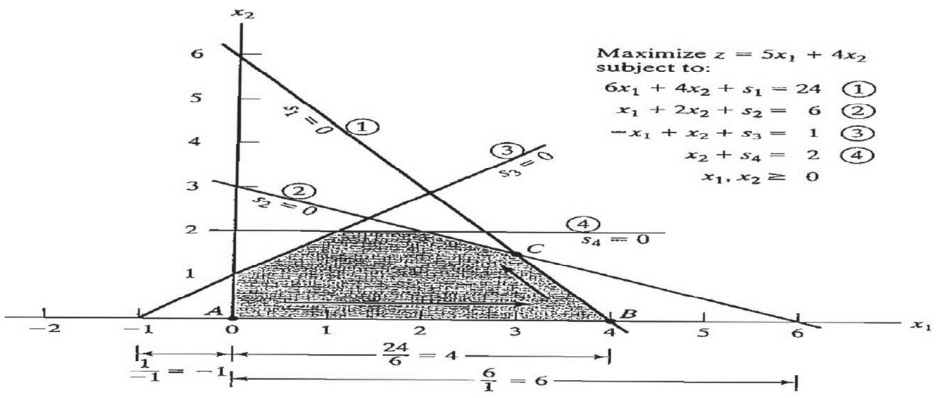

Fig. 7 Graphical interpretation of the ratios.

Table 7 Highlighted Simplex Pivot Row and Column.

		Enter							
Basic	Z	X_1	X_2	S_1	S_2	S_3	S4	Solution	
Z	1.0	-5.0	-4.0	0.0	0.0	0.0	0.0	0.0	
S_1	0.0	6.0	4.0	1.0	0.0	0.0	0.0	24.0	Pivot row
S_2	0.0	1.0	2.0	0.0	1.0	0.0	0.0	6.0	
S_3	0.0	-1.0	1.0	0.0	0.0	1.0	0.0	1.0	
S_4	0.0	0.0	1.0	0.0	0.0	0.0	1.0	2.0	
		Pivot Column							

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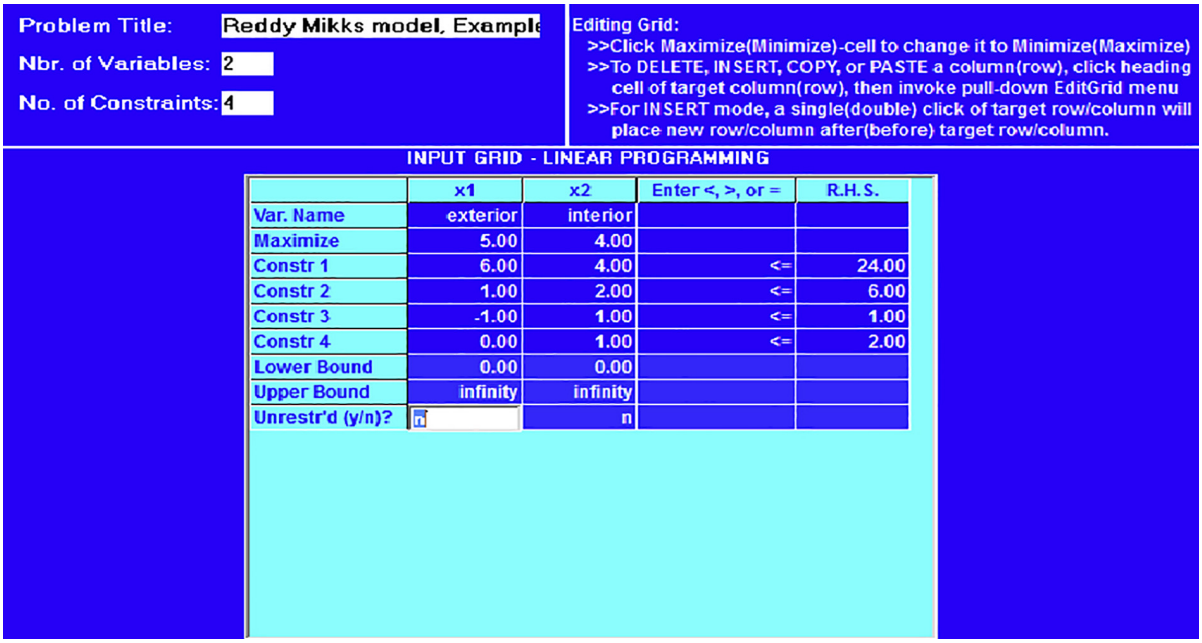


Fig. 8 TORA Simplex Input Wizard.

5- New $S_{4\text{-row}}$ = Current $S_{4\text{-row}}$ - (0) × New $X_{1\text{-row}}$ = (0 0 1 0 0 0 0 2) - (0) × (0 1 2/3 1/6 0 0 0 4) = (0 0 1 0 0 0 1 2)

The new basic solution is (X_1, S_2, S_3, S_4), and the new tableau as shown in Table 8.

Table 8 shows same properties as Table 5 and then it was set as new non-basic vars. X_2 and S_1 are equal to zero, also new basic solution of $X_1 = 4.0$ & $S_2 = 2.0$ & $S_3 = 5.0$ & $S_4 = 2.0$ and $Z = 20$, which is consistent with New $Z = 0 + 4 \times 5 = 20$. Table 9 give X_2 is entering var. as optimality with feasibility condition.

Thus, S_2 will leave basic solution after that X_2new value is equal to 1.5. Then corresponding increase of Z is 2/3 and $X_2 = 2/3 \times 1.5 = 1.0$, that give new $Z = 20.0 + 1.0 = 21.0$. Replacing leaving var. S_2 with entering var. X_2, the following Gauss-Jordan row operations are done as: 1) New pivot X_2-row = Current S_2-row/(4/3). 2) New Z-row = Current Z-row – (-2/3) × New X_2-row. 3) New X_1-row = Current X_2-row – (2/3) × New X_2-row. 4) New S_3-row = Current S_3-row – (5/3) × New X_2-row. 5) New S_4-row = Current S_4-row– (1) × New X_2-row. These computations produce the following Table 10:

Table 9 Simplex Optimality Condition and Feasibility Condition.

Basic	Entering X_2	Solution	Ratio (or intercept)
X_1	2/3	4.0	$X_2 = 4/(2/3) = 6.0$ Min.
S_2	4/3	2.0	$X_2 = 2/(4/3) = 1.5$
S_3	5/3	5.0	$X_2 = 5/(5/3) = 3.0$ Ignore.
S_4	1.0	2.0	$X_2 = 2/1 = 2.0$ Ignore.

Table 10 Simplex Final Result.

Basic	Z	X_1	X_2	S_1	S_2	S_3	S4	Solution
Z	1.0	0.0	0.0	3/4	1/2	0.0	0.0	21.0
X_1	0.0	1.0	0.0	1/4	-1/2	0.0	0.0	3.0
X_2	0.0	0.0	1.0	-1/8	3/4	0.0	0.0	3/2
S_3	0.0	0.0	0.0	3/8	-5/4	1.0	0.0	5/2
S_4	0.0	0.0	0.0	1/8	3/4	0.0	1.0	1/2

Table 8 Highlighted Simplex New Basic Solution.

			Enter					
Basic	Z	X_1	X_2	S_1	S_2	S_3	S4	Solution
Z	1	0	-2/3	5/6	0	0	0	20
X_1	0	2/3	2/3	1/6	0	0	0	4
S_2	0	0	4/3	-1/6	1	0	0	2
S_3	0	0	5/3	1/6	0	1	0	5
S_4	0	0	1	0	0	0	1	2
			Pivot Column					

Pivot row

Table 11 Simplex Final Decision.

Decision Variable	*Optimum Value*	*Recommendation*
X_1	3.0	Daily exterior paint production per tons.
X_2	1.0	Daily interior paint production per tons.
Z	21.0	$21,000 is equivelant to daily profit.

According to optimality condition no negative coefficients for Z-row. Finally Table 10 is converted to optimal solution table, then optimal values for studied problem are shown in Table 11.

5.4. (TORA) solution

(See-Fig. 9., Fig. 10.)

5.5. Minimization of linear simplex technique

For minimization problems optimality select entering var. as non-basic variable with objective function in most positive coefficient and opposite rule for maximization problems such as maximize of Z is equivalent to minimize of (-Z). In feasibility condition maximization or minimization problem is non-basic var. that had max negative or positive coefficient at z-row. Optimum at z-row coefficients iteration are nonnegative or non-positive. For maximization or minimization problems, basic variable (leaving) assigned with smallest non-negative ratio or positive ratio. Pivot row: Replace the leaving variable in the Basic column with the entering variable. New pivot row is equal to old pivot row divided by pivot element. Then the remaining rows, including z: New row is equal to old row minus (pivot column coefficient) multiply (New pivot row). Finally simplex steps are: (1) Determine starting solution of basic feasible. (2) Select entering var. using optimality condition. Stop in case of no entering var. and last solution is optimal. (3) Feasibility condition will select leaving var. (4) Determine new basic solution and repeat by go to step 2 [21,22].

6. Case study

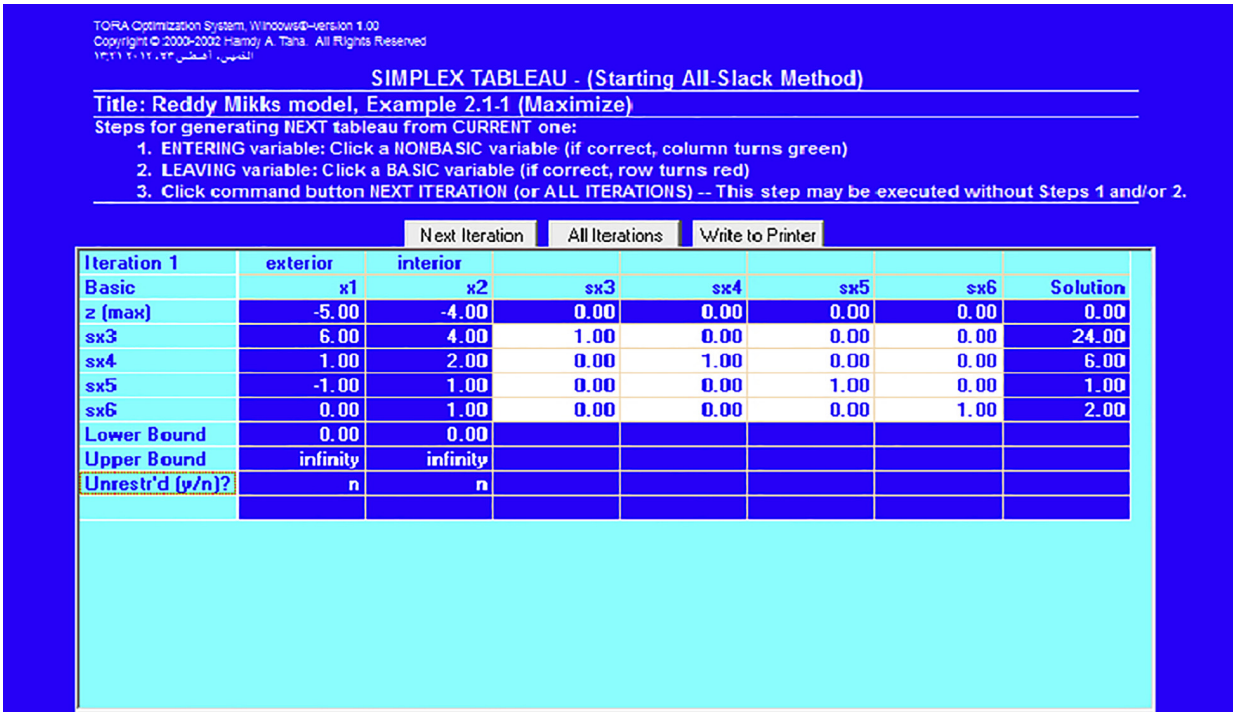
Project Selection with Competition at Limit Resource Using Linear Programming as Contractor View. Project Management Office has five bids and must make a decision to enter all of them or some of them or none of them with the note: (1) There is competition between the bidders. (2) Is the amount of existing resources enough or not enough. Table 12 gives problem basic data. The Bid Bonding is 0.2% of the amount of the tender and the Exposure Limit is 18 million. The following table provides the available resource which that Project Management Office Company has owned: 4 cranes, 3 air-compressors and 2 tractors.

It is required to determine which projects the company can entering it to give maximum profit through their resource.

6.1. Case study solution

It will be identified potential opportunities to win the likely price of each project can enter the bid as shown Table 13:

Where: Chance of Weighted Profit "CWP" = Profit × Probability of Winning.



Iteration 1	exterior	interior					
Basic	x1	x2	sx3	sx4	sx5	sx6	Solution
z (max)	-5.00	-4.00	0.00	0.00	0.00	0.00	0.00
sx3	6.00	4.00	1.00	0.00	0.00	0.00	24.00
sx4	1.00	2.00	0.00	1.00	0.00	0.00	6.00
sx5	-1.00	1.00	0.00	0.00	1.00	0.00	1.00
sx6	0.00	1.00	0.00	0.00	0.00	1.00	2.00
Lower Bound	0.00	0.00					
Upper Bound	infinity	infinity					
Unrestr'd (y/n)?	n	n					

Fig. 9 TORA Simplex Matrix.

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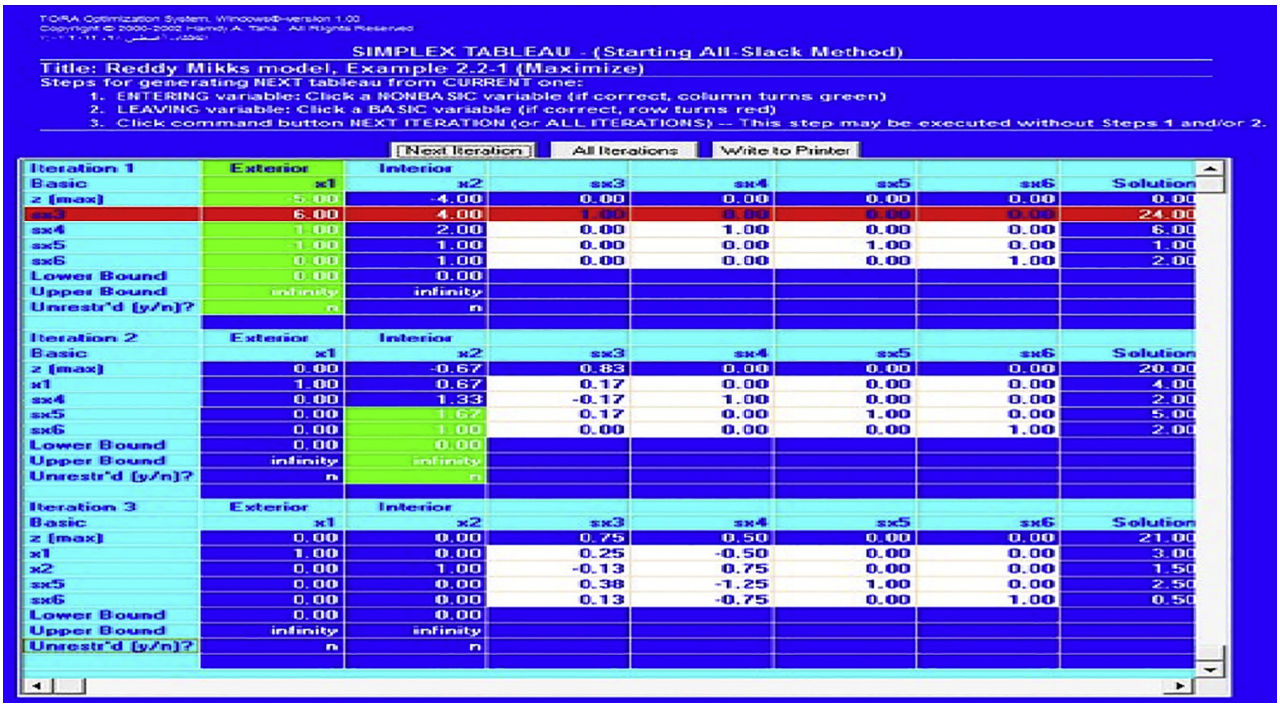

Fig. 10 TORA Simplex Results.

Table 12 Case Study Data.

Promising Bid	Pre-cost	Cranes	Air-Compressor	Tractors
1- Office	10.50	2	1	1
2- House	8.00	2	1	1
3- School	5.50	2	1	1
4- Shopping Mall	8.00	2	1	

Table 13 Case Study Potential Opportunities.

Project	Estimation Cost	Bid Amount	Probability (Chance of Winning)	Chance of Winning Profit
1- Office	10.50	11.00	60%	0.3
		11.50	40%	0.4
		12.00	20%	0.3
		12.50	10%	0.2
2- House	8.00	8.50	50%	0.25
		9.00	30%	0.30
		9.50	20%	0.30
		10.00	10%	0.20
3- School	5.5	5.70	80%	0.16
		5.90	40%	0.16
		6.10	30%	0.18
		6.30	10%	0.08
4- Shopping Mall	5.5	3.20	60%	0.12
		3.40	40%	0.16
		3.60	10%	0.06

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Table 14 Case Study Optimum Solution.

Office	House	School	Shopping Mall
$X_{11} = 0.0$	$X_{21} = 1.00$	$X_{31} = 0.0$	$X_{41} = 0.0$
$X_{12} = 0.0$	$X_{22} = 0.0$	$X_{32} = 1.00$	$X_{42} = 1.00$
No Entering	House = 8.50	School = 5.90	Shopping Mall = 3.40
Z = 564.00			

For Example: Chance of Weighted Profit "CWP" = (11–10.50) x 0.60 = 0.30.

6.2. Decision variables

o Binary Variable, where that:

(1) : Express, this value mustn't entering the Bid with Value Equivalent.

(2) : Express, this value must entering the Bid with Value Equivalent.

Then, Let X_{ji} (i = 1,4) be Binary Variable

o where that:

(j): Express, Number of Project, (i): Express, Number of Option (Project Cost).

o It means that:

j (1, 2, 3)→i (1, 2, 3, 4)
j (4) → i (1, 2, 3)

6.3. Objective function

$$Z_{max} = \sum_{J=1}^{J=j} (\text{CWP - } (Bid\ Amount \times Bond))^{i} x_{Ji}$$

$= (0.3 - (11 \times 0.002))\ X_{11} + (0.4 - (11.5 \times 0.002))\ X_{12} + (0.25 - (\mathbf{8.5} \times 0.002))\ X_{21} + (0.3 - (\mathbf{9.00} \times 0.002))\ X_{22} + (0.16 - (5.70 \times 0.002))\ X_{31} + (0.16 - (\mathbf{5.90} \times 0.002))\ X_{32} + (0.12 - (\mathbf{3.20} \times 0.002))\ X_{41} + (0.16 - (\mathbf{3.40} \times 0.002))\ X_{x42} = 0.278\ X_{11} + 0.377\ X_{12} + 0.233\ X_{21} + 0.282\ X_{22} + 0.149\ X_{31} + 0.148\ X_{32} + 0.1136\ X_{41} + 0.1532\ X_{42}$

Multiply by 1000

$Z_{max} = 278\ X_{11} + 377\ X_{12} + 233\ X_{21} + 282\ X_{22} + 149\ X_{31} + 148.20\ X_{32} + 113.6\ X_{41} + 153.20\ X_{42}$

6.4. Logic constraints

$X_{11} + X_{12} <= 1$ & $X_{21} + X_{22} <= 1$ & $X_{31} + X_{32} <= 1$ & $X_{41} + X_{42} <= 1$

6.5. Resource constraints

6.5.1. Cranes Constraint

$2X_{11} + 2\ X_{12} + 2\ X_{21} + 2\ X_{22} + X_{31} + X_{32} \leq 4$

6.5.2. Air-compressor Constraint

$X_{11} + X_{12} + X_{21} + X_{22} + X_{31} + X_{32} + X_{41} + X_{42} \leq 3$

6.5.3. Tractors Constraint

$X_{11} + X_{12} + X_{21} + X_{22} + X_{31} + X_{32} \leq 2$ & $X_{11} + X_{12} + X_{21} + X_{22} + X_{41} + X_{42} \leq 2$

Two Constraints Must be Verified at same time.

6.6. Bonding Constraint

$X_{11} + 11.5\ X_{12} + 8.5\ X_{21} + 9\ X_{22} + 5.7\ X_{31} + 5.9\ X_{32} + 3.2\ X_{41} + 3.4\ X_{42} \leq 18$

Then, Optimum solution is shown in Table 14:

7. Conclusion and recommendations

This research imply explain the linear programming models and its applications in the field of Project Management, where in the first part talked about introduction and a quick review of the general applications of linear Programming in the real world, In the second part it was dealt talk about some research which addressed The Application of Linear Programming that nearby field, and it was discussed in part three it was explain Introduction to Operations Research as access to a Linear Programming models and it was dealt explain the Graphical Solution Method, The Simplex Method and The Binary Variables Method, and in the fourth Part it was dealt with one of Linear Programming Applications in tasks of Project Management Offices of Engineering projects which studies evaluation and selection of Bids that should entering and participate in it and how to determine the right price to enter this Bid and probability of gaining it, In part five has been mentioned the conclusions of this study, as well as some of the topics that scholars can complete their studies until it wasachieve the highest benefit and focus our effort and our thought.

The main conclusions drawn from this study are taking advantage of the potential possibilities of a linear programming model to support decision-making processes and evaluate some tasks The Project Management Offices (PMO) of Construction Companies and also Offices of Projects Management and these tasks, for example, but not limited to: Determination and Evaluation The Bids which appropriated The Companies Resources, Determination and Evaluation The Optimal Resource for Projects and also, Determination and Evaluation The Optimal Time and The Optimal Cost for implementation Construction projects.

8. Future study

Further studies are needed in the following subjects: (1) Performing similar studies to Applications the Linear Program-

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ming in The relation between The Time, The Cost and The Quality. (2) Performing similar studies to Applications the Linear Programming in The Cost Analysis of the Different Items. (3) Performing similar studies to Applications the Linear Programming in Allocated Resource in Construction Projects.

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Modelling of the Usefulness of Carbon Nanotubes as Antiviral Compounds for Treating Alzheimer Disease

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Abstract

The new generations of nano-devices successfully apply with great promise as drug carriers in the treatment of different diseases. The proposed model aims to determine the pharmacological targets and evaluate the bio-safety of usefulness of carbon nanotube conjugated with two different antiviral compounds, Acetylcholine and Ravastigmine, for treating Alzheimer disease. We also obtain the medicinal model mathematically to evaluate the interaction energy arising from encapsulation of each antiviral compound inside the single-walled carbon nanotube. Acetylcholine is modelled as two-connected spheres, while Ravastigmine has two possible structures which are an ellipsoid and cylinder, all interacting with the interior wall of single-walled carbon nanotubes with variant radii r_c. Our calculations show that the single-walled carbon nanotube of radius r_c greater than 3.391 Å that will accept both drugs which are quite closer to the recent findings.

Keywords

Carbon Nanotubes (CNTs), Alzheimer Disease (AD), Acetylcholine (ACh) (Aricept), Ravastigmine (RAV) (Exelon), Mitochondria (MTCDH), Lysosomes, Van Der Waals Interaction and Lennard-Jones Potential

1. Introduction

Research in nanobiotechnology has rapidly increased since the development of molecular dynamic simulations (MDSs) in 1980, X-ray crystallography and scanning tunneling microscope in 1982. Nanobiotechnology is an interdisciplinary area combining the molecular biological approach with the micronanotechnology. This combination aims to design and develop new devices by ma-

nipulating at the nanoscale their size, shape, distinct properties. It also presents revolutionary opportunities by implying the creation of nano-materials, against the infection, cancer cells and cardiac disorder, designed to interact with targeted sites in the body at sub-cellular scales with a high degree of certainty. This has led the scientific researchers to find the lightest, strongest and most conductive carbon nano-materials that capable of transporting different biomolecules through their surfaces. Carbon nanodevices are a family of very small tubes which are wholly composed of carbon atoms, having diameter measured by nanometre level (one-billionth scale) which is about to ten-thousand times smaller than the human hair, such as peptides, fullerenes, nano-rods, nano-buds, graphenes and cylindrical carbon nanotubes. Carbon nanotubes (CNTs) are selective nanoparticle because of their huge potential, low solubility and toxicity, outstanding properties, maximum loading capability and extraordinary thermal conductivity [1] [2]. They are classified into two main sub-groups; multi-walled and single-walled CNTs (MWCNTS and SWCNTs). These nanotubes can be widely functionalized with proteins, bio-active peptides and drugs, and used to deliver their loads to the targeted cells, such as for treating the infected sites, inhibiting the growth of pathogens or attacking the cancer cells [3] [4].

CNTs have attracted a lot of interesting researches since their discovery [5] [6]. Due to their unusual properties that can be practically modified with different bio-molecules through several techniques [4] [7]. There have been several studies addressed the ability of CNTs to conjugate with a wide variety of drugs for treatment purposes. CNTs have been explored for disease therapy applications, especially for cancer treatment [8]. In addition, they are also used to build up smaller, lighter and more efficient nano-sensors as scaffolds for tissues repair and cell growth [9] [10] [11]. To drive the drug delivery systems into the lymph-node cancer cells, synthesized MWCNTs with magnetite nano-particles were functionalized folic-acid and successfully loaded with Cisplatin (an anti-cancer drug) [12] [13]. Furthermore, CNTs have also been employed as drug delivery agents for treatment of hypertension (carvedilol) [14], asthma (theophylline) [15], human immunodeficiency virus (HIV) [16] and inflammation (dapsone, dexamethasone and ibuprofen) [17] [18] [19] [20] as well as some of brain diseases [21] [22], e.g., Alzheimer disease (AD) [23]. SWCNTs have recently been used as safe carriers to increase the effectiveness of AD treatment (against Mitchidoria in the brain) [23].

AD is the most common type of dementia, progressive and irreversible brain disorder that causes problems with behavior and slowly destroys thinking skills and memory. Its symptoms often develops gradually and gets worse overtime and classified into three stages; mild, moderate then becomes severe, which can be noticeably seen in the X-ray image shown in **Figure 1**, interfering with daily life tasks. AD has no current and effective cure so far to get rid of the progressive form of Alzheimer. Nowadays, treatment of AD symptoms are available and researchers still paying more attentions to find new techniques to slow worsening

Figure 1. Schematic geametry (X-ray image) expose the difference between the health brain, and the mild and severe stages of Alzheimer disease.

of losing memory, improve quality of daily tasks and prevent Alzheimer's symptoms from developing. Yang *et al.* [23] who have shown that SWCNTs with diameter 0.8 to 1.6 nm and variant lengths 5 - 300 nm were successfully carried out with Acetylcholine (ACh) then directly delivered into brain, lysosomes are the targeted organelles of SWCNTs not mitochondria (MTCHD). This technique used the SWCNT as a catalyst due to its lack in the brain areas to increase the effectiveness of ACh drug. ACh can not be delivered directly into the brain with low doses because of its poor lipophilicity, this has recently been administrated that lack of ACh can be overcome by using SWCNT as carrier with high bio-safety [13]. Inside the brain, SWCNTs enter directly into the lysosomes, not to the MTCHD, which are the targeted organelles, but the high doses rise up the opportunity of SWCNTs to enter to the MTCHD. SWCNTs can be successfully exploited to deliver ACh into the targeted lysosomes to achieve therapeutic effects without undesired toxic effects [23].

The proposed model is designed to investigate the mechanism of encapsulation of two different antiviral compounds, Acetylcholine (used for the early stages) and Ravastigmine (RAV) (used for the moderate and severe stages) with chemical formulas $C_7NH_{16}O_2^+$ and $C_{14}H_{22}N_2O_2$ as shown in **Figure 2(a)** and **Figure 2(b)**, respectively, inside the SWCNTs of variant radii r_c. Firstly, we obtain the mathematical geometry for each antiviral compound and also evaluate the total energy arising form each antiviral compound encapsulated inside a SWCNT of radius r_c. ACh structure comprised as two-connected sphere with different radii r_s, while RAV modelled as two possible structres; an ellipsoid and cylinder, each interacting with the interior wall of SWCNTs with variant radii r_c. This paper is structured as, in the first section, we briefly outline the significance of usefulness of SWCNTs in many modern applications at nano-scales. Next, we apply the van der Waals force, Lennard-Jones potential and a discrete-continuum approximation to investigate the medical application which describes the possibility of conjugation between a SWCNT and antiviral compounds specialized to treat AD by inhibiting the growth of MTCDH (infected site in the brain). We also determine the magnitude of the potential energy arising from the interaction between antiviral compounds and nanotubes with various radii r_c. Followed by a discussion and analysis our results in section 3. Finally, conclusions and remarks are given in the last section.

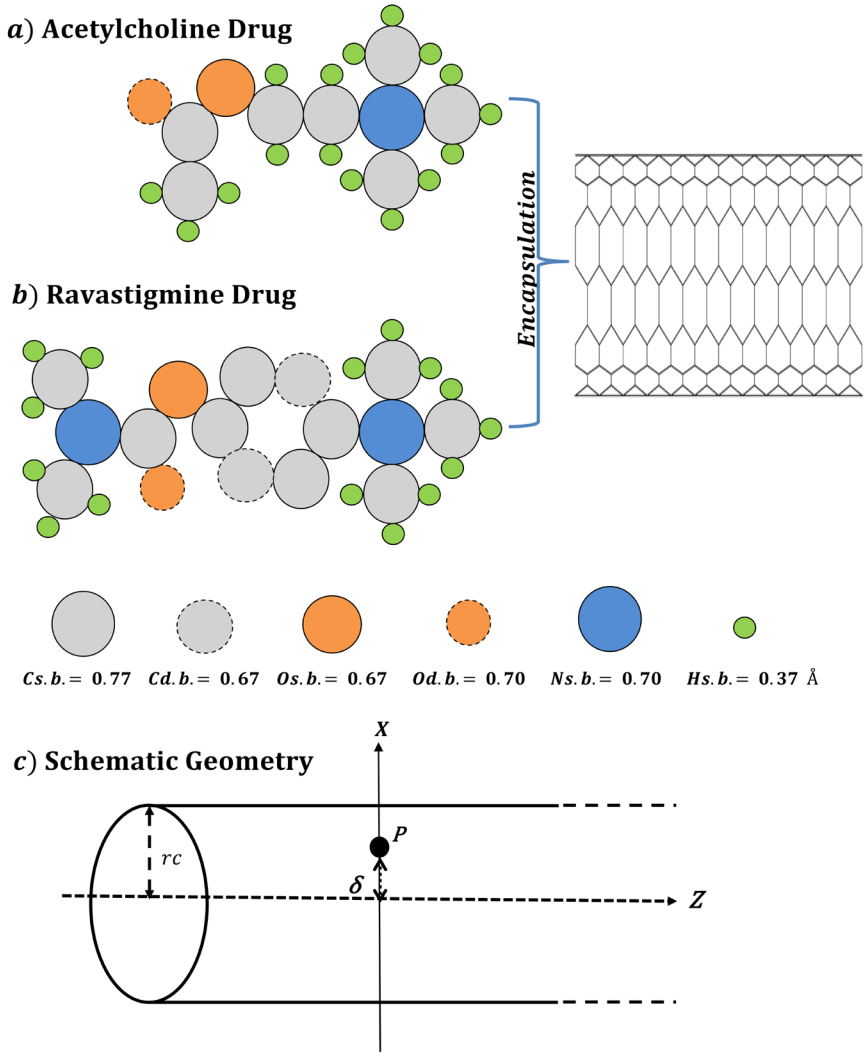

Figure 2. Schematic geometry for: (a) ACh antiviral compound as an interior atom interacting with a SWCNT of radius r_c (*sb*:single bond and *db*:double bond); (b) RAV antiviral compound as an interior atom interacting with a SWCNT of radius r_c (*sb*:single bond and *db*:double bond); (c) Antiviral compound as an interior atom at point P off-setting from the central-axis by a distance δ.

2. Mathematical Model

Here, we obtain the bio-physical model which describes the adsorption of two different drugs into SWCNTs with variant radii r_c as a mathematical model by using van der Waals forces. We use the Lennard-Jones potential and the continuum approach together to model the encapsulation of these drugs inside a SWCNT. Next, we use the Cartesian coordinate (x, y, z) as a reference system to model the two interacting molecules, the certain biomolecule and the cylindrical nanotube. We assume that the point at atom P has coordinates $(\delta, 0, 0)$ and the SWCNT defined as a cylindrical tube parameterized by $(r_c \cos\theta, r_c \sin\theta, z)$, where $0 \le \delta \le r_c$, $0 \le r_c \le 1$, $-\pi < \theta \le \pi$ and $-L < z \le L$ as shown in **Figure 2(c)**. Therefore, the distance ρ from point P to typical

surface element of the cylindrical tube given by

$$\rho^2 = \left(r_c \cos\theta - \delta\right)^2 + r_c^2 \sin^2\theta + z^2 = \left(r_c - \delta\right)^2 - 4\delta r_c \sin^2\left(\theta/2\right) + z^2. \quad (1)$$

The Lennard-Jones potential given as

$$\beta(\rho) = \frac{-A}{\rho^6} + \frac{B}{\rho^{12}}, \quad (2)$$

where $\beta(\rho)$ is the potential function, ρ denotes the distance between two molecular structures, and A and B are the attractive and repulsive constants. The physical parameters, $A = 4\varepsilon\sigma^6$ and $B = 4\varepsilon\sigma^{12}$, are calculated by using the empirical combining laws given by given by $\varepsilon_{ij} = \sqrt{\varepsilon_i \varepsilon_j}$, $\sigma_{ij} = \left(\sigma_i + \sigma_j\right)/2$ and $\zeta_{ij} = \sqrt{\zeta_i \zeta_j}$, where ε is the well depth, σ is the van der Waals diameter and ζ is the non-bond energy [24] [25]. Here, we apply continuum approximation, atoms are assumed to be uniformly distributed over the surfaces of the two interacting molecules, to evaluate the interaction energy between two well-defined molecules by performing double integral over the surface of each molecule. From the work of Thamwattana *et al.* [26], the interaction energy is given by

$$E_a = \eta_c \int_V \beta(\rho)\,\mathrm{d}V = \eta_c \int_V \left(-AI_3 + BI_6\right)\mathrm{d}V \quad (3)$$

where η_c is the atomic surface densities of atoms on the nanotube and $\mathrm{d}V$ is a typical surface element located on the interacting molecule. The integral I_n ($n = 3, 6$) is defined by

$$I_n = r_c \int_{-\infty}^{\infty}\int_{-\pi}^{\pi} \frac{1}{\left[\left(r_c - \delta\right)^2 - 4\delta r \sin^2\left(\theta/2\right) + z^2\right]}\mathrm{d}\theta\mathrm{d}z, \quad (4)$$

we may re-write the equation 4 by using the hypergeometric function as

$$I_n = \frac{2\pi}{r_c^{2n-2}} B\left(n - 1/2, 1/2\right) \sum_{m=0}^{\infty}\left(\frac{\left(n-1/2\right)_m \delta^m}{m! r_c^m}\right)^2. \quad (5)$$

Next, we assume that the atom at point P is within the volume element of each biomolecule. Thus, we can determine the molecular interaction arising from the certain drug by performing the volume integral of E_d over the volume of the certain drug, namely

$$\begin{aligned} E_d &= \eta_s \int_V E_a(\delta)\,\mathrm{d}V \\ &= \eta_s \eta_c \int_V \left(-AI_3(\delta) + BI_6(\delta)\right)\mathrm{d}V \\ &= \eta_s \eta_c \left(-AK_3 + BK_6\right), \end{aligned} \quad (6)$$

where δ is the distance from the nanotube axis to a typical point of the certain biomolecule and η_s is the mean volume density of the biomolecule, which depends on the assumed configuration of the interacting biomolecule and K_n can be given as

$$K_n = \int_V I_n(\delta)\,\mathrm{d}V \quad (7)$$

2.1. Insertion of ACh as Two-Connected Spheres into SWCNT

Here, we assume ACh structure modelled as two-connected spheres, the larger sphere centred at the origin point with radius r_{s_1} and the samller sphere with radius r_{s_2} located on the left side of the origin point. Each sphere assumed to be as a spherical shell parameterized $\left(r_s\cos\theta\sin\phi, r_s\sin\theta\sin\phi, r_s\cos\phi\right)$, where $-\pi<\theta\le\pi$, $0\le\phi\le\pi$, $0\le r_s\le 1$ and r_s is the radius of the spherical shell as shown in **Figure 3(a)**. Further, the distance is given by $\rho^2=r_s^2r_c^2\sin^2\phi$ and the spherical volume element is $\mathrm{d}V=r_sr_c^2\sin\phi\mathrm{d}r\mathrm{d}\phi\mathrm{d}\theta$. From the work of Thamwattana *et al.* [26], the interaction energy between a spherical molecule and a cylindrical nanotube is given as

$$E_{\text{Sphc-CNT}}=\eta_c\eta_s\left(-AD_3+BD_6\right)=\eta_c\eta_s\int_V\left(-AJ_3+BJ_6\right)\mathrm{d}V, \tag{8}$$

where η_c and η_s are the atomic volume densities of the cylindrical nanotube and spheroidal molecule, respectively. So, the integral J_n ($n=3,6$) is given by

$$J_n=\int_{-\pi}^{\pi}\int_0^{\pi}\int_0^1 r_s^{2n+2}r_c^{2n+2}\sin^{2n+2}\phi\mathrm{d}r\mathrm{d}\phi\mathrm{d}\theta, \tag{9}$$

by using the relation between the beta and hypergeometric functions, D_n can be expressed in terms of

$$D_n=\frac{8\pi^2r_s^3}{3r_c^{2n-2}}B\left(n-1/2,1/2\right)\sum_{m=0}^{\infty}\frac{\left(n-1/2\right)_m\left(n-1/2\right)_m}{\left(5/2\right)_m m!}\left(\frac{r_s^2}{r_c^2}\right)^m. \tag{10}$$

2.2. Insertion of RAV into SWCNT

To evaluate the total energy arising from the RAV drug interaction with SWCNT of radius r_c, we consider two possible structures as models for RAV molecule which are an ellipsoid and cylinder as shown in **Figure 3(b)** and **Figure 3(c)**, respectively.

2.2.1. An Ellipsoid Model

The RAV molecule assumed to be as a spheroidal structure, parameterized by $\left(ar\sin\phi\cos\theta, ar\sin\phi\sin\theta, br\cos\phi\right)$, where $0\le r\le 1$, $-\pi<\theta\le\pi$, $0\le\phi\le\pi$, and a and b are the equatorial semi-axis length and polar semi-axis length (along the z-axis) of spheroidal structure, respectively, as shown in **Figure 3(b)**. Further, the distance is given by $\rho^2=a^2r^2\sin^2\phi$ and the spheroidal volume element is $\mathrm{d}V=a^2br^2\sin\phi\mathrm{d}r\mathrm{d}\phi\mathrm{d}\theta$. From the work of Thamwattana *et al.* [26], the interaction energy between a spheroidal molecule and a cylindrical nanotube is given as

$$E_{\text{Sphd-CNT}}=\eta_c\eta_l\left(-AT_3+BT_6\right)=\eta_c\eta_l\int_V\left(-AW_3+BW_6\right)\mathrm{d}V, \tag{11}$$

where η_l is the mean volume density of the spheroidal molecule, respectively. So, the integral W_n ($n=3,6$) is given by

$$W_n=\int_{-\pi}^{\pi}\int_0^{\pi}\int_0^1 a^{2n+2}br^{2n+2}\sin^{2n+2}\phi\mathrm{d}r\mathrm{d}\phi\mathrm{d}\theta. \tag{12}$$

The Integral T_n can be expressed in terms of

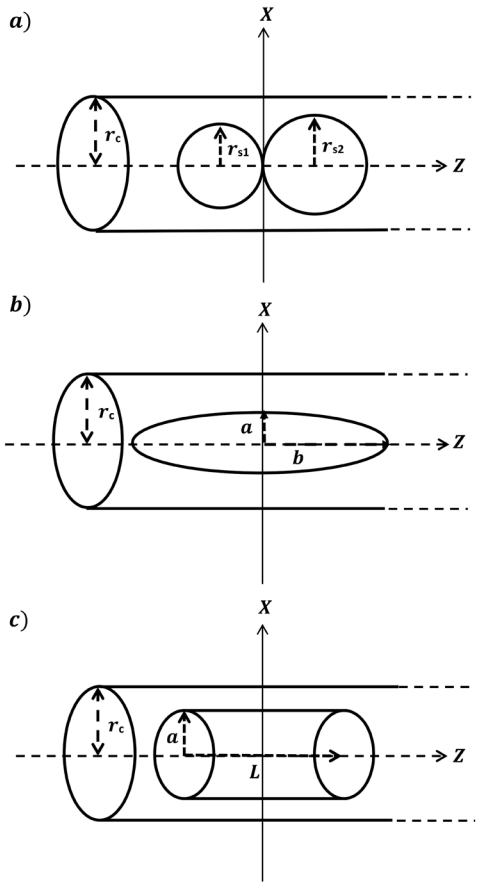

Figure 3. The possible configuration for each antiviral compound: (a) ACh molecule splitted as two-connected sphere located on the left and right sides of the origin point; (b) RAV molecule as an ellipsoid structure; (c) RAV molecule as a perfect cylinder, each configuration interacting with a SWCNT of radius r_c.

$$T_n = \frac{8\pi^2 a^2 b}{3r_c^{2n-2}} B\left(n-1/2,1/2\right) \sum_{m=0}^{\infty} \frac{\left(n-1/2\right)_m \left(n-1/2\right)_m}{\left(5/2\right)_m m!} \left(\frac{a^2}{r_c^2}\right)^m . \tag{13}$$

To obtain and evaluate the interaction energy for each configuration as shown in **Figure 3**, we need to determine the potential energy arising from the specific atom at point P inside the cylindrical nanotube as shown in **Figure 2(c)** (this atom is withing the volume of RAV).

2.2.2. Cylindrical Model

Here, we model the RAV molecule modelled as a perfect cylinder located at the origin (centered) with radius a and length $L = 2b$ as shown in **Figure 3(c)**. A typical point in the cylinder can be parameterized by $\left(ar\cos\theta, ar\sin\theta, z\right)$, where $0 \le r \le 1$, $-\pi \le \theta \le \pi$ and $-L \le z \le L$. Therefore, the distance δ is given by $\delta^2 = a^2 r^2$ and the volume element of cylinder is $\mathrm{d}V = a^2 r \mathrm{d}r \mathrm{d}\theta \mathrm{d}z$. From Thamwattana's work *et al.* [26], the interaction energy between a cylindrical molecule and a cylindrical nanotube given as

$$E_{\text{Cyld-CNT}} = \eta_c \eta_d \left(-AY_3 + BY_6\right) = \eta_c \eta_d \int_V \left(-AG_3 + BG_6\right) \mathrm{d}V , \tag{14}$$

where η_d is the mean volume density of the cylindrical molecule. So, the integral G_n ($n=3,6$) is given by

$$G_n = \int_{-L}^{L}\int_{-\pi}^{\pi}\int_{0}^{1} a^{2n+2} r^{2n+2} \mathrm{d}r\,\mathrm{d}\theta\,\mathrm{d}z. \tag{15}$$

So, Y_n is given as

$$Y_n = \frac{4\pi^2 a^2 L}{r_c^{2n-2}} B\left(n-1/2,1/2\right) \sum_{m=0}^{\infty} \frac{\left(n-1/2\right)_m \left(n-1/2\right)_m}{\left(2\right)_m m!} \left(\frac{a^2}{r_c^2}\right)^m. \tag{16}$$

3. Results and Discussion

In this section, we apply Lennard-Jones potential and the discrete-continuum approach to evaluate the interaction energy of each drug interacting inside SWCNTs with variant radii r_c. The non-bond energy, well-depth ε and van der Waals diameter σ are shown in **Table 1**. The physical parameters and illustrated radii r_c of CNTs are given in **Table 2**. The attractive and repulsive constants are calculated by using the combining laws ($A=4\varepsilon\sigma^6$ and $B=4\varepsilon\sigma^{12}$) and are given in **Table 3**. The volume density for each configuration calculated as the total number of atoms that are containing the specific molecule are divided by the volume of the molecule structure, spherical shape (η_s), spheroidal structure (η_l) and cylindrical shell (η_d), which are $\eta_s = 26/\left(4\pi r_s^3/3\right)$, $\eta_l = 31/\left(4\pi a^2 b/3\right)$ and $\eta_d = 31/\left(2\pi a^2 L\right)$, respectively. Next, we evaluate and plot the minimum energies (for all configurations) which are arising from the ACh-SWCNT and RAV-SWCNT interactions. We also deduce the critical radius of SWCNT that will accept both antiviral compounds (ACh-SWCNT and RAV-SWCNT). The minimum energies for all configurations are obtained based on the equilibrium position of each molecule being away from the interior wall of CNT and its radius r_c along the range of z-axis. In this model, we observe the encapsulation of ACh and RAV inside the nanotubes with radius in the range 3.204 Å < r_c < 7.551 Å and the minimum energies obtained for both configurations when r_c greater than 3.391 Å. The lowest interaction energy for ACh-SWCNT and RAV-SWCNT interactions is obtained when the radius of nanotube in the range 3.86 Å < r_c < 4.07 Å as shown in **Figures 4-6**.

For the three proposed configurations, we note that the both antiviral compounds, ACh-SWCNT and RAV-SWCNT, are repulsive and unstable when $r_c < 3.325$ and $r_c < 3.391$ Å, respectively, and the (9, 2) SWCNT of radius $r_c = 3.973$ Å is the most favorable nanotube followed by the condition where $r_c = 3.861$, 3.775, 4.615, 3.590, 3.523, 5.523, 6.102, 7.551 and 3.391 Å, respectively. For all interactions, ACh-SWCNT (connected-spheres), RAV-SWCNT (spheroidal) and RAV-SWCNT (cylindrical), are with minimum energies of approximately −0.664, −1.059 and 1.204 kcal/mol, respectively. Furthermore, we can noticeably see that the magnitude of the minimum energy for RAV-SWCNT (an ellipsoid structure) interaction is slightly smaller than that of RAV-SWCNT (perfect cylinder). We also note that the perfect cylinder (RAV) has the

Table 1. The Lennard-Jones constants (ε: Bond length, σ: Non-bond distance and ζ: Non-bond energy) (single bond: sb, double bond: db) [24] [27] [28].

Interaction	ε (Å)	σ (Å)	ζ (Kcal/mol)	Interaction	ε (Å)	σ (Å)	ζ (Kcal/mol)
H-H	0.74	2.886	0.044	O-H	0.96	3.193	0.051
O-O (sb)	1.48	3.500	0.060	O-O (db)	1.21	3.500	0.060
N-N	1.45	3.660	0.069	N-H	1.00	3.273	0.055
C-C (sb)	1.54	3.851	0.105	C-H	1.09	3.368	0.068
C-C (db)	1.34	3.851	0.105	C-O (sb)	1.43	3.675	0.079
C-O (db)	1.20	3.675	0.079	C-N	1.47	3.755	0.085

Table 2. Parameters for carbon nanotubes, ACh and RAV molecules.

Radius of CNT (7, 2)	3.204 Å [29]	Radius of CNT (8, 1)	3.325 Å [29]
Radius of CNT (5, 5)	3.390 Å [29]	Radius of CNT (9, 0)	3.523 Å [29]
Radius of CNT (8, 2)	3.591 Å [29]	Radius of CNT (7, 4)	3.775 Å [29]
Radius of CNT (8, 3)	3.861 Å [29]	Radius of CNT (9, 2)	3.973 Å [29]
Radius of CNT (10, 3)	4.615 Å [29]	Radius of CNT (13, 2)	5.523 Å [29]
Radius of CNT (9, 9)	6.102 Å [29]	Radius of CNT (14, 8)	7.551 Å [29]
Radius of the smaller sphere	$r_{s_1} = 2.03$ Å	Radius of the larger sphere	$r_{s_2} = 2.52$ Å
Equatorial-axes of the spheroidal molecule	$a = 2.54$ Å	Polar semi-axes of the spheroidal molecule	$b = 6.205$ Å
Length of cylinder molecule	$L = 2b = 12.41$ Å	Surface density for the SWCNT	$\eta_c = 0.381$ Å^{-2}
Volume density for the larger sphere	$\eta_{s_1} = 0.2388$ Å^{-3}	Volume density for the smaller sphere	$\eta_{s_2} = 0.2856$ Å^{-3}
Volume density for the spheroidal molecule	$\eta_l = 0.1849$ Å^{-3}	Volume density for the cylindrical molecule	$\eta_d = 0.0617$ Å^{-3}

Table 3. Numerical values of the significant constants (A and B) involved in this model.

Interaction	Attractive	Value (Å^6 kcal/mol)	Repulsive	Value (Å$^{12} \times 10^3$ kcal/mol)
ACh	A_{ACh}	23.38	B_{ACh}	54.386
RAV	A_{RAV}	23.43	B_{RAV}	56.598
CNT	A_{CNT}	17.40	B_{CNT}	29.000
Spherical shell ($r_{s_1} = 2.52$)	A_{s_1}	23.52	B_{s_1}	54.825
Spherical shell ($r_{s_2} = 2.03$)	A_{s_2}	23.24	B_{s_2}	53.946
An ellipsoid configuration (RAV)	A_l	23.43	B_l	56.598
Cylindrical configuration (RAV)	A_c	23.43	B_c	56.598

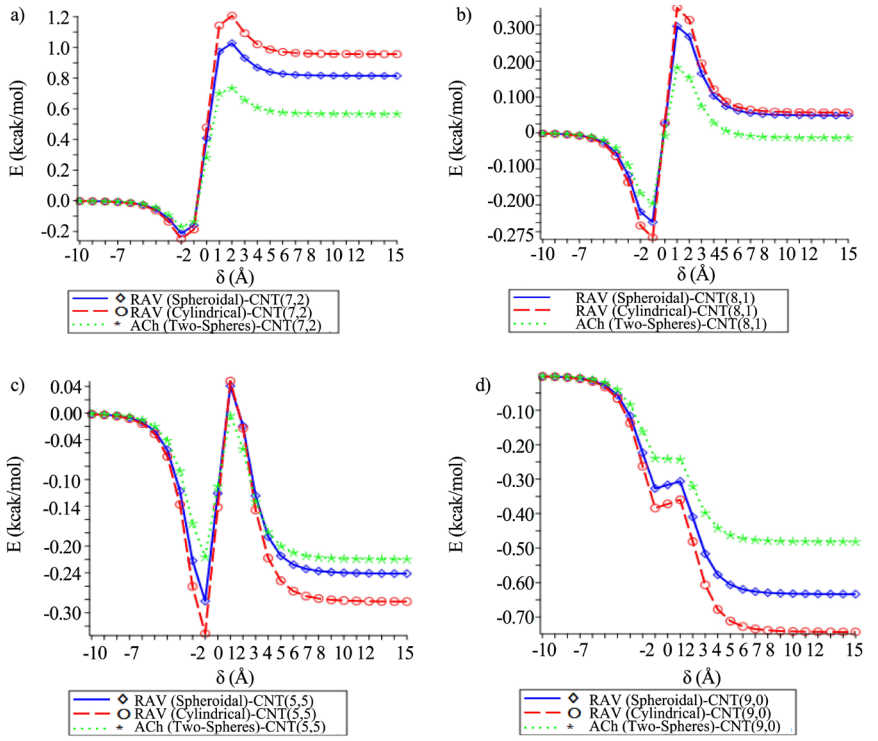

Figure 4. Interaction energy (E) arising from the encapsulation of two antiviral compounds (ACh and RAV) inside SWCNTs with varian radii r_c a) $r_c = 3.204$ b) $r_c = 3.325$ c) $r_c = 3.391$ d) $r_c = 3.523$ Å.

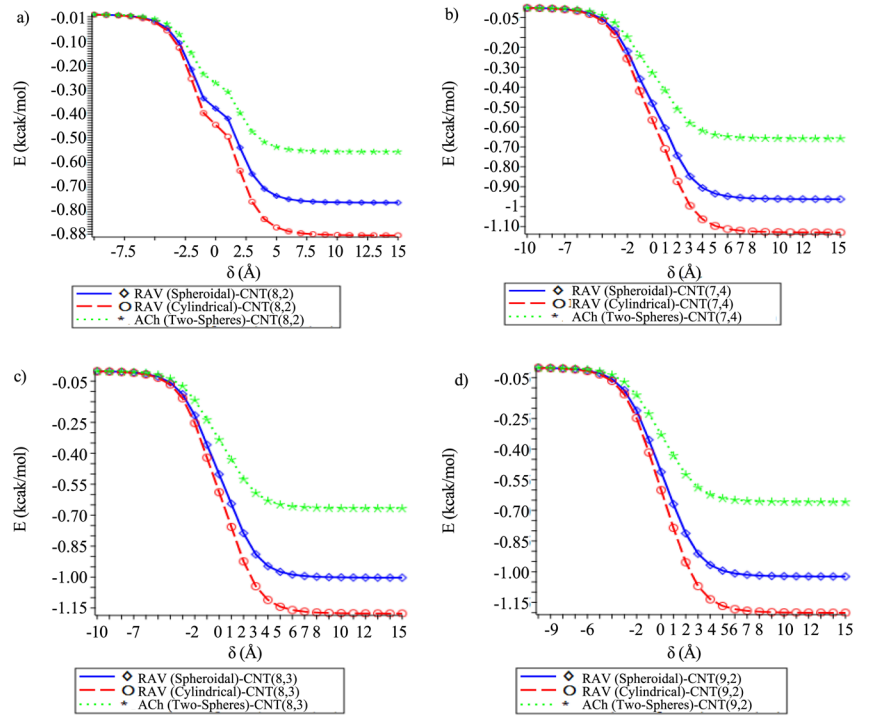

Figure 5. Interaction energy (E) arising from the encapsulation of two antiviral compounds (ACh and RAV) inside SWCNTs with varian radii r_c a) $r_c = 3.590$ b) $r_c = 3.775$ c) $r_c = 3.861$ d) $r_c = 3.973$ Å.

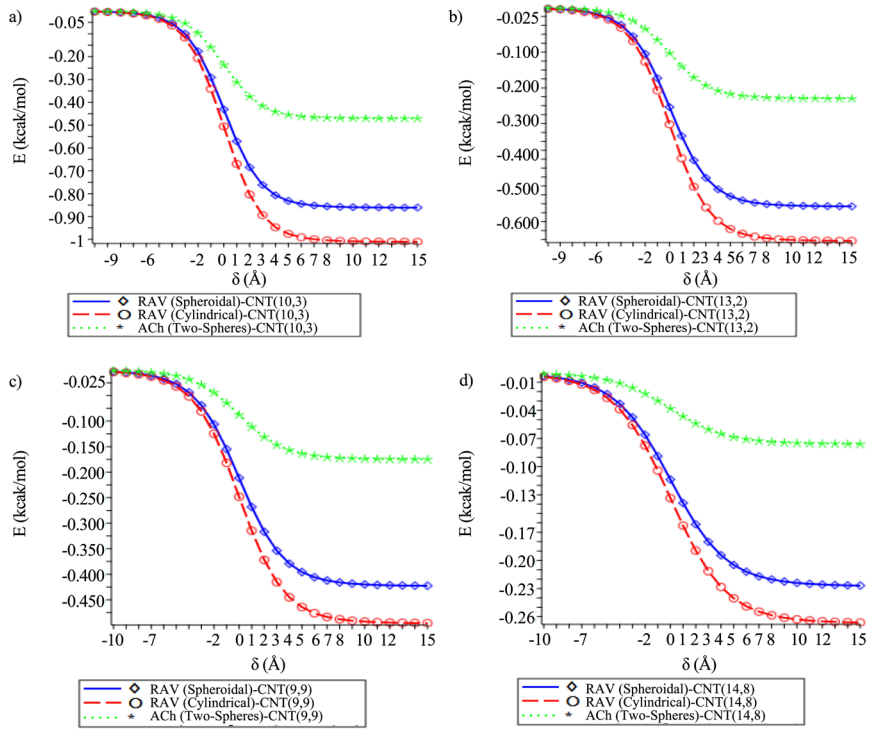

Figure 6. Interaction energy (E) arising from the encapsulation of two antiviral compounds (ACh and RAV) inside SWCNTs with varian radii r_c a) $r_c = 4.615$ b) $r_c = 5.523$ c) $r_c = 6.102$ d) $r_c = 7.551$ Å.

maximum binding energy because of its volume 502.804 Å^3 being larger than that of an ellipsoid structure (RAV) which is 167.601 Å^3. This means that smaller size of an ellipsoid ends requires smaller size of nanotube to accommodate the spheroidal shell (RAV) compared with that of cylindrical structure (RAV) despite having similar dimensions. Moreover, we observe that our results consistently agree with the most recent research findings, for example, Dresselhaus *et al.* [1] predict that the (5, 5) CNT of $r_c = 3.391$ could be the most significant and smallest effective physical nanotube, and ACh drug can be carried with SWCNT of radius in the range of 4 Å $\le r_c \le$ 8 Å (8 Å < diameter = $2r_c$ < 16 Å) delivered to the target and infected cells [23].

4. Conclusion

In this study, the Lennard-Jones potential and continuum approach are adopted to evaluate the minimum energy for each configuration. The proposed model obtained mathematically by representing each molecule using the rectangular coordinate (x, y, z) as a reference system. Through investigation, we find that the SWCNT plays a significant role by increasing the effectiveness of the antiviral compounds against the growth and symptoms of the AD. The SWCNT is a selective tool because of its distinct properties, such as high conductivity and low solubility in aqueous media. It can be concluded that the RAV antiviral compound is more effective against the AD growth, and both antiviral

compounds, ACh and RAV, would not be accepted when $r_c < 3.391$ Å. For all possible configurations, we note that the lowest minimum energy obtained when $r_c = 3.973$ Å. Our results are in very good agreement with Yang's work who has shown that the ACh antiviral compound is successfully carried out and conjugated with SWCNTs with variant radii r_c [23].

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Conflicts of Interest

Has no conflict of Interest.

Ethical Approval

This article does not contain any studies with animals performed by any of authors.

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Organizational Culture: A Case Study Measuring the Importance and Presence of Organization Values at a Higher Education Organization in Saudi Arabia

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Abstract

This paper presents the findings of a study that was conducted to investigate the levels of organizational culture values that are present in students and instructors in a higher education organization in Saudi Arabia. A Survey was prepared and conducted to obtain primary data from students and instructors perception of thirty two basic and common values that are relevant to the study of organizational culture. The study findings gives valuable insights into how students and instructors see the importance and presence of organizational values and beliefs in the organization. Moreover, the enthusiasm of instructors and students gave a clear indication of how significantly important the surveys were to them. Higher education organizations may look at this paper's findings and may choose to apply its methodology to their organization and utilize its outcomes to better understand and then improve their organizational culture. Finally, this study provide a thorough investigation of a higher education organization culture by ranking the thirty two common values and measures their presence in the students and instructors community. The study will hopefully open an area of interest that could provide considerable insight for researchers interested in this topic.

Keywords: organizational culture, organizational behavior, higher education, value measurement, Saudi Arabia

1. Introduction

Higher education institutes and organizations are considered key stone and corner base of any society since they provide the higher education needed for all classes of people in a country. The majority of the workforce in any facilities, institutions, companies, or government organizations have workers whom they graduated from a college or at least had some sort of a higher education experience.

Workers who does not have a post-secondary education are usually have far less job options than if they earned a college degree. They typically work in the services, manufacturing, or construction jobs that does not requires high educational and analytical capabilities.

College education traditionally equip students with many skills in various subject areas which enables them to make better choices in their personal and professional life. In addition it provide them with the tools necessary for improving their personal and social skills for self-discipline and effective interaction with others which will help them to achieve career advancement.

It is only logical to say that improving higher education organizations will benefit not only society but the whole world at large. It is an important subject that never stops to continue developing. It is in this context that this study is conducted to measure the importance and presence of organizational values in a higher education organization (Reda, 2001).

2. Literature Review

The organizational culture can be defined as the set of values, beliefs, and attitudes that are shared by the constituents of a given organization. Its importance stems from its influence on organizational performance as it derives the organizational members actions and subsequently its outcomes. Therefore, studying and understanding organizational culture enables the organization leaders to effectively manage and improves their organization performance (Cameron & Ettington, 1988).

Understanding the culture of an organization is a major key for effective management practices in universities. Organizational culture can further be defined as a system of shared meanings, beliefs, and values held by organizational members that determines how they act toward each other and outsiders. In other word, organizational culture can be considered as a pattern way of thinking, feeling, and reacting that exists in an organization. Organizational culture is descriptive; it is concerned with how members perceive the organization, not with whether they like it. It describes rather than evaluate (Crispen & Bulelwa, 2017). It is a crucial element in every organization to study their current culture and determine how it influences its members, in order to improve current values and beliefs not to mention introducing new values that will influence student positively and provides them with good academic behaviors (Kezar & Eckel, 2002).

2.1 Layers of Organizational Culture

Organizational culture is multi-layered. It is expressed in an organization's core values, mission, strategic objectives, and policies and procedures.

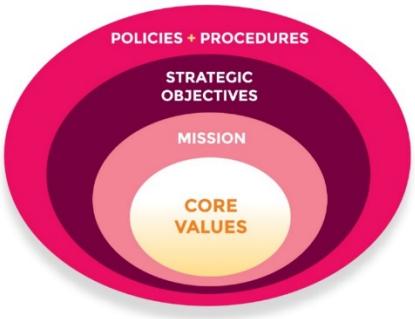


Figure 1. Layers of organizational culture

An organization's core values and mission lie at the centre of its culture. These, in turn, influence the direction of the organization's strategic objectives and the policies and procedures that it puts in place to support them. In the context of a non-profit merger, cultural integration requires the creation of a new culture that draws from the best aspects of each constituent organization's culture. This means starting at the centre, with a shared mission and core values, and working outward (Fralinger & Olson, 2007).

2.2 Importance of the Organizational Culture Study

There are four foreseeable benefits of studying organizational culture. First, it gives the organization a good reputation with a higher level of standards in values and beliefs. Second, it helps the organization to attract new students (customers). Third, it helps the organization to understand its culture, and fourth, it encourages the members of the organization to be more committed to organization values (Vasyakin et al., 2016).

2.3 Study Objectives

The objectives of the organizational culture study can be specified as follows:

First, to measure the most important values and beliefs that exist in the organization. Second, to measure how important are these values and beliefs to the targeted sample. Third, to measure how committed are the targeted sample to these values and beliefs. Fourth, to provide the organization administration with better understanding of how to deal with the members of the organization based on their values and beliefs. Fifth, to locate important values that don't exist or are lacking. Sixth, to increase general awareness of the organization culture. Finally, to provide a deeper insight of how the targeted sample behaves with member of university and outside visitors (William, 2016).

3. Methodology

According to previous studies on organizational culture, and literature search on the topic, thirty two values and beliefs that are crucial in most organizations were selected. It was believed that the listed values are the most common in higher education organizations. Subsequently, the survey structure was based on measuring three aspects of each value. First, its relevant importance to the organization. Second, its existence in the members of the organization. And finally, its existence in the evaluator themselves. Each aspect is evaluated on a scale from 1 to 5 where 1 represent the least presence and 5 the most.

The study of the organizational culture included a sample of 130 participants including 95 students and 35 instructors.

3.1 Organizational Culture Survey

The purpose of the survey was to measure the importance and presence of organizational ethics and values in the educational organization.

In the survey, thirty two of the most important and common values and beliefs that exist in organizations are selected. The participants are asked to evaluate their importance and presence using a scale of (1 – 5), where 5 represent the highest ranking and 1 is the lowest. There thirty two values are:

Truthfulness, Honesty, Devotion, Commitment - Respect for Time, Creativity, Stereotype - Impression, Affiliation, Cooperation/Teamwork, Competition, Confidence, Taking Initiatives, Clean Appearance, Responsibility, Self-censorship, Freedom of Expression, Forgiveness, Planning, Achievement - Time Management, Seriousness, Justice, Positivity, Privacy, Firmness and rigor, Directing, Sacrifice - Altruism, Harmony, Communication, Enthusiasm, Interest, and Carefulness.

4. Results of the Survey

The following tables (1, and 2) and figures (2, 3, and 4) show the overall findings of the survey as reported by the students and the instructors**.**

Table 1. Findings of the survey as reported by students

Values	**Points**			**Ranking**			**Number of Participant**
	Importance	Presence in others	Presence in individual	Importance	Presence in others	Presence in individual	
Truthfulness	4.73	3.57	4.13	3	5	12	94
Honesty	4.83	3.58	4.53	1	7	2	93
Devotion	4.7	3.33	4.26	5	18	8	93
Commitment–time respect	4.68	2.97	3.84	6	32	21	93
Respect	4.73	3.65	4.37	3	2	4	92
Creativity	4.03	3.26	3.73	28	22	25	92
Stereotype–Impression	3.92	3.38	3.63	30	15	31	87
Affiliation	4.07	3.54	3.66	27	9	29	90
Cooperation–Teamwork	4.27	3.38	3.97	23	15	16	90
Competition	3.84	3.45	3.64	32	12	30	94
Confidence	4.58	3.58	4.15	11	5	11	92
Initiative	4.31	3.27	3.81	22	21	23	89
Clean appearance	4.62	3.65	4.54	7	2	1	92
responsibility	4.59	3.36	4.2	9	17	9	94
Self-censorship	4.36	3.14	4.12	20	29	13	94
freedom of expression	4.34	3.4	3.93	21	14	18	93
The etiquette of	4.61	3.45	4.28	8	12	7	95

listening							
forgiveness	4.48	3.56	4.39	16	8	3	91
Planning	4.54	3.2	3.71	14	27	26	94
Achievement - Time Management	4.56	3.14	3.7	13	29	27	93
Seriousness	4.43	3.21	3.96	17	25	17	93
Justice	4.74	3.48	4.29	2	11	6	93
Positivity	4.59	3.5	4.18	9	10	10	92
Privacy	4.57	3.75	4.34	12	1	5	93
Firmness and rigor	3.89	3.17	3.39	31	28	32	92
Directing	4.24	3.24	3.87	24	24	20	91
Sacrifice – altruism	3.95	3	3.7	29	31	27	94
Harmony	4.12	3.21	3.77	26	25	24	94
Communication	4.43	3.65	3.82	17	2	22	94
Excitement	4.19	3.28	3.9	25	19	19	93
Interest	4.49	3.28	4.09	15	19	14	94
Carefulness	4.39	3.26	4.04	19	22	15	95

Table 2. Findings of the survey as reported by instructors

Values	**Points**			**Ranking**			**Number of Participant**
	Importance	Presence in others	Presence in Individual	Importance	Presence in others	Presence in Individual	
Truthfulness	4.91	3.54	4.44	1	6	5	34
Honesty	4.91	3.77	4.62	1	2	1	34
Devotion	4.8	3.43	4.56	5	11	3	34
Commitment–time respect	4.83	3.26	4.55	3	17	4	33
Respect	4.82	3.97	4.62	4	1	1	34
Creativity	4.29	2.73	3.76	23	32	29	33
Stereotype–Impression	3.74	3.49	3.68	32	7	32	34
Affiliation	4.12	3.33	4.06	26	16	18	33
Cooperation–Teamwork	4.41	3.37	3.79	17	12	26	34
Competition	4.4	3.23	3.76	18	21	29	34
Confidence	4.57	3.34	4.24	13	13	13	34
Initiative	4.31	3.14	3.76	21	25	29	34
Clean	4.71	3.6	4.44	7	4	5	34

appearance							
responsibility	4.66	3.2	4.35	10	22	7	34
Self-censorship	4.63	3.09	4.29	11	27	11	34
freedom of expression	4.31	3.06	3.94	21	28	23	34
The etiquette of listening	4.74	3.63	4.32	6	3	9	34
forgiveness	4.54	3.49	4.32	15	7	9	34
Planning	4.71	3.17	4.06	8	24	19	34
Achievement/ Time Management	4.63	3	4.06	11	29	19	34
Seriousness	4.57	2.88	4.34	13	31	8	32
Justice	4.69	3.26	4.18	9	17	15	33
Positivity	4.4	3.49	4.03	18	7	21	34
Privacy	4.26	3.57	4.09	25	5	17	34
Firmness/ rigor	3.97	3.34	3.82	30	13	24	34
directing	4.09	3.26	4.26	27	19	12	34
Sacrifice - altruism	4.09	2.97	3.79	27	30	26	34
harmony	3.86	3.2	3.81	31	22	25	32
Communication	4.29	3.46	4	24	10	22	34
Excitement	4	3.11	3.79	29	26	26	34
interest	4.49	3.34	4.18	16	13	16	34
Carefulness	4.34	3.26	4.24	20	19	13	34

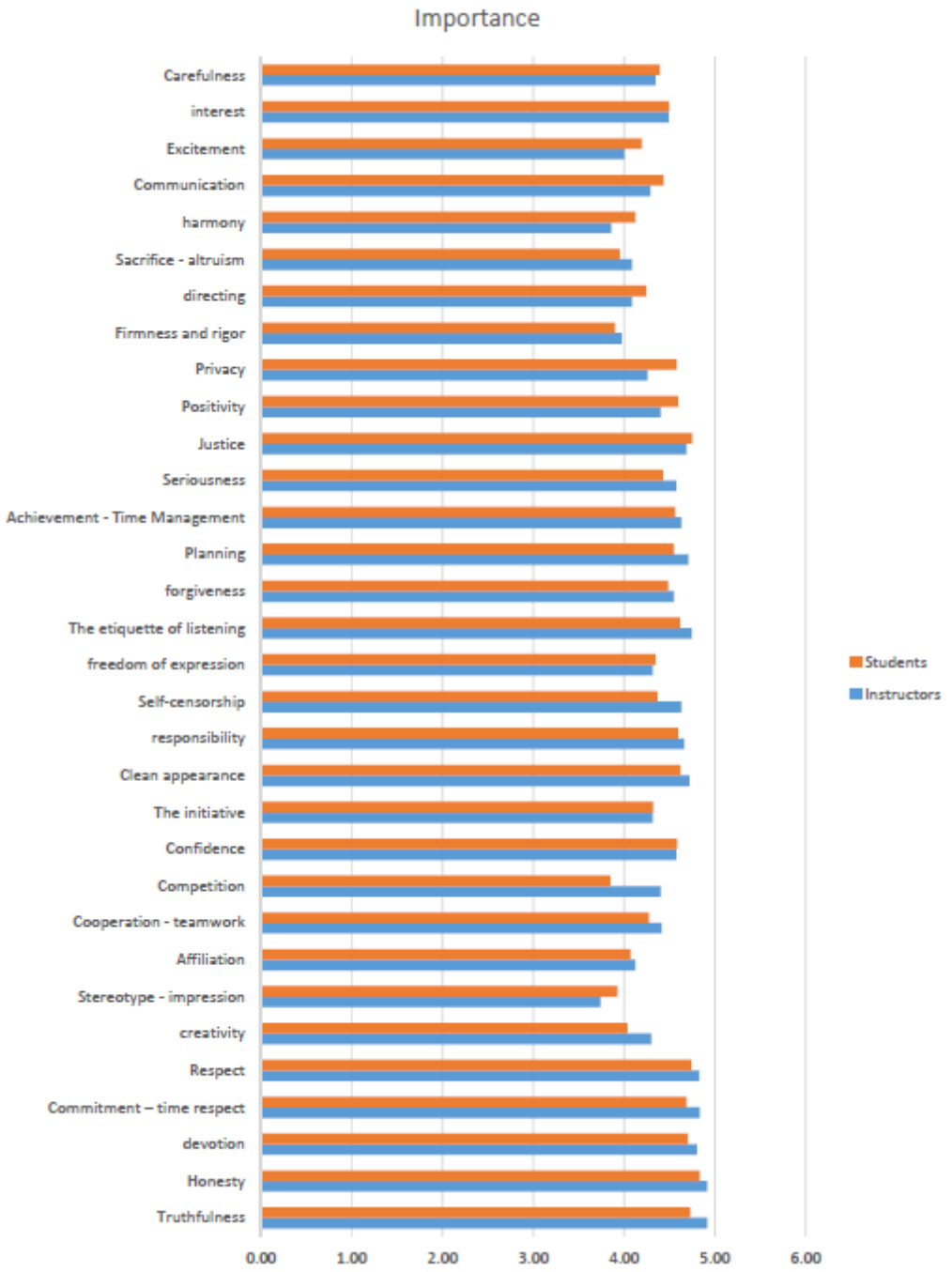


Figure 2. Importance of the vaues

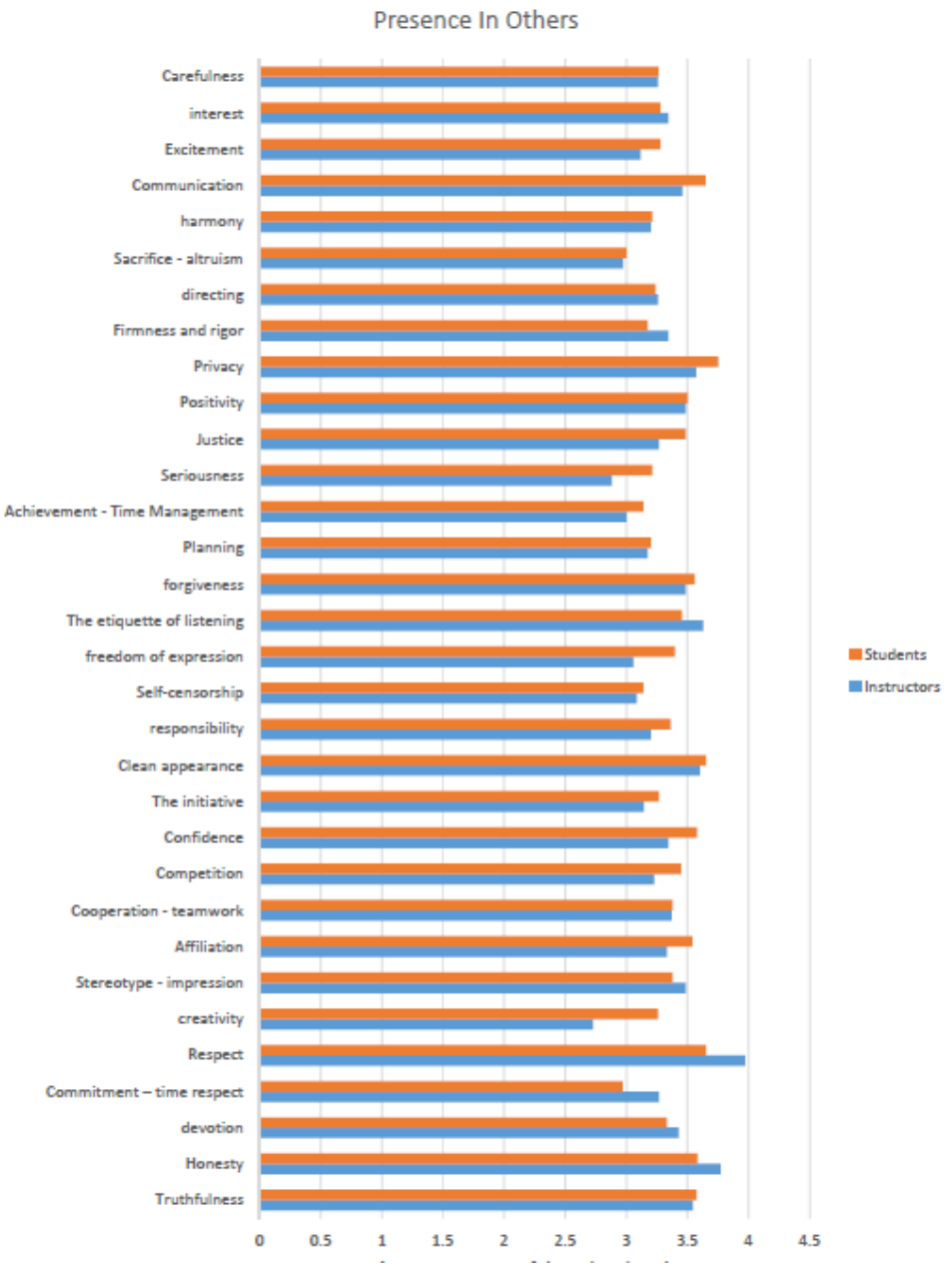


Figure 3. Presence of the values in others

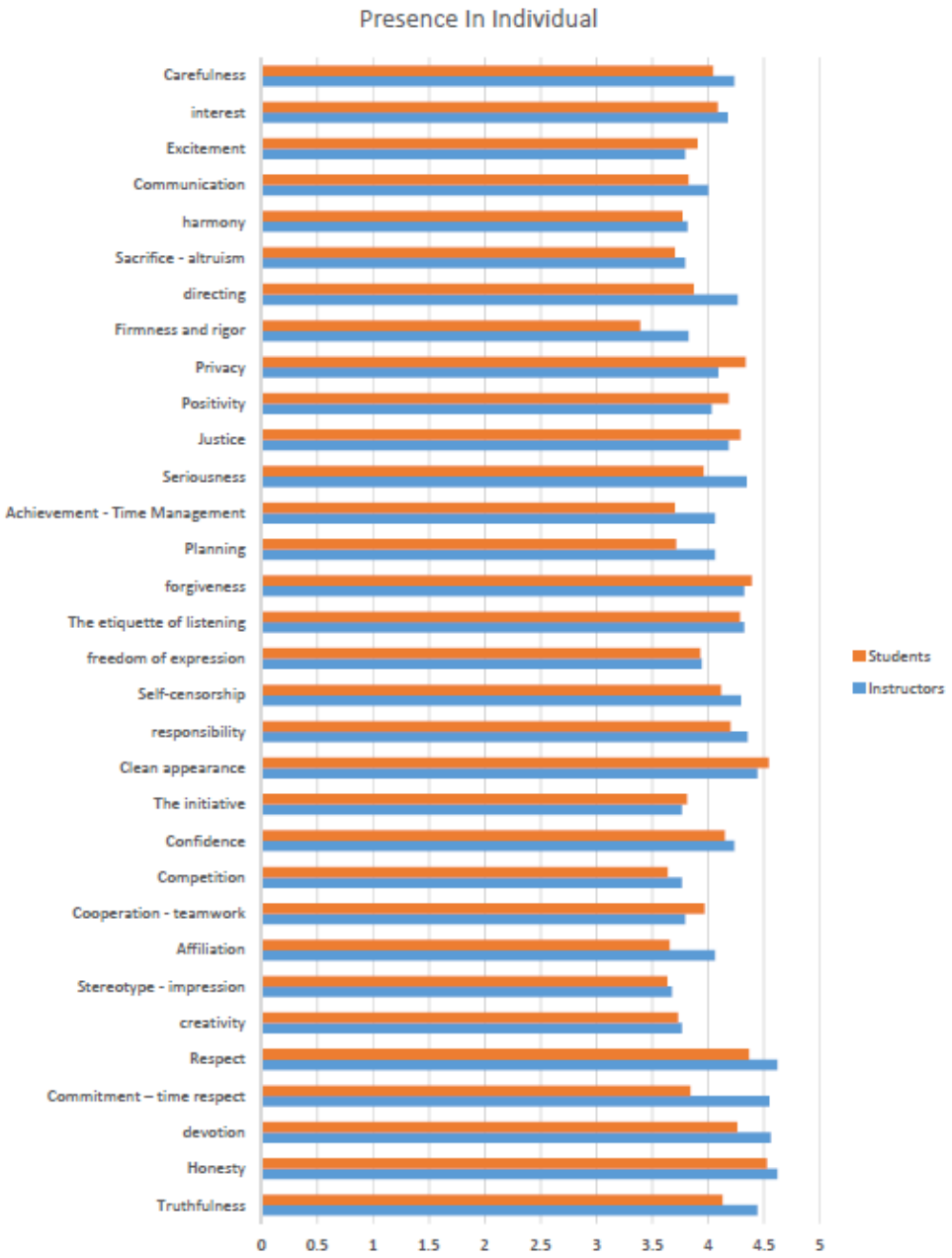


Figure 4. Presence of the values in individuals

4.1 Reliability of Survey

In order to measure how reliable our survey, the Cronbach's alpha was calculated and it was 99%. Most of the values fall within 0.75 to 0.85 interval.

4.2 Analysis of Instructors Responses

It was found from the survey that was handed to instructors that the five most important values are shown in the following tables.

4.3 The Five Most Important Values

Table 3. The five most important values

Truthfulness	Honesty	commitment	Respect	Devotion
4.9143	4.9143	4.8286	4.8235	4.8

As seen in Table 3 the most important values to the instructors are Truthfulness and Honesty with both scoring 4.9143. This indicates how vital these two values are that they both had the same importance. It is clear from the table that the values instructors perceive most important are the same values organizations are more likely to implement.

4.4 The Five Least Important Values

Table 4. The five least important values

Sacrifice	Enthusiasm	Firmness	Harmony	Stereotype
4.0857	4.0	3.9714	3.8571	3.7353

As seen from Table 4, even though these are the five least important values its score still high and above 3.5; this shows how committed the instructors are about these values.

4.5 Presence in Others

This part of the organization culture survey measures the values that are perceived to be present in the other members of the organization.

4.6 The Most Five Perceived Values Present in Others

Table 5. The most five perceived values present in others

Respect	Honesty	Etiquette of Listening	Clean appearance	Privacy
3.971	3.771	3.629	3.60	3.571

From Table 5, the two most perceived values are respect and honesty and this indicate a positive feedback from instructors regarding the values that are seen to be present in the organization.

4.7 The Least Five Perceived Values in Others

Table 6. Least five perceived values in others

Freedom of speech	Achievement	Sacrifice	Seriousness	Creativity
3.057	3.0	2.971	2.879	2.727

From the instructors' point of view, table 6 shows the values that scored the least presence in others. Thus, it direct attention to its need for improvement and better awareness of how important these values are in the organization.

4.8 Presence in Individual

This part of the survey evaluation shows the presence level of the values in the individual instructors themselves.

4.9 The Five Most Perceived Values in Individuals

Table 7. The five most perceived values in individuals

Honesty	Respect	Devotion	Commitment	Truthfulness
4.618	4.618	4.559	4.545	4.441

From Table 7, the most perceived values evaluators see in themselves are Honesty and Respect since they both scored the same high score. It is noted that these most perceived values are the same values that are ranked most important and this shows a high degree of consistency regarding instructors organisation values.

4.10 The Least Five Perceived Values in Individuals

Table 8. The least five perceived values in individuals

Enthusiasm	Creativity	Competition	initiative	Stereotype
3.794	3.765	3.765	3.765	3.676

Table 8 shows the least perceived values present in the evaluator themselves.

4.11 The Five Most Important Values

It was found from the survey that was handed to students that the most five important values the students perceive are shown in following table.

4.12 The Five Most Important Values

Table 9. The five most important values

Honesty	Justice	Respect	Truthfulness	Devotion
4.83	4.74	4.73	4.73	4.7

As seen in Table 9 the most important value to students is Honesty. The rest of the most important values have very close scores and this shows how they are all highly important in the point of view of students.

4.13 The Least Five Important Values

Table 10. The least five important values

Creativity	Sacrifice	Stereotype	Firmness	Competition
4.03	3.95	3.92	3.89	3.84

It is clear from Table 11 that even though these values are the least important, they are all still very close to scoring 4 out 5, and this gives a clear indication of how important all the values listed in the survey to the students.

4.14 The Most Five Perceived Values in Others

Table 11. The most five perceived values in others

Privacy	Respect	Clean Appearance	Communication	Honesty
3.75	3.65	3.65	3.65	3.58

Table 11 shows that the most perceived values that is present in the students is privacy, and that gives an impression about the behaviour of the students.

4.15 The Least Five Perceived Values in Others

Table 12. The least five perceived values in others

Firmness	Achievement	Self-censorship	Sacrifice	Commitment
3.17	3.14	3.14	3.00	2.97

Table 12 shows the values in that scored the least perceived to be present according to the students perspective. This in turn direct attention to the values that needs improvement and better awareness of how important these values are to the students.

4.16 Presence in Individual

This part of the survey evaluation shows the ranking of the values that are present in the individual students themselves.

4.17 The Five Most Perceived Values in Individuals

Table 13. The five most perceived values in individuals

Clean Appearance	Honesty	Forgiveness	Respect	Privacy
4.54	4.53	4.39	4.37	4.34

From Table 13 the most perceived value students see in themselves is Clean Appearance. However, the values Honesty and Respect are second most important values in the student's organisation values.

4.18 The Least Five Perceived Values in Individuals

Table 14. The least five perceived values in individuals

Sacrifice	Affiliation	Competition	Stereotype	Firmness
3.70	3.66	3.64	3.63	3.39

Table 14 shows the least perceived values present in the student's as they evaluated themselves.

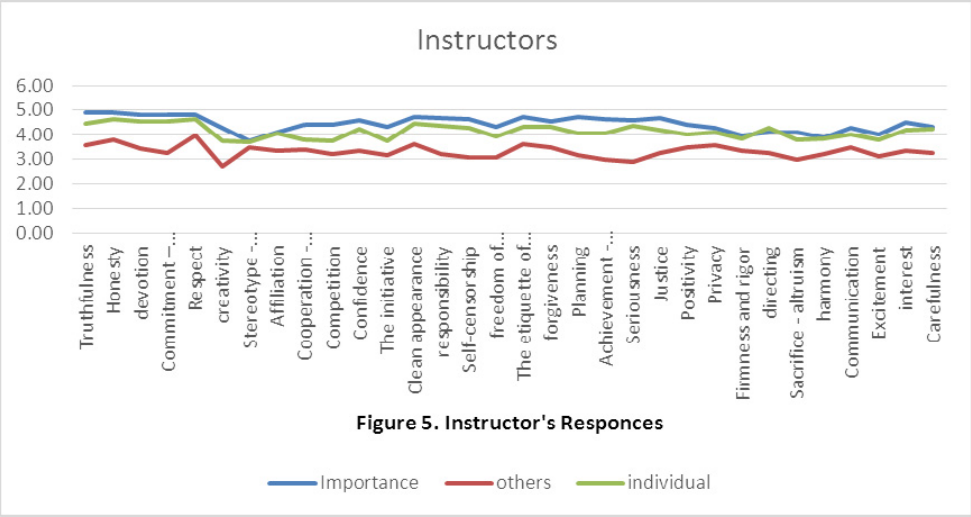
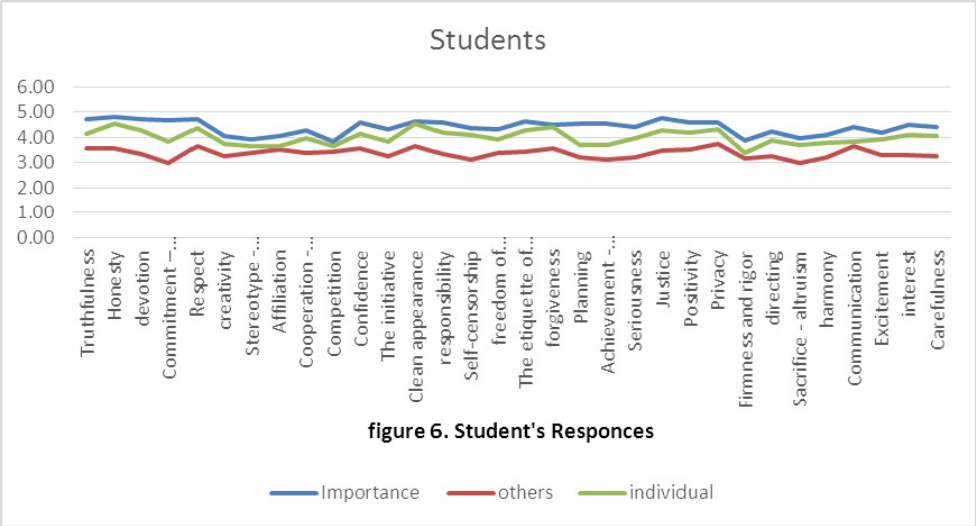


Figure 5. Instructor's Responces



Figures 5, 6. The Relationship between importance, presence in others, and presence in individual for Instructors and Students

From Figures 5 and 6, it can be see that importance of the values has scored the highest level on the graph. While the presence of these values in others scored the lowest.

5. Conclusion

The study results and analysis shows that both instructors and students see these values with significant importance since the average scores for all listed values were above 3.7. On the other hand, presence in others measures scores were about 2.7. A reason for this drop in score is that some of these values might not be visible from the evaluator point of view. That's why another part was added to measure these values presence in individuals, where the lowest scores was 3.39 which is higher than the 2.7 score in Presence in others part.

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Quality Cost in Saudi Arabia Plastic and Glass Industry

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Abstract

Quality costs are those resulting from producing, identifying, repairing, and avoiding defective products. Quality costs consist of the following four categories Internal costs, failure costs, external failure costs, and appraisal costs. A survey of several plastic and glass industries in Saudi Arabia is conducted. The survey includes a cross representation of manufacturing activities existing in the region. The survey is intended to assess the level of awareness and quantitative estimates of quality costs as related to the plastic and glass industries. The survey design and findings are presented along with analysis. Specific conclusions are drawn regarding quality costs studies and reduction/improvements programs as related to the surveyed industry category.

Keywords: TQM, plastic and glass industry, quality cost, quality improvement

1. Introduction

Quality costs are those resulting from producing, identifying, repairing, and avoiding defective products. The following four categories are used to define and quantify manufacturing quality costs. A survey of plastic and glass industries in Saudi Arabia is conducted. The survey includes a cross representation of manufacturing activities existing in the region. The survey is intended to assess the level of awareness and quantitative estimates of quality costs as related to the above four categories. The survey design and findings are presented along with analysis. Specific conclusions are drawn regarding quality costs studies and reduction/improvements programs as related to the surveyed industry categories.

2. Literature Review

In process improvement efforts, cost of quality is a concept used to measure the overall cost of non-quality conformance result's and deficiencies. Cost of quality was initially defined by A. Feigenbaum in a review paper published by Harvard Business Review in 1956 (Feigenbaum, 1956). However, the earlier understanding of quality cost was that better quality requires more costs that may be achieved through the use of higher quality raw materials or more advanced machines and through employing highly experienced workers (Feigenbaum, 1991). In addition, the traditional practice of cost accounting categories any financial costs into revenues, expenses, and changes in shareholder equity. However, it did not provide any classification for the costs resulting from quality deficiencies. This exclusion of quality costs turned out to be critical due to the fact that the concerned parties dealing with the manufacturing process have no direct exposures to the products (Crosby, 1979). On the other hand, re defining the factors affecting product quality into the traditional financial books allows managers and quality personnel to better asses the firm's investments in quality and to tie it more closely to their quality improvement and cost reduction efforts (Arnold, 1994).

The classical approach towards the improvement of quality is based on the concept that the more investment in inspection and testing will result in higher amounts of saving in quality defects and associated inspection efforts. Feigenbaum's classification permits the concerned parties to utilize these costs for their own benefits (Feigenbaum, 1991). Furthermore, firms usually resort to install more measures of control and appraisal when they are faced with increased rates of rejected parts. However, this increase in appraisal effort does not guarantee reduction of the failure costs. The other possible option is to invest more in the prevention cost in order to reduce if not eliminate the failure causes and eventually cost. Thus classification of quality costs would provide a quantified foundation for measuring, monitoring, and forecasting quality (Feigenbaum, 1991). Other and additional forms of quality costs principles can be found in the concept of the cost of poor quality which was

developed and described by Juran on quality cost accounting (Juran, 1962). A paper titled "Hidden quality costs and the distinction between quality cost and quality loss" (Georgios et al., 2001), suggests that there are other types of quality costs other than prevention, appraisal and failure costs. These are considered hidden costs and they are described that study. The significance of these costs is the manufacturing defects and the design malfunctioning are overlooked because they are considered too large to be calculated.

Furthermore, prevention, appraisal and failure are categories as quality costs and quality losses. So, it introduces the classification of defects avoidance and inspection loss.

Many organizations encounter nowadays the inefficiency of majority of cost- accounting formats in recording and measuring quality costs and in providing suitable framework that covers total quality cost. The major factor for this failure is absence of formal tools for measuring the financial results of low quality that are the product of many quality tasks.

A paper titled "Improving the definition and quantification of quality costs" (Ching-Chow, 2008) presents a study that discuss the emerging trends by redefining the classical 'Prevention, Appraisal, and Failure' classification of quality costs and the unclear costs that comes from the emerging of a couple of hidden types of costs, namely the "extra resultant cost" and the "estimated hidden cost". Adopting these emerging classification, this paper presents a comprehensive categorization of the components of the cost of quality with reference to an elaborate list of quality tasks in addition to the concept of "product life-cycle". The paper also explains how to measure the different types of quality costs using various methods based on what it calls "cost of quality account matrix". This method consists of measuring the relevant percentage of accountabilities for the quality costs that each group of activities share.

Navee Chiadamrong in his paper titled "The development of an economic quality cost model" (Navee, 2003) indicates that the meaning of the word "economics of quality" extends far beyond the commonly understood meaning of "quality cost". Usually, whenever a rework job is done or when an effort is conducted to sort out defects, the cost of quality increases. Nevertheless, the costs of resolving these issues extends far more than the obvious costs of the tasks of appraisal and inspection. Traditional practice of cost accounting does not provide solutions to organizations that they can resort to quantify quality cost data because of its shortage to measure the hidden and specifically, unrecognized costs. Therefore, it is not possible to measure extra costs. This study describes a classical model of quality economics in relation to two major factors, namely the classical prevention, appraisal, failure costs and the invisible quality loss costs. This method considers that process costs permits for the tracing of the costs that are usually result from production process itself and to the costs that are related to quality. Thus this model would help organizations to have a more defined frame for total quality costs.

Also, a paper by Plunkett and Dale titled "Quality costs: a critique of some economic cost of quality models" (Plunkett & Dale, 1988) provides a review of several quality costs surveys that were carried out in several regions. Limited number of these surveys covered extended dimensions on cost of quality however, the majority of the other surveys dealt with cost of quality in general management style dealing with it in a general and wide scope covering financial factors and assessment of management behaviors. One section of the study dealt with matters concerned with data gathering, measuring, analysis and utilization of quality cost information. Another section of the paper dealt with matters related to classical evidence of interactions among cost of quality items.

A survey study of Quality tools used in the Food industry in Saudi Arabia was conducted. Its findings were presented by the paper published by Naser (2007). The food industry in Saudi Arabia is facing many challenges that stem from aggressive competition from multinational food companies. However, this industry have continuously made marketable levels of growth exemplified by its higher rate of exportations. The challenge is increased due to the subscription of Saudi Arabia to the "World Trade Organization Agreement". This paper discusses the status of quality in Saudi food firms and its ability to face up to the emerging competition and asses its chances to successfully face up the new realities of the world market. The study further examined the utilization of the quality models in the processing activities of the food making organizations. It explored the tools of Total Quality Management and it is applied to measure these firms' capabilities and performance. Many examples that are reflective of the Saudi's food firms were presented. These findings were supported by a prototype survey which included some market data to quantify the quality status of the companies. The findings were presented in statistical models and a discussion of its validity were presented. It showed that some measures of the use of total quality management fundamentals activities were practiced. It also showed that other highly developed quality tools are in use in some of the food firms in Saudi Arabia. Additional results showed continued inspirations of the food industry to achieve world class recognition and quality awards. A review of research on cost of quality models and best practices was presented by Andrea and Vince (2006). In their paper,

they presented a summary of published articles dealt with multiple topics related to the cost of quality models. It discusses their effectiveness in measuring the quality cost of quality methods. The study reviewed and discussed the issues surrounding quality costing approaches. Their finding indicates that although the publication summary indicates a growing attention of the surveyed researchers on the cost of quality quantifications modeling and the importance of including it in all of the quality management research. The survey also indicated that many organizations actually apply such models and consequently are making progress in lowering the cost of quality while increasing customer's satisfaction.

In this research, a survey study was conducted to measure the cost of poor quality in Saudi Arabia plastics and glass industry. This study targeted 48 affiliations, where 19 affiliations responded, five of them were excluded due to incomplete/erroneous responses.

3. Research Methodology

The objective of this study is to assess the status of poor quality in Saudi plastic and glass industries. In order to achieve this goal, a questionnaire was designed and conducted online to related people. Data of this questionnaire covered the following aspects:

3.1 Internal Cost

Costs refer to these costs incurred prior to the product delivery to the customer. They include costs resulting from scrap, rework, retest, downtime, yield losses or disposition.

3.2 External Failure

Costs refer to these costs occurring after the products are delivered to the customer. They include categories such as complaint adjustment, returned products, warranty charges, and liability or allowances concessions.

3.3 Appraisal Cost

Appraisal costs are those resulting from measuring, evaluating, and auditing of material and products to determine their condition and conformance to specifications. They include costs of inspection and testing of incoming material and through production, associated material and services consumed, and instruments and testing equipment calibration.

3.4 Preventive Costs

Preventive costs are these associated with activities aimed at reducing appraisal and failure costs. They include costs of quality planning and design, new products review, process control, training, quality data acquisition, analysis and reporting, and improvement projects.

Cost of poor quality is measured as the sum of all costs such as inspection cost, training cost, cost of scrap, cost of rework, and cost of return. Results show that the annual average cost of poor quality is 7.0145% and is categorized as in Figure 1.

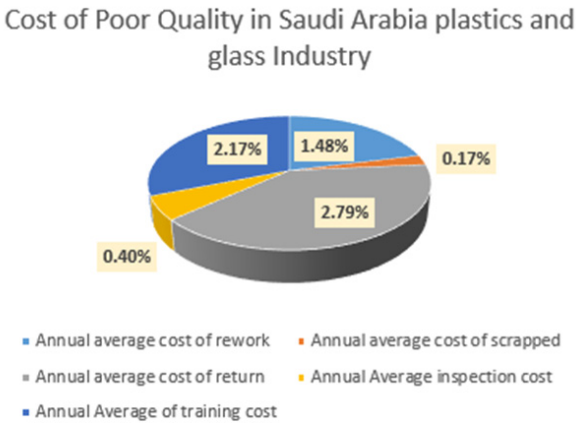

Figure 1. Average annual cost of poor quality

Providing a high level of quality products is not costly. In fact, in many cases, it is less expensive. In addition, when applying quality concepts and methodologies, cost and scheduling problem will be reduced. Executive

officers have to take more considerations on putting quality first in every decision.

Cost of poor quality varies from one affiliation to the next. This variation depends on many factors such as Product complexity, technology used, how customers use the product, elements of quality costs included, and the level of refinement of the quality system (Harrington, 1999).

4. Summary and Major Findings

Through the previous discussion of the questionnaire, plastic and glass industry faces real problem related to the cost of poor quality. This study has found that the annual average cost of rework is 1.48%, annual average cost of scrapped is 0.17, annual average cost of return has the highest percentage of 2.79%, annual average of inspection cost is 0.4%, and the annual average of training cost is 2.17%. These costs resulted be the lack of quality knowledge aspects in this industry. Technicians have to get more training on how to reduce waste and increase productivity. These companies showed keep periodic maintenance tables and machine breakdown records.

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Self-cleaning and self-cooling photovoltaic system with feedback control

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Abstract
One of the most important problems in using photovoltaic systems (PV) is the low power production due to increasing the ambient temperature, and the accumulation of dust on PV panels surfaces.
In this work, self-cleaning and self-cooling PV system with feedback control was designed, constructed and operated .The programming method of control of water pumping system is achieved by means of programmable logic controller (PLC)and frequency inverter(FI).The control system consists of two subsystems based upon the same electromechanical system .One system for controlling the cooling of PV system by using temperature sensor and feedback system, and the other system for controlling the cleaning of PV system by using huge pressure of water to push away the accumulated dust on the PV surface.
An experimental study was performed to investigate the effect of using self-cleaning and self-cooling system on the electrical power generation at the output of PV system. The electrical power generation at the output of PV modules with self-cleaning and self-cooling system has increased by 34 % and the efficiency by 26 %.

Keywords: PV system; Feedback control; Self-cleaning; Self-cooling; PLC system; Frequency inverter.

1. Introduction

In the last few years, PV systems and their applications witnessed a wide spread around the world. PV modules are subjected to deposition of sands on their glass cover, and to high ambient temperature. These effects are great, especially, in semi-arid and desert lands, such as, Middle East and North Africa, where the degradation in performance of PV modules is huge.
The following studies discussed the effect of dust accumulation and temperature increasing on the performance of PV modules, and different methods for solving these problems. Sontake et al., Muhsen et al., and Elkholy et al. [1,2,3] studied the application of solar photovoltaic water pump systems, various optimization methods, design methods, control strategies and field characteristics. Charabi and Gastli [4] carried out land suitability analysis for large PV farms implementation for the case study of Oman. The results show that several areas are declassified because of their exposure to high temperature and dust risks, where the highly suitable land areas decreased by 81% after considering the temperature and dust

constraint layers. Different PV technologies are considered and it is found that the concentrated PV technology provides higher potential for implementing large scale solar plants. Lai and Chen [5] suggested the using of heat pipe as a channel for heat dissipation to conduct the heat out of PV modules. Because DC combiner boxes are waterproof, dust proof, air tight and made of heat-insulating material, thermal energy is easily accumulated, affecting the performance and safety of power cables and other electronic components near the diodes in the DC combiner box.

Meneses-Rodriguez et al. [6] investigated the possibility of PV cell work at a relatively high temperature (from 100 to 200 °C). The conducted experiments in the temperature interval of 25 to 170 °C and the calculated data, show a real possibility of construction of a two-stage solar-to-electric energy converter with high temperature-second stage, having the overall conversion efficiency of 30-40%. In [7] Royne et al. presented a review of various methods that can be employed for cooling of PV cells. They found that single cells typically only need passive cooling, even for very high concentrations. For densely packed cells under high concentrations, an active cooling system is necessary. Only impinging jets and micro-channels have been reported. Two-phase forced convection would also be a viable alternative. In [8] Akbarzadeh and Wadowski reported about a prototype of an east-west trough solar concentrator using the profile developed for the reflecting surface and incorporating a thermo-syphon cooling system for PV cells.

In [9] Moharram et al. developed a cooling system based on water spraying of PV panels. A mathematical model has been used to determine when to start cooling of PV panels. A cooling model has been developed to determine how long it takes to cool down the PV panels. It is found that the PV panels yield the highest energy if cooling of the panels starts when the temperature of PV modules reaches a maximum allowable temperature (MAT) of 45 °C. The MAT is a compromise temperature between the output energy from the PV panels and the energy needed for cooling. Zhu et al. [10] utilized a 250 x dish concentrator with two axes tracking to evaluate a new CPV system using de-ionized water for immersion cooling. They showed that the cooling capacities of the liquid immersion approach are very favorable. The module temperature can be cooled to 45 °C at a 940 W/m2 direct normal irradiance, 17 °C ambient temperature and 30 °C water inlet temperature. The temperature distribution of the module is quite uniform, but the electrical performance of the cell module degrades after a fairly long time immersion in the de-ionized water.

Kaldellis and Kapsali [11] studied and analyzed the effect of three representative air pollutants (i.e. red soil, limestone, and carbonaceous fly-ash particles) on the energy performance of PV installations. According to the results obtained, a considerable reduction of PVs' energy performance is recorded, depending strongly on particles composition and source. Mikhilef et al. [12] studied the impact of dust accumulation, humidity level and the air velocity separately and the impact of each on the other. They showed that each of these three factors affect the other two and it is concluded that, in order to have a profound insight of solar cell design, the effect of these factors should be taken into consideration in parallel.

Biattie et al. [13] presented numerical and analytical models of sand and dust particles accumulation on PV modules in dry regions. Both models and experimental data indicate that the reduction in the free fractional area can be described by an exponential decay resulting from the formation of clusters of particles. Such clusters can support particles in upper layers which reduce the available area for photon capture by a much smaller amount than particles resting directly on the glass surface. Sarver et al. [14] provided a comprehensive overview of soiling problems, primarily those associated with sand and combined dust moisture conditions that are inherent to many of the most solar rich geographic locations worldwide. In [15] Hee et al. investigated the conditions affecting dust fall in Singapore and its effect on the optical transmission through glass modules. It was found that for bar glass samples, transmission reduces despite the heavy rains in Singapore over several months. Also, they investigated the effect of substrate tilt in keeping them clean. Bar glass substrates were tilted at angles of 10, 20, 30, 40, 50, 60, 80, and 90 degrees during outdoor exposure. They investigated the performance of TiO2 films as an outdoor self-cleaning coating for solar panels. TiO2 of different thicknesses were deposited on glass substrate by hydrolysis method which is a low-cost and commercially viable process. In [16] Pavan et al. studied the effect of soiling on energy production for large-scale ground mounted PV plants in the country side of southern Italy. The results presented showed that both the soil type and the washing technique influence the losses due to the pollution. A 6.9% of losses for the plant built in sandy soil and a 1.1% for the one built on a more compact soil have been found.

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Ghazi et al. [17] made a review for dust effect on flat surfaces. They showed that since 1942 many efforts have been made to address the severity of deposited particles like dust. Various innovative methods have been employed to clean the surface of the grimy PVs, a holistic approach needs to show the cleaning mechanism under different climate conditions. The pattern of dust distribution in different parts of the world is assessed and it was found that the Middle East and North Africa have the worst dust accumulation zones in the world. Verma et al. [18] showed that simple antireflective coatings on the glass can help alleviate reflection in systems with motorized tracking, the problem of dust accumulation on module surfaces over time remains and can even be exacerbated by certain antireflective coatings. A process of non-lithographic nano-structuring of the packaging glass surface is shown to both reduce reflection at the air/glass interface and to have a self-cleaning property. Kamlesh et al. [19] studied the performance of controllers for solar PV water pumping applications. In [20] Kalogirou et al. presented a study of the characteristics of three types of PV panels: mono-crystalline, polycrystalline, and amorphous silicon and the effects of soiling on their performance using on site measurements. They performed the test of degradation of PVs performance under extreme soiling conditions caused by artificial deposition of dust on the panels when their surface was dry and when it was wet before the dust deposition. The results showed that especially the artificial soiling on the PV surface presents a serious degradation of the PV performance. The effect of natural dust deposition on the panel's surfaces for a year is investigated. The first finding of the study is that in winter the occasional rain is adequate to keep the PV surfaces clean whereas when a dust episode occurs, the panels should be cleaned manually. This is not the case for the summer time, which for Cyprus lasts for more than 8 months. The recommended cleaning is immediately after a dust episode and every 2-3 weeks in summer time according to how much loss the owner of the PV is willing to accept and the associated cleaning cost. In [21] Sayah et al. presented a brief review of the energy yield losses caused by dust deposition on solar collectors, with particular emphasis on flat-panel PV systems. They reported on degradation in the performance of solar plants based on the type of solar collectors, geographical location, local climate, and exposure period of the collectors and absent any manual cleaning. An analysis of the advantages of cleaning processes that include natural, manual, automatic and passive methods is presented.

In [22] Adinoyi and Said studied the effect of dust accumulation on the power output of solar PV modules in the Eastern province of Saudi Arabia. This study indicate that power decrease by as much as 50% can be experienced for PV modules that are left unclean for a period of over six months. Solar tracker improves power output and helps reduce dust accumulation effect by 50% at off-peak time.

In [23] Kaldellis et al. experimentally investigated the performance of two identical pairs of PV panels, the first being clean and the second being artificially polluted with three different commonly met in urban and other environments, air pollutants (i.e. red soil, limestone and carbonaceous fly-ash particles). The results obtained showed a considerable reduction in of PVs energy performance, depending on both particles composition and origin, and on the total mass accumulated on the PV panel's surfaces. The highest reduction is caused by the deposition of red soil particles, followed by the deposition of limestone, and finally by the carbon-based ash. In [24] Jiang et al. studied the dust accumulation onto different types of solar PV modules and the corresponding efficiency degradation. The results indicated the dust pollution has a significant impact on the PV module output. The reduction of PV output efficiency grew from 0 to 29 %. The reduction of efficiency has a linear relationship with the dust deposition density, and the difference caused by the cell types was not obvious. The polycrystalline silicon module packaged with epoxy degraded faster than other modules with glass surface under the same dust concentration.

Aim of this work is the design, construction and operation of self-cleaning and self-cooling PV system with feedback control. The programming method of control of water pumping system is achieved by means of programmable logic controller (PLC) and frequency inverter (FI). The control system consists of two subsystems based upon the same electromechanical set up, one system for controlling the cooling of PV system by using temperature sensor and feedback system, and the other system for controlling the cleaning of PV system by using the pressure of water to push away the accumulated dust on the PV surface.

2. Experimental setup

The panel with self-cleaning and self-cooling system is supplied with controlled pumping system which pumps water into the surface of PV module through the nozzle which is mounted at the upper side of module. The running film of water over the surface of PV module decreases the temperature, and cleans

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the accumulated dust on the panel surface. The control system consists of two subsystems based upon the same electromechanical system. One system for controlling the cooling of PV system by using temperature sensor and feedback system, the cooling frequency of PV module is determined by the module temperature. The other system for controlling the cleaning of PV system by using huge pressure to push away the accumulated dust on the PV surface.
For purpose of experimentation the electromechanical self-cleaning and self-cleaning system was designed and constructed as shown in Figure 1.

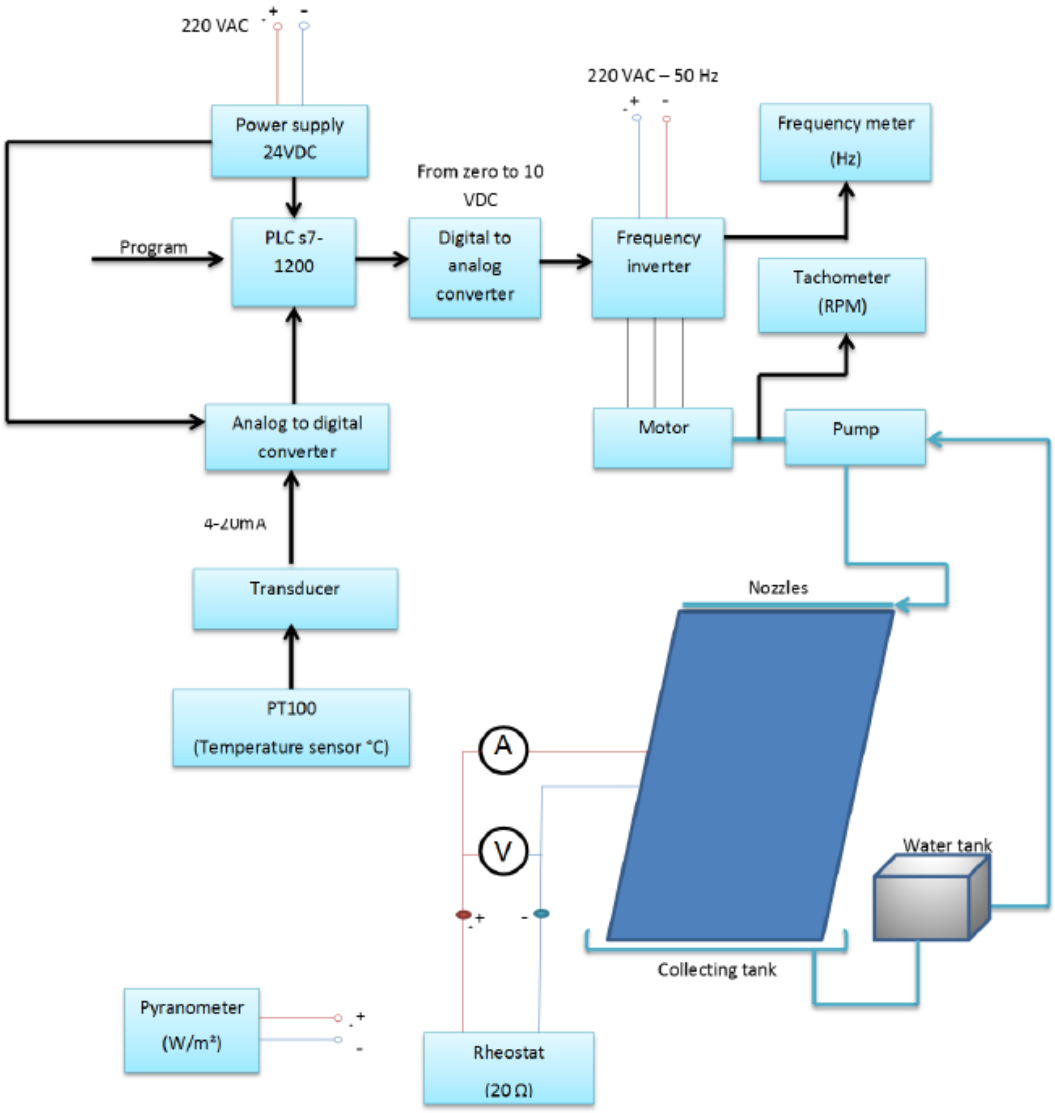

Figure 1. Block diagram of self-cleaning and self-cooling system with feedback control.

The system is consisting of PLC and frequency inverter, AC motor driven centrifugal pump, PV panel, temperature sensor , analog to digital converter, transducer, and DC power supply.
The main controller of this system is a PLC-S7-1200, which has 8 inputs, 6 outputs and 24 VDC power supply voltage. Control panel of system including PLC-S7-200 is shown in Figure 2. This PLC system has two functions in this system: one of them is to control pumping flow rate according to the ambient temperature, the more the ambient temperature rises the more the pumping flow rate increases. The other function is to control the pump at maximum power for 1 minute each hour. First function work on cooling the PV panel, while the second function works on cleaning the PV panel .The programming method of control in which stored instructions in PLC memory was used to operate the AC motor driven centrifugal pump. The personal computer is used to write the ladder program then download it to PLC-S7-1200 through communication cable.

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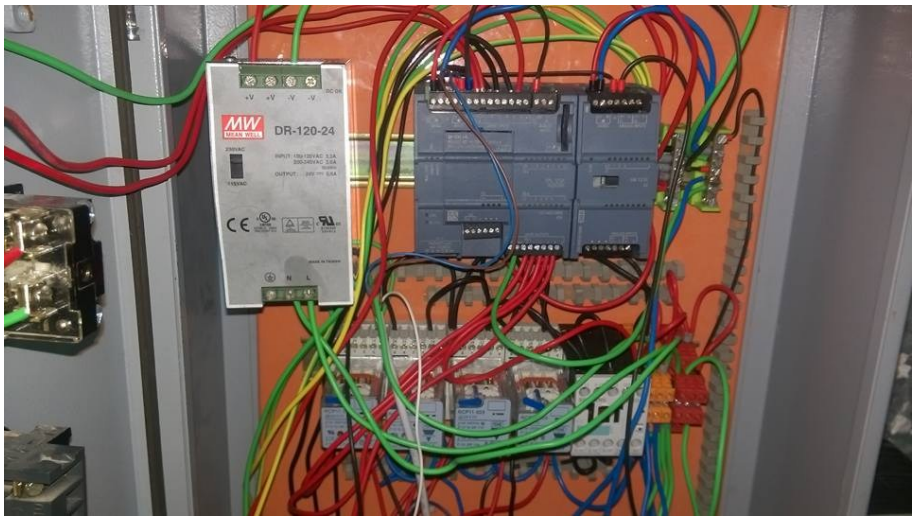

Figure 2. Control panel of self-cleaning and self-cooling system.

The digital to analog converter function is to transfer the digital output value, which ranges from 0 to 27684 digits at the output of PLC into analog value, which ranges from 0 to 10 VDC. Frequency inverter (FI) used in this work is Emerson brand, which has one phase input, three phase output with range from 0 to 240 VAC. The range of voltage at the control input of FI is ranging from zero to 10 VDC. Different values of output voltage are supplied to the AC motor driven centrifugal pump by the FI, which is originally stated by digital to analog converter, where 0 VDC equals 0 VAC at the output of FI, and 10 VDC at the input of FI gives 240 VAC at the output. The flow rate of used centrifugal pump is 10-30 L/min, with a head 14-22 m, temperature sensor used to the feedback control is PT-100, the range of measured temperature 0-100 C. Transducer is used for linearization the drop of voltage at the output of temperature sensor PT-100. Analog to digital converter is used to transfer the current at the output of transducer from analog value into digital values.
The general characteristics of photovoltaic module used in experiment are as following: module type YL 245P-29b, nominal power 245 W, rated voltage 30.2 V, and rated current 8.11 A.

3. Experimentation and results

In this work, different electronic measurement instruments and devices were used to measure the experimental variables. These instruments and devices were tested and calibrated before being used.
Electrical current generated at the output of PV module is measured using a clamp ammeter. The range of measurement is from 0 to 20 A. the accuracy of measurement is 3%. Voltage measurement is accomplished with voltmeter, where the range of measurement is from 0 to 40 VDC and the accuracy of instrument is 4%.
Two identical PV modules one with self-cleaning and self-cooling system and the other without are involved in experiment. Both panels were facing south with the same slope angle of 11 degrees, and they are connected to the same load resistance.
A continuous test during May and June 2015 was done in the Renewable Energy Center at the Applied Science University in Amman, Jordan.
The rate of cooling of the PV module is a very important factor that affects their performance. The PV module temperature depends on solar radiation, ambient temperature and nominal operating cell temperature NOCT. Therefore the module temperature will be a function of time during a day. The solar radiation, ambient air temperature and PV module temperature were measured during one day with cooling and without cooling and presented in Figure 3.
Figure 4 shows generated electrical power at the output of PV modules for the system with cleaning and cooling, and for other system without, the results of experimentation indicate that there were increases in daily measured electrical output power up to 34% in sunny days and 29% in cloudy days.
Experimental measurements of the efficiency of the PV module during June 2015 are shown in Figure 5. As seen as the module temperature increase, the PV module efficiency decrease. Its found that PV module efficiency increased from (26 % - 29%) with cooling compared with PV module without cooling system.

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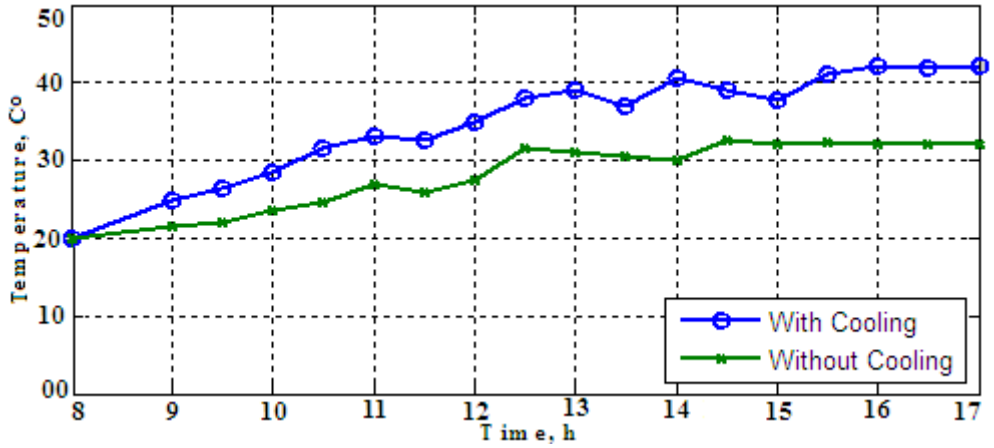

Figure 3.The measured module temperature during June 2015.

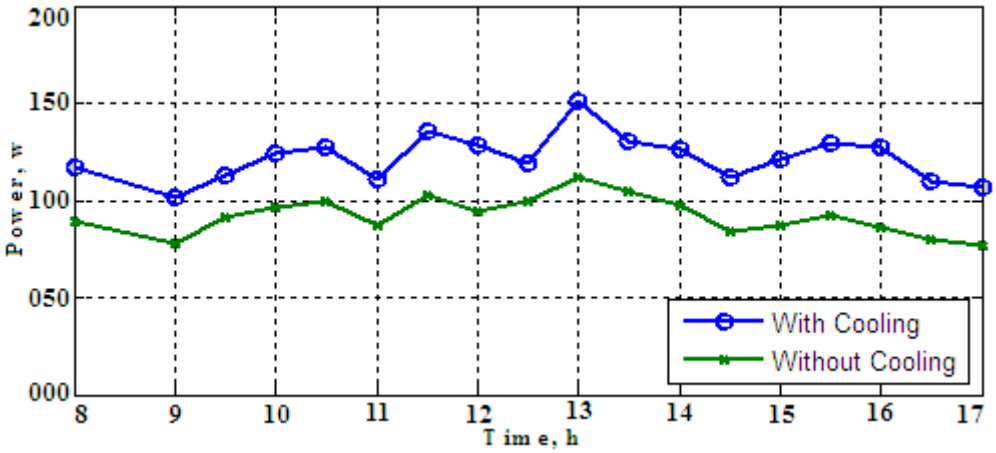

Figure 4. Generated electrical power at the output of PV modules.

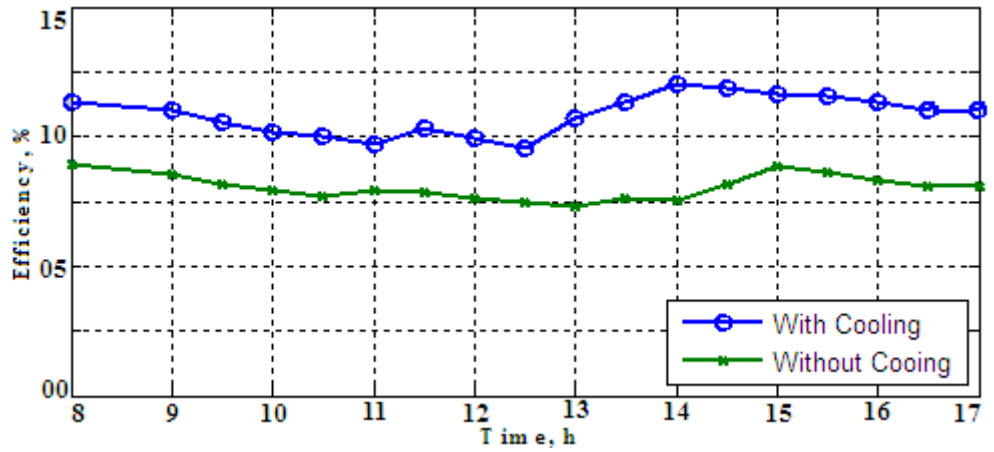

Figure 5. Experimental measurements of the efficiency during June 2015.

4. Conclusions

In this work, the hard ware and software elements of self-cleaning and self-cooling PVsystem were designed, constructed, and operated.

Feedback method of control is used to control the pumping flow rate according to temperature rises in purpose of cooling the PV system. Open loop method of control is used to control the pumping flow rate function of time in purpose of cleaning the photovoltaic system. It can be concluded that the proposed

cooling and cleaning system suitable for application in the hot and dusty regions and the use of automatic cleaning and cooling of PV system results in an increase total daily power production up to 29%.

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ORIGINAL ARTICLE

Statistical model for predicting and improving ready mixed concrete batch plants' performance ratio under different influences

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KEYWORDS

Ready mix concrete;
Concrete batch plant;
Productivity prediction;
Factors;
Performance ratio;
Improvement

Abstract Producers of ready mixed concrete think of improving concrete batch plants' performance ratio to provide the construction market with high quality standards, save cost and time. Ready mixed concrete (RMC) is a mixture of different materials, which is delivered to customer in unhardened state and freshly mixed. Major objective of this study was to provide a clear understanding for predicting and improving the concrete batch plants' performance ratio by use analysis of large collected data from more and different concrete batch plants and determining the most effective factors that have a great effect on concrete batch plants' performance ratio. Predicting the actual future performance ratio and production rates for any concrete batch plant according to a groups of effective factors is the essential sector which is suggested in this paper using smart modeling analysis. Improving the performance ratio of concrete batch plant is selected because of its importance in construction field by studying and analyzing the most effective factors. The study will be done by collecting and studying large detailed data through start of 2012 till the end of 2016 and it will illustrate the time, quantities, distances and factors which affect concrete batch plants' performance ratio. This paper is divided into six main groups, which are illustrated as follows: (1) It concludes the historical information about concrete batch plants and RMC, and introduces the objective of this paper and the most convincing definitions for productivity and Performance Ratio (PR). (2) It explains general information for ready mixed concrete batch plants, classifies plant types for determining criteria of pumping method and declares the modeling techniques, concept of standard performance, measuring productivity difficulties, productivity cycles, factors affecting equipment productivity, applications of construction productivity, concrete placement process, concrete equipment selection and methods of construction. Factors affecting

Abbreviations: AI, Artificial Intelligence; ANN, Artificial Neural Network; ANOVA, ANalysis Of VAriance; APR, Actual Performance Ratio; CBP, Concrete Batch Plant; DES, Discrete-Event Simulation; DF, Degree of Freedom; ES, Expert Systems; GAs, Genetic Algorithms; MODE, Multi-Objective Differential Evolution; OSPIP, On Site Performance Improvement Programs; PAR, Performance Ability Ratio; PLC, Programmable Logic Controller; PR, Performance Ratio; RMC, Ready Mixed Concrete; SD, Standard Deviation; SE, Standard Error; SPSS, Statistics Package for Social Science.

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concrete batch plants' performance ratio were mentioned and it discussed the related studies for problem statement. (3) It mentions the concrete batch plant classifications, advantages and disadvantages of ready mix concrete batch plants, mixing process and the methodology. It analyzes and improves the concrete batch plant performance ratio using optimizing of its most effective variables. (4) It introduces and analyzes all variables data at the same time using input phase by Statistics Package for Social Science (SPSS) software; then the estimated model was developed in the final form. Stepwise forms of the model were done using SPSS to reduce and simplify the proposed model for getting the alternative simplified formulas and neglect the variables that have lowest and negligible effect. On the other hand, correlation matrix was done to indicate what will be impacted on concrete batch plant performance ratio when each variable changes. (5) It introduces an application of general and simplified models for a real case study on Suez power station project, which uses ready mixed concrete with theoretical capacity equal to 160 m^3/h. The case study will be conducted to validate and verify the applications of the proposed general and simplified models to give optimum expressway for ready mixed concrete construction projects. (6) It introduces conclusions, recommendations and suggests future studies.

1. Introduction

Construction teams face critical decisions making challenges that have enormous effects and plenty of questions that ought to been answered before starting the studied project. Culture of the company should help them for project risks while decisions making allow the work to behave faster than traditionally predicted. Stakeholders have to provide authority to manage their tasks and need to support for construction projects using concrete batch plants [1]. RMC is defined as a concrete type that is mixed by batch plants using different processes such as handling raw materials, batching concrete, mixing concrete, loading the admixtures, and then delivering to construction sites. Pumped concrete might be defined as concrete that is pressure conveyed through either flexible hose or rigid pipe and discharged immediately into the desired place [2]. Planning concrete supply, site layout, pump locations, placing sequence and complete pumping operation will result in saving expense and time [3]. Factors influencing choice of good concrete batching system are as follows: (1) Job Size, (2) Required production rate and (3) Required standards for performance of concrete batching. Concrete can be transported via more equipment and methods such as open top trucks with or without agitators, truck mixers, buckets hauled by railroad car or truck, pipeline, and hose or belt conveyors [4].

2. Problem statement

Performance ratio is the ratio between actual production rate (with affecting variables) and ideal production rate (without affecting variables) as given in Eq. (1):

$$\text{Performance ratio} = \frac{\text{Actual Production Rate}}{\text{Ideal Production Rate}} \quad (1)$$

Improving the performance ratio of an equipment is an essential sector in construction sites because of saving a lot of money and time. In this paper, it was focused on mentioned procedures and getting how they can improve the concrete batch plants' performance ratio by saving the total time, which will minimize delivery cost. Collected data and factors are used to propose a general model to predict and improve concrete batch plant performance ratio by simulating most effective variables that have a great effect on productivity, and then it is formulated by Statistics Package for Social Science (SPSS) software.

3. Paper objectives

The major objective of this study was to focus on predicting and improving concrete batch plants' performance ratio by: (1) Classifying the concrete batch plants; (2) Using large scale of detailed data which is collected from different and more concrete batch plants, and this will be done through studying them during start of 2012 till the end of 2016; (3) Using collected field data to recognize variables affecting concrete batch plants' performance ratio to propose a general and simplified models for predicting actual performance ratio at any concrete batch plant as function with all variables; (4) Improving concrete batch plants' performance ratio by optimizing most effective variables that affect the concrete batch plants' performance ratio; (5) Using the Statistics Package for Social Science (SPSS) software; then develop a general model in its final form; (6) Obtaining stepwise forms of general model using SPSS to simplify and reduce the lowest and negligible effective variables in proposed general model and estimating alternatives for simplified formulas, by using these proposed models any manager can forecast the behavior of concrete batch plant and its performance ratio for any new construction site orders after knowing the values of all variables; (7) Evaluating the correlation matrix for censoring the impact on concrete batch plants' performance ratio by variable changes for proposed models; (8) Applying the general and simplified models using a real case study on Suez power station project which use ready mixed concrete with theoretical capacity equal to 160 m^3/h. The case study will be conducted to validate and verify the applications of the proposed general and simplified models to give optimum expressway for ready mixed concrete construction projects; and (9) Listing the conclusion, recommendations and suggested future studies.

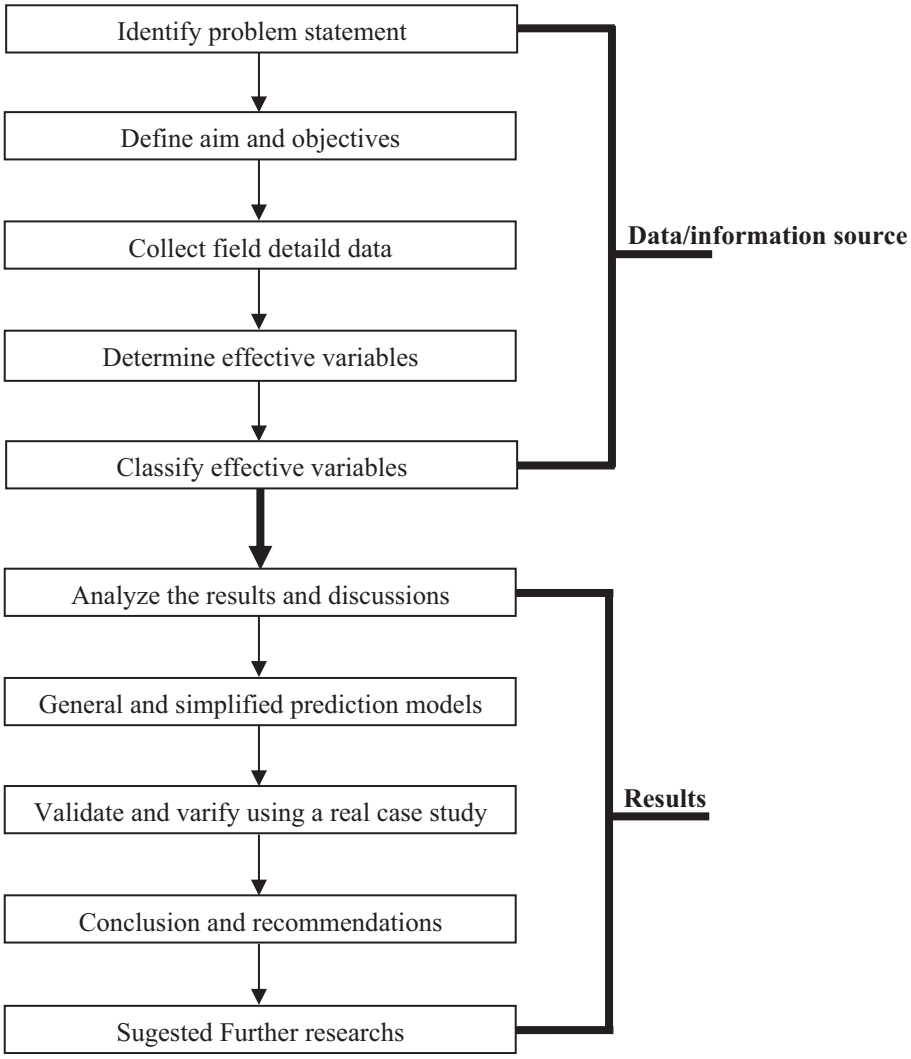

Fig. 1 Paper main activities/methodology.

4. Paper layout

This paper is categorized into seven main parts as follows: (1) Introduction; (2) Literature Review; (3) Methodology of Data Source, Field Measurement; (4) Collecting Data and Analyze its Effect on Concrete batch Plants' Performance Ratio; (5) Developing General and Simplified Models between concrete batch plant performance ratio as dependant variable with all effective variables as independent variables; (6) Applying a real Case Study for testing the proposed models accuracy and (7) Determining the Conclusion and Recommendations, as concluded in Fig. 1.

5. Modeling techniques

System definition is a set of interacting components or elements that act together to acquire a common goal. Zayed and Nosair [5] explained a model purpose which determines how more changes in numerous components of the system model might affect other system elements. It was aided for designing, learning, predicting, and comparing options harmlessly and cheaply [6]. Simulation is the most widely used tools in construction management, and it has been implemented to production, strategy analysis and more other fields [7]. Moreover, simulation can use the complicated relationships between most uncertain factors and construction contractors that must be aware of it [8]. CYCLONE (CYCLic Operations NEtwork) is a modeling construction operations simulation tool, which was originally developed by ***Halpin*** since 1973. CYCLONE plan and control construction project were illustrated in real case study that presents the results and analysis using RMC for dam project, and the main goal for simulating plant operations was to estimate maximum production rate which can be predicted from concrete batch plant if no lack of raw materials occurs; the plant maximum production rate from simulation using actual observations is close to 33 m^3/h, not 50 m^3/h as batch plant has claimed [9].

5.1. Simulation input modeling

Data collection for system suitable elements is one of the vital and initial step in successful input modeling; the simulation development models are delayed when accurate data are not

Table 1 Input data sample in SPSS.

ID	PR %	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
1	90.05	0.90	0.9	0.9	0.8	95	0.8	77.9	0.88	4	2	0	1	0.7	110
2	20.69	0.60	0.6	0.7	0.9	75	0.6	12.5	0.89	3	1	0	1	0.6	20
3	68.57	0.70	0.7	0.8	0.8	95	0.7	36.4	0.90	4	0	0	1	0.9	55
4	64.96	0.60	0.9	0.9	0.9	75	0.6	12.9	0.90	4	0	0	1	0.9	20
5	48.31	0.60	0.6	0.8	0.8	75	0.6	11.1	0.86	3	0	1	1	0.9	15
6	82.98	0.80	0.8	0.9	0.9	95	0.8	59.6	0.89	5	1	0	1	0.8	85
7	66.84	0.80	0.7	0.9	0.9	95	0.8	55.0	0.89	5	1	0	1	0.9	70
8	56.06	0.70	0.8	0.7	0.8	95	0.7	43.2	0.88	5	0	1	1	0.9	55
9	28.57	0.60	0.9	0.7	0	0	0.6	1.8	0.75	0	0	1	0	0.9	5
10	93.38	0.90	0.9	0.9	0.9	85	0.9	165.4	0.89	6	2	0	2	0.6	220

ID	PR %	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}
1	90.05	0.9	12.8	218	4	0.9	0.8	0.9	0.9	2	0.8	0.9	0.6	14
2	20.69	0.6	35.0	35	2	0.7	0.9	0.6	0.7	0	0.6	0.6	0.6	14
3	68.57	0.9	15.8	102	2	0.9	0.9	0.9	0.8	0	0.9	0.8	0.6	15
4	64.96	0.9	22.2	36	4	0.9	0.9	0.9	0.8	0	0.9	0.8	0.6	14
5	48.31	0.8	4.7	31	3	0.9	0.9	0.7	0.7	0	0.9	0.7	0.6	13
6	82.98	0.9	17.7	167	3	0.9	0.9	0.9	0.9	1	0.8	0.9	0.6	12
7	66.84	0.9	19.6	154	2	0.9	0.9	0.8	0.8	0	0.8	0.9	0.6	11
8	56.06	0.8	29.0	121	2	0.9	0.8	0.8	0.8	0	0.7	0.9	0.6	13
9	28.57	0.7	5.0	5	1	0.9	0.9	0.9	0.8	0	0.9	0.8	0.6	12
10	93.38	0.9	17.0	463	1	0.9	0.9	0.9	0.9	3	0.9	0.9	0.6	14

Table 2 Selected model summary.

Model	*R*	*R* square	Adjusted *R* square	Std. error of the estimate
1 (PR)[a]	.974[b]	.948	.941	5.47814

[a] Dependent Variable: PR.
[b] Predictors: (Constant), X_{27}, X_1, X_{11}, X_{23}, X_{26}, X_{21}, X_{16}, X_{18}, X_4, X_{24}, X_{10}, X_{20}, X_{19}, X_3, X_2, X_8, X_{22}, X_{25}, X_9, X_{12}, X_{13}, X_{15}, X_{14}, X_6, X_5, X_7.

Table 3 Selected model ANOVA test.

Model		Sum of squares	*df*	Mean square	*F*	Sig.
1 (PR)[a]	Regression	102159.729	26	3929.220	130.931	.000[b]
	Residual	5551.844	185	30.010		
	Total	107711.572	211			

[a] Dependent Variable: PR.
[b] Predictors: (Constant), X_{27}, X_1, X_{11}, X_{23}, X_{26}, X_{21}, X_{16}, X_{18}, X_4, X_{24}, X_{10}, X_{20}, X_{19}, X_3, X_2, X_8, X_{22}, X_{25}, X_9, X_{12}, X_{13}, X_{15}, X_{14}, X_6, X_5, X_7.

available in right format at right time. Moreover, data collections and identifications are consuming more time and cost [10].

5.2. Simulation output analysis

Arising in simulation output analysis is shortage of clear understanding for asked questions. Important issue for selecting output measures is assurance for answer right question. Best way to summarize simulation output analysis is to convey information for output measure distribution [11,12].

5.3. Modeling process

The modeling process consists of a sequential steps, which are performed as follows:

5.3.1. Problem determination

Ashworth [13] stated most important steps for model building that must be determined for real issues, problem statement starts after studying system definition, and then goals specification and boundary conditions establishment must be made. Finally, the system is represented in a logical flow diagram. It is important to notice that system flow diagram must include study objectives and problem formulation during the study.

5.3.2. Collected data

Collected data from concrete batch plant must be concerned with inputs and outputs of system and they must be collected carefully and timely related to study problem. The collected data scope and types should be illustrated [13].

Table 4 Descriptive statistics for all variables in selected model.

	Mean	Std. deviation	*N*
PR	62.7797	22.59384	20,132
X_1	0.7123	0.12445	20,132
X_2	0.7410	0.11422	20,132
X_3	0.8264	0.07765	20,132
X_4	0.7528	0.30329	20,132
X_5	74.2217	30.76409	20,132
X_6	0.7066	0.09810	20,132
X_7	46.4618	41.08677	20,132
X_8	0.8772	0.02606	20,132
X_9	3.6274	1.81823	20,132
X_{10}	1.3443	0.89724	20,132
X_{11}	0.2453	0.43127	20,132
X_{12}	1.0283	0.55001	20,132
X_{13}	0.8396	0.09457	20,132
X_{14}	65.3538	53.63111	20,132
X_{15}	0.8321	0.08981	20,132
X_{16}	21.2866	14.06121	20,132
X_{17}	130.0943	115.05066	20,132
X_{18}	2.2406	1.18987	20,132
X_{19}	0.8816	0.04761	20,132
X_{20}	0.8476	0.07693	20,132
X_{21}	0.7981	0.08814	20,132
X_{22}	0.7825	0.08884	20,132
X_{23}	0.4151	0.75247	20,132
X_{24}	0.8118	0.09134	20,132
X_{25}	0.8170	0.09974	20,132
X_{26}	0.7580	0.08913	20,132
X_{27}	24.9245	8.51171	20,132

5.3.3. Data preparation and analysis

Collected data from field should be checked in order to determine needed data valid for problem solving technique [13].

5.3.4. Model building

Neelamkavil [14] demonstrated how to build the problem by mathematical form, and it should perform the following tasks: (1) Specification for model purpose, (2) Specification for model components, (3) Specification for parameters and variables, which are associated with components and (4) Specification for functional relationships among components, parameters and variables.

5.3.5. Model starting

Diab et al. [15] mentioned that Eldin [16] presented 12 steps in starting a simulation model: (1) Define the problem; (2) Understand the system; (3) Determine goals and objectives; (4) Learn simulation basics; (5) Confirm simulation as a right tool; (6) Attain support from management; (7) Learn about software for simulation; (8) Determine the data that are needed; (9) Develop a group of assumptions; (10) Determine the needed outputs; (11) Get simulation outputs and (12) Kickoff the project.

5.3.6. Model testing

The model should be tested for validity; model structure must be verified such as mathematics of model structure and program translations, and model outcomes accuracy should be checked [14].

Table 5 Coefficient of all variables in used model.

	Unstandardized coefficients		Standardized coefficients	*t*	Sig.
	B	Std. error	Beta		
Constant	−226.495	27.580		−8.212	0.000
X_1	27.157	8.474	0.150	3.205	0.002
X_2	23.058	5.486	0.117	4.203	0.000
X_3	15.936	8.304	0.055	1.919	0.057
X_4	4.749	5.543	0.064	0.857	0.393
X_5	−0.017	0.054	−0.023	−0.316	0.752
X_6	−15.781	13.350	−0.069	−1.182	0.239
X_7	−0.131	0.239	−0.239	−0.551	0.583
X_8	86.318	27.808	0.100	3.104	0.002
X_9	0.020	0.503	0.002	0.040	0.968
X_{10}	0.359	0.590	0.014	0.608	0.544
X_{11}	3.397	1.915	0.065	1.773	0.078
X_{12}	−2.319	1.665	−0.056	−1.393	0.165
X_{13}	−18.402	9.445	−0.077	−1.948	0.053
X_{14}	0.154	0.183	0.366	0.842	0.401
X_{15}	114.404	10.199	0.455	11.217	0.000
X_{16}	−0.016	0.031	−0.010	−0.528	0.598
X_{18}	−0.190	0.395	−0.010	−0.482	0.631
X_{19}	17.873	15.746	0.038	1.135	0.258
X_{20}	7.340	7.434	0.025	0.987	0.325
X_{21}	17.053	6.385	0.067	2.671	0.008
X_{22}	58.286	7.229	0.229	8.063	0.000
X_{23}	−0.786	1.050	−0.026	−0.749	0.455
X_{24}	3.361	5.749	0.014	0.585	0.559
X_{25}	−3.038	6.737	−0.013	−0.451	0.653
X_{26}	12.113	4.751	0.048	2.549	0.012
X_{27}	0.021	0.057	0.008	0.371	0.711

Table 6 Minimum and maximum variables values.

	PR	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
Ave	62.78	0.71	0.74	0.83	0.75	74.0	0.71	46.5	0.88	3.63	1.34	0.25	1.03	0.84	65.4
Max	99.23	0.90	0.90	0.90	0.90	95.0	0.90	236.4	0.90	8.00	2.00	1.00	2.00	0.90	295
Min	11.01	0.60	0.60	0.70	0.00	0.00	0.60	0.70	0.75	0.00	0.00	0.00	0.00	0.60	5.00

	PR	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}
Ave	62.78	0.83	21.3	130	2.24	0.88	0.85	0.80	0.78	0.42	0.81	0.82	0.80	24.9
Max	99.23	0.90	75.0	662	6.00	0.90	0.90	0.90	0.90	3.00	0.90	0.90	0.90	40.0
Min	11.01	0.60	0.50	2.00	1.00	0.70	0.70	0.60	0.60	0.00	0.60	0.60	0.60	11.0

5.3.7. Standard performance

Standard performance means average effectiveness, which a qualified worker will work normally when adhering and knowing a specific method due to the fact that allowance is made for necessary required time [17].

6. Equipment productivity

The construction equipment productivity tells how many units of equipment production through a unit of time, which was presented by [18]. Robert and William [19] defined activity work rate as work amount that accomplished for a given time spent in direct activity performance. The expression of productivity is calculated using Eq. (2) by dividing equipment production over unit of time (m^3/h) according to [20]:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} \tag{2}$$

Performance ratio is the productivity relative loss compared with some baseline period. The Performance Ratio (PR) is the ratio of actual work units per hour divided by expected work units per hour, and its value is defined as less unity [17]. Performance Ability Ratio (PAR) is a ratio between the estimated productivity and the current productivity. PAR value near unity that indicates the current productivity is comparatively good, while PAR value is greater than unity that indicates a poor productivity, which was presented by [21]. Laufer [22] developed a comprehensive program called On-Site Performance Improvement Programs (OSPIP) to simulate productivity cycles.

7. Construction productivity applications

Diab et al. [15] mentioned that Abdel-Razek and McCaffer [23] developed a labor productivity model that is capable of quantifying the vary of labor production rates effect on projects' cost and time. Abdel-Razek et al. [24] utilized the activity sampling technique for construction projects in Egypt, measured the bricklayers productivity and determined daily patterns for productivity of bricklayers' during hours of working day and days of the working week. Hosny et al. [25] used again the same activity sampling technique for tiling operation and measured tiling productivity and allocated productivity improvement areas. Abdel-Razek [26] established the relationship between utilization and productivity, developed a new formula for measuring resources utilization and concluded proposed formula to improve resources utilization that directly will lead to productivity improvement. Abdel-Razek [27] applied the developed formula to measure and improve three dredgers working productivity and utilization on large scale construction project. Abdel-Razek [28] utilized time study measurement technique to measure reinforcement concrete operation productivity in Egypt. Thomas et al. [29] tried to find lost time effect of labor operating system and crew structure on labor productivity, and the collected data were developed to calculate actual productivity for the chosen crafts. Badrel-Dien [30] demonstrated several constraints information system which affects heavy equipment usage especially on piles equipment, which were used for get final decision to continue the use of equipment or not. Abdel-Monem [31] developed general mathematical model to measure equipment productivity under certain construction operating conditions. Fifteen independent variables were determined and recorded against productivity. Zayed and Minkarah [32] declared that lean construction is the main objective for improving construction performance by eliminating wastes and employee training was applied to reduce any wastes that found in construction field operation. Song [33] stated that lean construction is a strategy of production management to achieve considerable continuous improvement in performance during elimination of time and resource wastes that don't add value to customer services. Oglesby et al. and Baudet et al. [34,35] had developed productivity analysis techniques using CYCLONE and STROBOSCOPE. Alkass et al. [9] suggested two stage methodologies to solve scheduling problems, first step involved discrete event simulation (DES) model development, and second step investigated Genetic Algorithms (GAs) for solving problems of concrete batch scheduling. Baudet et al. and Yan and Lai [36,37] showed overtime considerations incorporation in ready mixed concrete (RMC) and find optimal dispatching schedule using genetic algorithms, simulation approaches and linear programming techniques. Ahuja et al. [38] proposed a model that integrates truck dispatching and RMC production scheduling into one framework to find out optimal RMC supply schedule, which includes overtime with minimizing of operating cost that subject to related operating constraints. Al-Araidah et al. [39] employed space and time technique, which formulates truck fleet flows and RMC productions in construction projects. Dietz et al. [40] stated that efficiently delivering Ready Mixed Concrete with overtime considerations to construction sites is an important issue to managers. Jarkas [41] clarified that the construction productivity improvement can result lowest production cost that includes following procedures: (1) Transporting, (2) Placing, (3) Vibrating, and (4) Surface finishing and leveling [34].

Table 7 Proposed model correlation matrix.

	PR	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}
PR	1.000	0.746	0.681	0.782	0.378	0.437	0.748	0.722	0.253	0.602	0.408	0.001	0.534	0.213	0.727	0.905	−0.222	0.722	0.181	0.586	0.575	0.577	0.832	0.136	0.069	0.665	0.140	−0.020
X_1	0.746	1.000	0.615	0.560	0.381	0.465	0.902	0.858	0.146	0.655	0.408	0.076	0.673	0.108	0.862	0.592	−0.290	0.858	0.239	0.334	0.444	0.287	0.645	0.092	−0.300	0.529	0.085	−0.005
X_2	0.681	0.615	1.000	0.513	0.099	0.136	0.585	0.584	0.018	0.300	0.157	0.083	0.351	0.160	0.584	0.536	−0.172	0.584	0.087	0.401	0.575	0.441	0.599	0.104	0.031	0.575	−0.012	−0.169
X_3	0.782	0.560	0.513	1.000	0.385	0.414	0.568	0.548	0.217	0.503	0.338	0.018	0.449	0.179	0.549	0.755	−0.157	0.548	0.213	0.440	0.423	0.478	0.672	0.079	0.069	0.535	0.031	−0.015
X_4	0.378	0.381	0.099	0.385	1.000	0.956	0.452	0.418	0.352	0.610	0.412	−0.031	0.744	−0.110	0.423	0.348	−0.189	0.418	0.343	−0.047	0.020	−0.002	0.286	0.109	−0.250	−0.061	0.035	−0.058
X_5	0.437	0.465	0.136	0.414	0.956	1.000	0.540	0.472	0.348	0.673	0.441	−0.007	0.711	−0.097	0.476	0.409	−0.216	0.472	0.383	0.021	0.072	0.038	0.323	0.141	−0.254	0.017	0.045	−0.100
X_6	0.748	0.902	0.585	0.568	0.452	0.540	1.000	0.907	0.152	0.681	0.496	0.096	0.708	0.150	0.912	0.627	−0.300	0.907	0.254	0.361	0.423	0.330	0.644	0.078	−0.305	0.487	0.097	−0.015
X_7	0.72ii2	0.858	0.584	0.548	0.418	0.472	0.907	1.000	0.160	0.690	0.472	0.113	0.740	0.087	0.998	0.551	−0.252	1.000	0.220	0.286	0.351	0.354	0.640	0.084	−0.242	0.420	0.088	−0.072
X_8	0.253	0.146	0.018	0.217	0.352	0.348	0.152	0.160	1.000	0.478	0.019	−0.652	0.254	−0.078	0.172	0.271	−0.054	0.610	0.156	−0.080	−0.120	−0.120	0.147	0.057	−0.052	0.033	0.009	−0.188
X_9	0.602	0.655	0.300	0.503	0.610	0.673	0.681	0.690	0.478	1.000	0.375	−0.143	0.641	−0.046	0.682	0.538	−0.178	0.690	0.449	0.189	0.182	0.220	0.485	0.197	−0.245	0.249	0.020	−0.195
X_{10}	0.408	0.408	0.157	0.338	0.412	0.441	0.496	0.472	0.019	0.375	1.000	0.001	0.460	−0.033	0.482	0.392	−0.054	0.472	0.237	0.216	0.105	0.200	0.296	0.194	−0.183	0.130	0.223	0.172
X_{11}	0.001	0.076	0.083	0.018	−0.031	−0.007	0.096	0.113	−0.652	−0.143	0.001	1.000	0.070	0.051	0.074	−0.045	−0.041	0.113	0.060	0.059	0.103	0.100	0.013	−0.052	−0.050	0.013	0.010	0.058
X_{12}	0.534	0.673	0.351	0.449	0.744	0.711	0.708	0.740	0.254	0.641	0.460	0.070	1.000	0.015	0.743	0.423	−0.243	0.740	0.250	0.056	0.158	0.128	0.466	0.029	−0.309	0.138	0.063	0.058
X_{13}	0.213	0.108	0.160	0.179	−0.110	−0.097	0.150	0.087	−0.078	−0.046	−0.033	0.051	0.015	1.000	0.104	0.296	0.031	0.087	−0.148	0.510	0.319	0.299	0.196	−0.725	0.132	0.330	0.091	0.099
X_{14}	0.727	0.862	0.584	0.549	0.423	0.476	0.912	0.998	0.172	0.682	0.482	0.074	0.743	0.104	1.000	0.558	−0.259	0.998	0.210	0.293	0.357	0.353	0.644	0.069	−0.245	0.425	0094	−0.064
X_{15}	0.905	0.592	0.536	0.755	0.348	0.409	0.627	0.551	0.271	0.538	0.392	−0.045	0.423	0.296	0.558	1.000	−0.188	0.551	0.149	0.649	0.560	0.558	0.694	0.104	0.139	0.674	0.128	0.045
X_{16}	−0.222	−0.290	−0.192	−0.157	−0.189	−0.216	−0.300	−0.252	−0.054	−0.178	−0.054	−0.041	−0.243	0.031	−0.259	−0.188	1.000	−0.252	−0.138	0.008	−0.204	−0.027	−0.184	0.011	0.060	−0.139	0.186	0.117
X_{17}	0.722	0.858	0.584	0.548	0.418	0.472	0.907	1.000	0.160	0.690	0.472	0.113	0.740	0.087	0.998	0.551	−0.252	1.000	0.220	0.286	0.351	0.354	0.640	0.084	−0.242	0.0420	0.088	−0.072
X_{18}	0.181	0.239	0.087	0.213	0.343	0.383	0.254	0.220	0.156	0.449	0.237	0.060	0.0250	−0.148	0.210	0.149	−0.138	0.220	1.000	−0.072	−0.012	0.009	0.152	0.158	−0.240	−0.023	−0.003	−0.271
X_{19}	0.586	0.334	0.401	0.440	−0.047	0.021	0.361	0.286	−0.080	0.189	0.216	0.059	0.056	0.510	0.293	0.649	0.008	0.286	−0.072	1.000	0.512	0.568	0.484	0.029	0.333	0.625	0.141	0.133
X_{20}	0.575	0.444	0.575	0.423	0.020	0.072	0.423	0.351	−0.120	0.182	0.105	0.103	0.158	0.319	0.357	0.560	−0.204	0.351	−0.012	0.512	1.000	0.475	0.497	−0.057	0.135	0.623	−0.059	−0.222
X_{21}	0.577	0.287	0.441	0.478	−0.002	0.038	0.330	0.354	−0.120	0.220	0.200	0.100	0.128	0.299	0.353	0.558	−0.027	0.354	0.009	0.568	0.475	1.000	0.492	0.026	0.332	0.516	0.080	0.077
X_{22}	0.832	0.645	0.599	0.672	0.286	0.323	0.644	0.640	0.147	0.485	0.296	0.013	0.466	0.196	0.644	0.694	−0.184	0.640	0.0152	0.484	0.497	0.492	1.000	0.102	0.072	0.563	0.039	−0.096
X_{23}	0.136	0.092	0.104	0.079	0.109	0.141	0.078	0.0847	0.057	0.197	0.194	−0.252	0.029	−0.725	0.069	0.104	0.011	0.084	0.158	0.029	−0.057	0.026	0.102	1.000	0.059	0.051	−0.015	−0.066
X_{24}	0.069	−0.300	0.031	0.069	−0.250	0.254	−0.305	−0.242	−0.052	−0.245	−0.183	−0.050	−0.309	0.132	−0.245	0.139	0.060	−0.242	−0.240	0.333	0.135	0.332	0.072	0.059	1.000	0.134	0.038	0.016
X_{25}	0.665	0.529	0.575	0.535	−0.061	0.017	0.487	0.420	0.033	0.249	0.130	0.013	0.138	0.330	0.425	0.674	−0.139	0.420	−0.023	0.625	0.623	0.516	0.563	0.051	0.134	1.000	0.006	0.029
X_{26}	0.140	0.085	−0.012	0.031	0.035	0.045	0.097	0.088	0.009	0.020	0.223	0.010	0.063	0.091	0.094	0.128	0.186	0.088	−0.003	0.141	−0.059	0.080	0.039	−0.015	0.038	0.006	1.000	0.272
X_{27}	−0.020	−0.005	−0.169	−0.015	−0.058	−0.100	−0.015	−0.072	−0.188	−0.195	0.172	0.058	0.058	0.099	−0.064	0.045	0.117	−0.072	−0.271	0.133	−0.022	0.077	−0.096	−0.0666	0.016	0.029	0.272	1.000
PR	–	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.494	0.000	0.001	0.000	0.000	0.001	0.000	0.004	0.000	0.000	0.000	0.000	0.024	0.160	0.000	0.021	0.387
X_1	0.000	–	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.135	0.000	0.059	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.091	0.000	0.000	0.109	0.469
X_2	0.000	0.000	–	0.000	0.076	0.024	0.000	0.000	0.389	0.000	0.011	0.114	0.000	0.010	0.000	0.000	0.006	0.000	0.102	0.000	0.000	0.000	0.000	0.065	0.329	0.000	0.434	0.007
X_3	0.000	0.000	0.000	–	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.398	0.000	0.004	0.000	0.000	0.011	0.000	0.001	0.000	0.000	0.000	0.000	0.126	0.157	0.000	0.327	0.415
X_4	0.000	0.000	0.076	0.000	–	0.000	0.000	0.000	0.000	0.000	0.000	0.328	0.000	0.056	0.000	0.000	0.003	0.000	0.000	0.247	0.388	0.491	0.000	0.057	0.000	0.188	0.306	0.201
X_5	0.000	0.000	0.024	0.000	0.000	–	0.000	0.000	0.000	0.000	0.000	0.460	0.000	0.080	0.000	0.000	0.001	0.000	0.000	0.381	0.149	0.292	0.000	0.020	0.000	0.400	0.257	0.073
X_6	0.000	0.000	0.000	0.000	0.000	0.000	–	0.000	0.014	0.000	0.000	0.082	0.000	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.128	0.000	0.000	0.080	0.412
X_7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	–	0.010	0.000	0.000	0.051	0.000	0.104	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.111	0.000	0.000	0.102	0.150
X_8	0.000	0.017	0.398	0.001	0.000	0.000	0.014	0.010	–	0.000	0.392	0.000	0.000	0.129	0.006	0.000	0.217	0.010	0.011	0.124	0.040	0.041	0.016	0.205	0.226	0.317	0.450	0.003
X_9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	–	0.000	0.019	0.000	0.253	0.000	0.000	0.005	0.000	0.000	0.003	0.004	0.001	0.000	0.002	0.000	0.000	0.386	0.002
X_{10}	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.392	0.000	–	0.493	0.000	0.316	0.000	0.000	0.216	0.000	0.000	0.001	0.065	0.002	0.000	0.002	0.004	0.029	0.001	0.006
X_{11}	0.494	0.135	0.114	0.398	0.328	0.460	0.082	0.051	0.000	0.019	0.493	–	0.153	0.230	0.141	0.257	0.277	0.051	0.193	0.195	0.067	0.074	0.424	0.224	0.236	0.426	0.441	0.200
X_{12}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.153	–	0.415	0.000	0.000	0.000	0.000	0.000	0.208	0.011	0.031	0.000	0.339	0.000	0.022	0.181	0.200
X_{13}	0.001	0.059	0.010	0.004	0.056	0.080	0.014	0.104	0.129	0.253	0.316	0.230	0.415	–	0.065	0.000	0.326	0.104	0.015	0.000	0.000	0.000	0.002	0.000	0.027	0.000	0.092	0.076
X_{14}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.141	0.000	0.065	–	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.160	0.000	0.000	0.086	0.175
X_{15}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.257	0.000	0.000	0.000	–	0.003	0.000	0.015	0.000	0.000	0.000	0.000	0.066	0.022	0.000	0.032	0.259
X_{16}	0.001	0.000	0.006	0.011	0.003	0.001	0.000	0.000	0.217	0.005	0.216	0.277	0.000	0.326	0.000	0.003	–	0.000	0.022	0.455	0.001	0.348	0.004	0.435	0.193	0.021	0.003	0.044
X_{17}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.051	0.000	0.104	0.000	0.000	0.000	–	0.001	0.000	0.000	0.000	0.000	0.112	0.000	0.000	0.102	0.149
X_{18}	0.004	0.000	0.102	0.001	0.000	0.000	0.000	0.001	0.011	0.000	0.000	0.193	0.000	0.015	0.001	0.015	0.022	0.001	–	0.148	0.432	0.449	0.013	0.011	0.000	0.372	0.485	0.000
X_{19}	0.000	0.000	0.000	0.000	0.247	0.381	0.000	0.000	0.124	0.003	0.001	0.195	0.208	0.000	0.000	0.000	0.455	0.000	0.148	–	0.000	0.000	0.000	0.338	0.000	0.000	0.020	0.026
X_{20}	0.000	0.000	0.000	0.000	0.388	0.149	0.000	0.000	0.040	0.004	0.065	0.067	0.011	0.000	0.000	0.000	0.001	0.000	0.432	0.000	–	0.000	0.000	0.206	0.024	0.000	0.195	0.375
X_{21}	0.000	0.000	0.000	0.000	0.491	0.292	0.000	0.000	0.041	0.001	0.002	0.074	0.031	0.000	0.000	0.000	0.348	0.000	0.449	0.000	0.000	–	0.000	0.352	0.000	0.000	0.122	0.133
X_{22}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.000	0.424	0.000	0.002	0.000	0.000	0.004	0.000	0.013	0.000	0.000	0.000	–	0.070	0.148	0.000	0.288	0.082
X_{23}	0.024	0.091	0.065	0.126	0.057	0.020	0.128	0.111	0.205	0.002	0.002	0.224	0.339	0.000	0.160	0.066	0.435	0.112	0.011	0.338	0.206	0.352	0.070	–	0.195	0.231	0.417	0.169
X_{24}	0.160	0.000	0.329	0.157	0.000	0.000	0.000	0.000	0.226	0.000	0.004	0.236	0.000	0.027	0.000	0.022	0.193	0.000	0.000	0.000	0.024	0.000	0.148	0.195	–	0.026	0.292	0.410
X_{25}	0.000	0.000	0.000	0.000	0.188	0.400	0.000	0.000	0.317	0.000	0.029	0.426	0.022	0.000	0.000	0.000	0.021	0.000	0.372	0.000	0.000	0.000	0.000	0.231	0.026	–	0.466	0.338
X_{26}	0.021	0.109	0.434	0.327	0.306	0.257	0.080	0.102	0.450	0.386	0.001	0.441	0.181	0.092	0.086	0.032	0.003	0.102	0.485	0.020	0.195	0.122	0.288	0.417	0.292	0.466	–	0.000
X_{27}	0.387	0.469	0.007	0.415	0.201	0.073	0.412	0.150	0.003	0.002	0.006	0.200	0.200	0.076	0.175	0.259	0.044	0.149	0.000	0.026	0.375	0.133	0.082	0.169	0.410	0.338	0.000	–

Table 8 General or/and simplified model variables input data for first case study.

PR gen.	PR sim.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
94.47	93.52	0.90	0.90	0.90	0.90	0.95	0.90	90.0	0.90	13.0	10.0	0.00	3.00	0.80	150
PR gen.	PR sim.	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	
94.47	93.52	0.90	4.00	1360	1.00	0.90	0.90	0.90	0.90	6.00	0.90	0.90	0.90	15.0	

Table 9 General or/and simplified model variables input data for second case study.

PR gen.	PR sim.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
78.75	77.58	0.90	0.80	0.90	0.80	0.75	0.90	78.2	0.85	5.00	3.00	0.00	3.00	0.70	160
PR gen.	PR sim.	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	
78.75	77.58	0.80	5.00	1626	1.00	0.90	0.90	0.90	0.90	6.00	0.90	0.80	0.90	38.0	

Table 10 Comparison sheet between field and proposed models' results for two cases of studies.

Case study ID	From field			From proposed models		Act. PR ÷ gen. PR (%)	Act. PR ÷sim. PR (%)
	Act. productivity (m^3/h)	Theo. productivity (m^3/h)	Actual PR	General PR	Simplified PR		
1	146.76	160.0	93.00	94.47	93.52	98.44	99.44
2	50.810	65.00	78.17	78.75	77.58	99.30	100.8

Alkass et al. [9] mentioned that contractors need to reduce cost and maximizing profit within contract documents constraints and including specifications, this objective requires more knowledge for mixing cost, transporting, placing and finishing concrete unit. Expert Systems (ES) and Artificial Intelligence (AI) techniques had been applied where heuristics of techniques were used to formulate equipment selection methodology. Thomas et al. [29] declared that an important issue for any construction enterprise is labor and equipment productivity. However, where projects might have a tight schedule and fast tracked that needs to assume greater importance for assuring satisfactory productivity. Zayed et al. [42] concentrated on estimating the delays, cost and productivity for Concrete Batch Plant (CBP) using Artificial Neural Network (ANN) method, through two models with the result of average validity percent for ANN output equal to 96.25%. Sajadieh et al. [43] stated a traditional strategy that was taken into consideration to treat project materials ordering and scheduling which is determined using activity schedule as a known parameter. Abd et al. [44] mentioned how to develop construction productivity, which is considered as critical factor using many measures that should be taken into consideration for construction projects. Anderson et al. [45] reported that low skilled employments and low technology give low productivity for construction industry field, and to maximize construction productivity level it recommended the following features: (1) High degree of standardization; (2) Well managed construction planning and specifications and (3) High level of skilled workers and mechanized methods. Eriksson and Westerberg [46] declared that the productivity is associated with single input (hours) and single output (Quantity) in order to calculate the productivity ratio index; the case study was assumed as special system with more factors still constant except input and output information [47]. Lu and Lam [48] proposed a simulation modeling system with related analysis for RMC production in Hong Kong; benchmarking for concrete placing performance was covered, and it was found that the productivity was impacted not only by site factors and placing method but also by insufficient concrete supplying [37]. Videla and Imbarack [49] presented how to estimate the placing duration and simulating RMC is performed to get best matching between site requirements and concrete supply assuming equipment conditions and extra factors. Walke et al. [50] developed new methodology for measuring productivity and safety risk together to assess the changes of effective factors that affect both safety and productivity. Maghrebi et al. [51] analyzed the operation productivity to solve RMC problems using heuristic methods and to determine different variables with their influences. Vikan [52] presented construction sector productivity, which had a bad development compared with another fields. Marzouk and Younes [53] proposed a simulation model that was applied to RMC to test the transportation resources and production utilization. Cheng and Tran [54] presented an optimization framework, which merges Multi-Objective Differential Evolution (MODE) with Discrete Event Simulation (DES) to find out operations scheduling RMC solutions.

8. Concrete batch plants types

There are many concrete batch plant types as presented in following subsections:

8.1. Weight concrete batching

Weight concrete batch plants were divided into three groups: (1) Manual, (2) Semiautomatic and (3) Automatic.

8.1.1. Manual weight concrete batching

In manual weight concrete batching, operations of concrete batching and weighting were controlled manually.

8.1.2. Semiautomatic weight concrete batching

In semiautomatic weight concrete batching, charging concrete batchers and aggregate gates was opened manually, controlled by switches, and designated weight of material has been delivered then gates were closed automatically.

8.1.3. Automatic weight concrete batching

Automatic weight concrete batching is activated by switch such as: (1) Cumulative automatic weight concrete batching or (2) Individual automatic weight concrete batching.

8.2. Volumetric concrete batching

Materials are batched by volume; concrete placing is performed between two stages: mixing and hardening. Through concrete placing, two procedures should be controlled: (1) Concrete hauling and (2) Concrete pouring, and it is transported from batch to construction sites using truck mixers [55,56].

9. Methodology

(1) Selecting different concrete batch plants in Egypt and collecting data from 2012 to 2016; (2) Developing a general model to estimate concrete batch plants' performance ratio; (3) Designing detailed formula to predict concrete batch plants' performance ratio according to changes of affecting variables as displayed in Eq. (3). Applying Multiple regression analysis by SPSS software. (4) Getting abbreviated formula after excluding the variables, which have less effect on concrete batch plants' performance ratio. (5) Forecasting concrete batch plant actual productivity and getting the accuracy.

$$\text{Performance Ratio} = f(X_1, X_2, \ldots, X_{27}) \quad (3)$$

where Performance Ratio % is the studied concrete batch plant efficiency as dependent percentage at left hand side and X_n is the most effective variables as independent variables at left hand side of Eq. (3).

10. Variables affecting concrete batch plants performance ratio

10.1. Group (A) concrete batch plant variables

This group was broken down into seventeen variables as follows: (1) concrete batch manager efficiency (X_1) which was expressed as a percentage; (2) batch plant operator efficiency (X_2) which was expressed as a percentage; (3) truck mixers drivers efficiency (X_3) which was expressed as a percentage; (4) concrete pump operator efficiency (X_4) which was expressed as a percentage; (5) concrete pump efficiency (X_5) which was expressed as a percentage either new one that gives efficiency equal to 95% or old one that gives efficiency equal to 75%; (6) procurement plan efficiency (X_6) such as plans which provide cement, sand, gravel, etc. to fill the needs of RMC which was expressed as a percentage, (7) batch plant market plan efficiency (X_7) that was presented as a percentage if the concrete batch plant is worked in maximum capacity or not, (8) truck mixers efficiency (X_8); (9) 12 m^3 concrete truck mixers number that used for transporting concrete from batch plant to sites (X_9); (10) 10 m^3 concrete truck mixers number used for transporting concrete from batch plant to sites (X_{10}); (11) 6 m^3 concrete truck mixers number used for transporting concrete from batch plant to sites (X_{11}); (12) concrete pumps number (X_{12}) used for casting; (13) machines maintenance efficiency in the plant (X_{13}) which was expressed as a percentage, (14) workers bonus system inside batch plant (X_{14}) which was expressed as EGP for every trip; (15) raw material transportation method from washing area to the concrete batch area and washing plant efficiency (X_{15}) which was expressed as a percentage; (16) average distance between construction projects and concrete batch plant (X_{16}); (17) construction projects schedules (X_{17}) that supply the concrete referring to daily concrete quantities production.

10.2. Group (B) road variables

It was broken down into six variables: (18) sites number, which gives order for using RMC (X_{18}), (19) plant safety with efficiency (X_{19}) which was expressed as a percentage, (20) site arrangement (X_{20}) which was expressed as a percentage, (21) casted items types (X_{21}) which was expressed as a percentage, (22) communications between site crews (X_{22}) which was expressed as a percentage, and (23) machine damages number (X_{23}) which was expressed as a number.

10.3. Group (C) project variables

It was broken down into four variables: (24) roads quality (X_{24}), which was expressed as a percentage, (25) traffic conditions (X_{25}) which was expressed as a percentage, (26) weather conditions (X_{26}) which was expressed as a percentage, and (27) average temperature (X_{26}) which was measured by Celsius.

11. SPSS input variables data

Statistics Package for Social Science (SPSS) statistical analysis is used for all collected data during start of 2012 till the end of 2016. Statistics Package for Social Science (SPSS) concluded the impact for each variable on performance ratio of concrete batch plant using regression technique. Analysis of variance (ANOVA) is defined as a procedure for testing the hypothesized equality of two population means or more, in other words ANOVA is defined as a statistical test that any user can apply it to determine how much of studied data can be trusted [57]. Correlation analysis is related to measure the strength of relationship between different variables. On the other hand, the correlation between all different studied variables is calculated and then they are plotted in a diagonal matrix. The coefficient between two or more different studied variables which affect dependent variable is ranged between −0.725 and 0.998, and thus they are taken into consideration to be strongly correlating. Table 1 presents the input data sample in SPSS software.

12. Developed model final form

Performance Ratio (PR) of concrete batch plant will be estimated as a dependent variable with effective independent variables X_n that were formulated as final form. As discussed in previous sections, the individual variable behavior with performance ratio of concrete batch plant was formulated as linear relationship as a best fit. On the other hand, variables values and data are inserted in SPSS software, and then multiple regressions are performed using stepwise method to estimate available and accurate models in this section. Many trails were done, and it was declared from these trials that the optimal fitting could be performed as linear relationships between effective variables as independent variables with concrete batch plant performances ratio as a dependent variable. For each proposed model, R^2 & F and Significant F were calculated, and also SPSS software can provide these values for each variable separately as mentioned before. The standard optimization model should be given as $R^2 = 1.0$ & $F =$ Maximum and Sig. $F = 0.000$. The best proposed model gave $R^2 = 0.974$ & $F = 130.931$ and Sig. $F = 0.000$ as presented in Tables 2–4. These tables, which were estimated by SPSS software, assume a proposed model and its terms are the effective variables (X_n) as independent variables with concrete batch plants' performance ratio as dependent variable are proposed in linear relationship form.

Where: R^2 is the fit model goodness or determination coefficient as presented in Eq. (4) and it is the variation proportion of dependent variable that is explained by the regression model (Confidence $\propto R^2$) and it ranges between 0.0 and 1.0. Small values near 0.0 indicate that the model does not fit the data well; large values near 1.0 indicate that the model fits the data well.

$$R^2 = \frac{[N \times \sum x_i y_i - (\sum x_i) \times (\sum y_i)] \times P^2}{[N \times \sum x_i^2 - (\sum x_i)^2] \times [N \times \sum y_i^2 - (\sum y_i)^2]} \tag{4}$$

F is the dispersion measure around mean, which is presented in Eq. (5). The variance is measured in units that are the square of those of the variable itself. (Confidence $\propto F$)

$$F = \frac{R^2 \times (n-2)}{(1-R^2)} \tag{5}$$

Significant F gives the doubt percentage. (Confidence $1/\propto$ Sig. F); Standard error (SE) is estimate measures of observed points variability around the regression line and assess the estimating equation reliability. Degree of Freedom (DF) is a distribution mathematical property, which is related to values in the sample. Standard Deviation (SD) is a measure of dispersion, and it is the positive square root of the average square deviation of each observation from the mean as presented in Eq. (6); also the standard deviation is the positive square root of variance.

$$SD = \sqrt{\frac{N \times \sum x_i^2 - (\sum x_i)^2}{N^2}} \tag{6}$$

The used model and its coefficient $PR = F[X_n]$ are given by SPSS software in Table 5.

After studying and analyzing the collected data from fields using SPSS software, it was predicted that a proposed general model with high confidence is formulated in the following general formula, Eq. (7):

$$\begin{aligned}\text{Performance Ratio} = {} & -226.495 + 27.157X_1 + 23.058X_2 \\ & + 15.936X_3 + 4.749X_4 - 0.017X_5 \\ & - 15.781X_6 - 0.131X_7 + 86.318X_8 \\ & + 0.020X_9 + 0.359X_{10} + 3.397X_{11} \\ & - 2.319X_{12} - 18.402X_{13} + 0.154X_{14} \\ & + 114.404X_{15} - 0.016X_{16} \\ & - 0.190X_{18} + 17.873X_{19} + 7.340X_{20} \\ & + 17.053X_{21} + 58.286X_{22} \\ & - 0.786X_{23} + 3.361X_{24} - 3.038X_{25} \\ & + 12.113X_{26} + 0.021X_{27}\end{aligned} \tag{7}$$

where formula limitation is as follows:

Performance Ratio is the percentage % of studied concrete batch plant efficiency as dependent percentage at left hand side and X_n is the most effective variables as independent variables at left hand side of Eq. (7).

Using verification for proposed general formula as shown in equation (7), the minimum and maximum PR% values are ranged between 11.01% and 99.23% and variable values are stated as shown in Table 6.

13. Stepwise forms

Stepwise forms were done for proposed general formula using SPSS to reduce and simplify it, also to predict more alternative simplified formulas and neglect the variables that have lowest and negligible effect on batch plant performance ratio. Stepwise form results were concluded as presented in the following formulas from Eqs. (8)–(17):

$$\text{Performance Ratio} = -126.727 + 227.752X_{15} \tag{8}$$

$$PR = -147.860 + 159.027X_{15} + 100.080X_{22} \tag{9}$$

$$PR = -122.812 + 0.118X_7 + 147.858X_{15} + 72.925X_{22} \tag{10}$$

$$PR = -128.535 + 24.151X_2 + 0.098X_7 + 142.659X_{15} + 64.130X_{22} \tag{11}$$

$$PR = -136.993 + 25.302X_2 + 0.095X_7 + 140.353X_{15} + 65.254X_{22} + 11.576X_{26} \tag{12}$$

$$PR = -143.347 + 24.738X_2 + 21.255X_3 + 0.091X_7 + 130.460X_{15} + 61.239X_{22} + 12.576X_{26} \tag{13}$$

$$PR = -138.146 + 25.271X_2 + 20.182X_3 + 0.087X_7 - 10.512X_{13} + 134.436X_{15} + 61.832X_{22} + 13.236X_{26} \tag{14}$$

$$PR = -143.035 + 14.657X_1 + 23.349X_2 + 20.166X_3 + 0.057X_7 - 10.187X_{13} + 132.192X_{15} + 60.658X_{22} + 13.006X_{26} \tag{15}$$

$$PR = -146.278 + 18.497X_1 + 21.158X_2 + 19.007X_3 + 0.050X_7 - 11.874X_{13} + 127.790X_{15} + 13.079X_{21} + 58.553X_{22} + 12.583X_{26} \tag{16}$$

$$PR = -183.334 + 20.108X_1 + 22.357X_2 + 17.907X_3 + 0.045X_7 + 41.559X_8 - 10.624X_{13} + 121.535X_{15} + 17.745X_{21} + 58.477X_{22} + 12.869X_{26} \quad (17)$$

where Performance Ratio is the percentage % of studied concrete batch plant efficiency and X_n is the most effective variables.

14. Correlation matrix

Using regression technique a statistical analysis has been performed between effective variables and concrete batch plants' performance ratio. Correlation benefits are to measure the relationship strength degree between variables and concrete batch plants' performance ratio. Correlation coefficient indicates what will be done when variable is changed and its impact on concrete batch plant performance ratio, as shown in Eq. (18):

$$\text{Coefficient of Correlation} = \frac{N \times \sum x_i y_i - (\sum x_i) \times (\sum y_i)}{\sqrt{[N \times \sum x_i^2 - (\sum x_i)^2]} \times \sqrt{[N \times \sum y_i^2 - (\sum y_i)^2]}} \quad (18)$$

If Correlation coefficient indicates a positive sign that means direct proportion; if Correlation coefficient indicates a negative sign that means inverse proportion; if Correlation coefficient is more than or equal to 0.8 that means there is a strong correlation between concrete batch plant performance ration and studied variable; and if Correlation coefficient is less than 0.8 that means there is a weak correlation between concrete batch plant performance ration and studied variable.

Correlation matrix shows concrete batch plant performance ratio and independent variables, which give major impact between them because most correlated coefficients are more than 0.8 and remaining values give minor impact between them because few correlated coefficients are less than 0.8. Table 7 presents the correlation matrix between performance ratio and independent variables.

15. Cases of studies

Concrete batch plant manager will use variables values from X_1 to X_{27} by general or/and simplified formulas to predict near actual concrete batch plants' performance ratio as mentioned before, on the other hand batch plant manager can observe actual performance ratio according to ratio between actual observed and theatrical production rates, respectively. These discussions will be declared in the following case study:

15.1. First case study

Pouring 1360 m^3 concrete raft foundation of warehouse building for Suez power station from Suez power concrete batch plant in Ismailia which was monitored and observed in July 2016, and it was observed that practical working hours were equal to 9 h and 15 min using 23 concrete truck mixers and 3 pumps. Table 8 presented the values of effective variables that influence the performance ratio of concrete batch plant, then inserting these values to general formula to predict concrete batch plant performance ratio (PR) and compare the result with Actual Performance Ratio (APR) for studied concrete batch plant as shows in Eqs. (19 and 20):

$$APR = \frac{\left(\frac{Q}{T}\right)_{act}}{\left(\frac{Q}{T}\right)_{therotical}} \times 100 \quad (19)$$

$$APR = \frac{\left(\frac{1376}{9.25}\right)_{act}}{160} \times 100 = 93.0\% \quad (20)$$

15.2. Second case study

Pouring 1626 m^3 concrete raft foundation of Suez canal university from Ismailia concrete batch plant in August 2016, and it was observed that practical working hours were equal to 32 h using 10 concrete truck mixers and 3 pumps. Table 9 presented the values of effective variables that influence the performance ratio of concrete batch plant, then inserting these values to general formula to predict concrete batch plant performance ratio (PR) and compare the result with Actual Performance Ratio (APR) for studied concrete batch plant as shows in Eqs. (19 and 21):

$$APR = \frac{\left(\frac{1626}{9.2532}\right)_{act}}{65} \times 100 = 78.17\% \quad (21)$$

Table 10 shows the comparison between proposed models' results and field data results for two cases of studies.

16. Conclusions

Predicting and improving performance ratio for concrete batch plant is the important stage which is suggested in this paper using smart modeling techniques. Predicting and improving performance ratio was selected because of its importance in construction field using most influenced factors study. This paper will be done through collecting and studying large detailed data from start of 2012 to the end of 2016. A General model was formulated to predict concrete batch plants' performance ratio as a function of all effective variables using SPSS multiple regression technique, and it is helpful for concrete batch plant managers. A Simplified model was formulated to predict concrete batch plants' performance ratio as a function of major effective variables using SPSS multiple regression technique. Matches between proposed models' results and field results were 99.5 ± 1.5% that indicate a good and optimal accuracy.

17. Recommendations

From daily records of this study regarding different variables affecting concrete batch plants' performance ratio may be noticed that is equal to 62.78%, and then to improve it the company should follow: (1) Applying continuous training programs for concrete batch plant manager and staff, (2) Establishing a good bonus system for all crews, (3) Improving market plan for concrete quantities to get optimal range which is ranged between 285 and 375 m^3 considering 12 working hours including rests, (4) Constructing a recycling concrete factory follows concrete batch plant to produce bricks, and manholes from extra quantities, (5) Putting a constrains for transportation distance limitation up to 30 km, (6) Putting a

constrains for concrete production per one cycle not less than 6 m^3, and (7) Applying previous recommendations to insure minimizing time, cost and efforts with maximizing profitability.

18. Future studies

Additional future researches should study the following: (1) Optimization model for batch plant fleet (concrete batch plant, truck mixers and pump) to maximize productivity, minimize time and cost; (2) Integration between concrete batch plant productivity softwares and simulation softwares; (3) Influence for improving concrete batch plants' performance on reducing time and cost, and (4) Use of TQM system for measuring and categorizing concrete batch plants' performances.

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Study The Properties of Sintered Al-Composites Matrix Reinforced With Nano-Al Oxide And/Or Carbon Nano Tubes

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Abstract

The present work is concerned with studying the synthesis and characterization of hybrid aluminum bronze matrix strengthened with nano-aluminum oxide particles (n-Al_2O_3), and carbon nano tubes (CNTs). The selected matrix composite was successfully incorporated with different weighted percentages of CNTs (i.e. 1.0 and 2.0 wt.%) and/or n-Al_2O_3 (i.e. 1.0 and 2.0 wt.%) by sintering process. From the microstructure analysis, n-Al2O3 particles was dispersed uniformly and holding over the surface of aluminum bronze. Furthermore, some agglomeration was found due to reinforced CNTs into aluminum bronze matrix. From hardness tests, it was found that incorporated n- Al_2O_3 and CNTs into matrix increased the hardness of composites to be equal 230 HV, which is around 2.3 times higher than that of an aluminum bronze matrix. Moreover, the wear loss of CNTs - Al_2O_3/aluminum bronze composites diminished because of the impact of homogeneous circulation of CNTs in aluminum bronze and low corrosion coefficient of uncovered CNTs on the well-used surface. Notable from the results, the electrical resistivity of the hybrid composites are lower than the matrix. Hopefully, the findings are expected to provide profound knowledge and further reference towards the studied composites of the miniaturised electronic package.

Indexing terms/Keywords: CNTs; Nano Al_2O_3; Electrical Resistivity; Hardness; Wear; Composites.

Subject Classification: Matherial science Classification; Composite materials Classification.

Type (Method/Approach): Characterization of aluminum bronze matrix composite strengthened with different wt. % (0–2) of CNTs and n-Al2O3 particles were studied. Furthermore, the microstructure, microhardness, wear, density and electric resistivity were investigated.

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1. Introduction

In recent years, metal matrix composites (MMCs) reinforced with nano-particles are being developed worldwide, due to their promising properties appropriate for a large number of functional and applications. Composites of nano crystalline copper network and a couple percent of finely scattered nanoparticles of alumina demonstrate grand warm soundness of miniaturized scale structure and mix of high quality and conductivity over a broad assortment of temperatures. For the practical invigorating, the second stage particles (dispersoid) must be thermo powerfully consistent, fine with general estimations of 5.0–50.0 nm, homogeneously appropriated inside the network grains to reinforce material by an appealing direct association of the particles with moving disengagements [1-2]. The dispersoids can give significant quality to the composite even at high temperatures, where other strengthening frameworks (e.g. precipitation or icy working solidifying) quickly lose their sufficiency [3]. These various properties are great with organization in high-temperature warm or electrical transports, microwave tubes, switches, breakers, and resistance welding anodes. Aluminum bronze is considered as very useful in different applications of industries due to its good tough and ductile at all temperatures and retain their strength well at elevated temperatures. The joining of clay particles can significantly improve the high-temperature mechanical properties, oxidation and wear resistance, without genuine disintegrating of warm and electrical conductivity of the copper matrix. Therefore, various nano-sized oxides have been used as dispersion into composites. In view of the more affordable researches, Al2O3 particles have been used as reinforced element in the matrix [4–16].

Extensive investigations have been directed in carbon nano tubes (CNTs) fortified polymer matrix composites with a surprising upgrade in mechanical properties contrasted with those of solid materials. Nonetheless, constrained examination has been finished in planning, auxiliary, physical and mechanical properties of metal–CNT nano composites. Poor wetting conductor powerless inter facial clinging to lattice materials, agglomeration among themselves with Van-der-Waals power, in homogeneous dispersion of CNTs in the grids and corrupted thermal security at high handling temperature are the prime disadvantages to use CNTs as fortifications of metal grid composites. For example, Kuzumaki et al. reported almost no change in the tractable quality of CNT strengthened Al nano composites arranged by routine powder blending, hot-squeezing took after by hot expulsion due to in homogeneous scattering of CNTs in the metal grid [17]. Additionally, CNTs as fortifications of metal matrix composites have accounted for poor efficiency due to agglomeration among themselves with Van-der-Waals power, poor wetting conduct or powerless inter facial attaching to grid materials and corrupted warm dependability at high sintering temperature [18–21]. It was reported that the increase in weight% of nano CuO particles improved the mechanical properties of sintered hybrid aluminum matrix [18]. In addition, a hybrid composite of copper metal matrix reinforced with TiC and graphite particles through microwave processing has been developed [22]. Vencl et al. [23] illustrated that Cu–2.5 wt.% Al composite exhibited the best wear resistance, 2.5 times higher than that of Cu–5 wt.% Al2O3 composite. Also, high hardness and nano-sized Al2O3 particles improved wear resistance of Cu–2.5 wt.% Al composite. On the other hand, it was reported that adding carbon nanotubes into copper matrix composites reduced the wear rate, the friction coefficient, and the plastic deformation [24].

In the light of the survey, although a lot of research has been done on synthesis and characterization of different ceramic particles or CNTs fortified aluminum bronze framework composites. However, to the best of our knowledge, aluminum bronze matrix composites reinforced by nanoparticles (2.0 wt. % n-Al2O3), nanotubes (2.0 wt.% CNTs) or (1.0 wt. % CNTs + 1.0 wt.% n-Al2O3) have not yet studied. Hence, the present work aims to study characterization of aluminum bronze matrix composite strengthened with different wt. % (0–2) of CNTs and n-Al2O3 particles. Furthermore, the microstructure, microhardness, wear, density and electric resistivity of the examined nanocomposites were investigated.

2. Materials and Methods

As received n-Al2O3 particles were 99.99% in purity, 50 nm in normal size. CNTs 95% in purity, 30 nm in normal distance across, and 30 μm in normal length, created by nanotech Egypt. Pure copper powder with a normal molecule size of 70 μm purity 99.8%, and Al, powder of 99.98% with average particle size of 100 μm

created by Alpha Chemika, were chosen as the beginning materials of matrix of the composites. Four samples were prepared, Aluminum bronze (89 wt.% Cu - 11 wt.% Al) matrix, Aluminum bronze – 2.0 wt.% CNTs, Aluminum bronze – 2.0 wt.% n-Al2O3, and Aluminum bronze – 1.0 wt. % CNTs + 1.0 wt.% n-Al2O3. The initial powders of the grid compound, the support and 2.0 wt% acetone as a binder were mixed for 90 min at 300 rpm in a stainless steel blending container with stainless steel bars with 10 mm measurement and 50 mm length, giving a rod to-powder weight proportion of 3:1. Then, the blend was placed in dryer for 60 min. at 80 °C to evacuate the acetone. The blended powder was filled into a cylindrical die with distance across (8.0 mm), 5.0 mm height, and uni-pivotally pressed at pressure of 800 MPa. The prepared green compacts were sintered in vacuum furnace at a temperature of 900 °C for one hour with 10 °C/min heating rate. The presence and distribution of the reinforced nanoparticles were studied using scanning electron microscope (SEM). The SEM used in this study was SEM-JEOL JSM5800-LV. An energy dispersive spectrometry (EDS) was used to determine chemical composition of the studied composites. Vickers hardness tester (Lecco Vickers hardness analyzer, Model: LV 700, USA) was measured using 1.0 kg for 15 s. The average hardness of at least six readings of different indentations was taken for each specimen. Rough wear tests were conducted for composites using a pin-on-plate method under typical heaps of 2, 4 and 6 N, at steady sliding velocity 1.5 m/s. In these tests, every example is ground up to review 1200 emery paper to guarantee that the wear surface is in finished contact with the grating counter-face. Round samples having contact region of 12.57 mm2 are stacked against a circle, which pivoted at 250 rpm. The plate conveyed a rough SiC paper of 400 Grit. The sliding separation was kept consistent at 200 m for every sample. During sliding, the abrasive wear rate of the pins was defined as the weight loss suffered per unit sliding distance. An electronic equalization having a determination of 0.0001 gm. was used to gauge the weight reduction. The pins were cleaned in acetone and dried preceding weight measurement. The relative dampness was measured yet not controlled and was in the scope of 60% amid these tests. Electrical resistivity was discovered utilizing smaller scale ohm Meter of motwane make (Demonstrate LR-2045). The Motwane LR 2045 is computerized smaller scale ohm meter equipped for measuring low resistance.

3. Results and Discussion

3.1 Microstructure

The microstructural of CNTs and n- Al_2O_3 particles strengthened in Aluminum bronze matrix composites were examined using SEM, as shown in Figs. 1-4. Besides, the constituents of nanocomposites were identified using the EDS analysis. It is clear that the diverse microstructures are created by the composites relating to the sort of supports of n- Al_2O_3 and CNTs. The composite demonstrates a split free and all around cleaned surface. This split free surface might be credited to the best possible circulation of weight amid compaction and legitimate cleaning of the test [25]. Additionally, it was observed uniform dispersion and holding of n- Al2O3 particles over the surface of Aluminum bronze, as seen in Fig. 2. Moreover, EDS analysis was carried out for n-Al_2O_3 fortified Aluminum bronze matrix composite to probe the composition of the attached nanoparticles. For 2 wt. % n-Al2O3 fortified Aluminum bronze matrix, it reveals the presence of Al, O and Cu. The oxygen pinnacle is because of the nearness of n- Al_2O_3 which include by 2% weight in the specimen. In addition, the SEM and EDS of CNTs strengthened in Aluminum bronze composite are revealed in Fig.3. It is noted that the scattering of CNTs into Aluminum bronze matrix was normal and some agglomeration was found. This can be credited to the correct ball processing of powder. Additionally, it was found that CNTs was broken into pieces when they are ball processed for a drawn out time with high vitality balling [26]. Besides, CNTs have no breaks on its surface because of the best possible day, age of ball processing, weight proportions of ball and powder. EDS investigations of the 1.0 wt.% CNTs and 1 wt.% n- Al_2O_3 fortified aluminum bronze matrix composite are presented in plainly the tops for the upper, oxygen, aluminum and carbon, as observed in Fig. 4. The EDS investigation confirms that CNTs and n- Al_2O_3 particles are existing inside the composites.

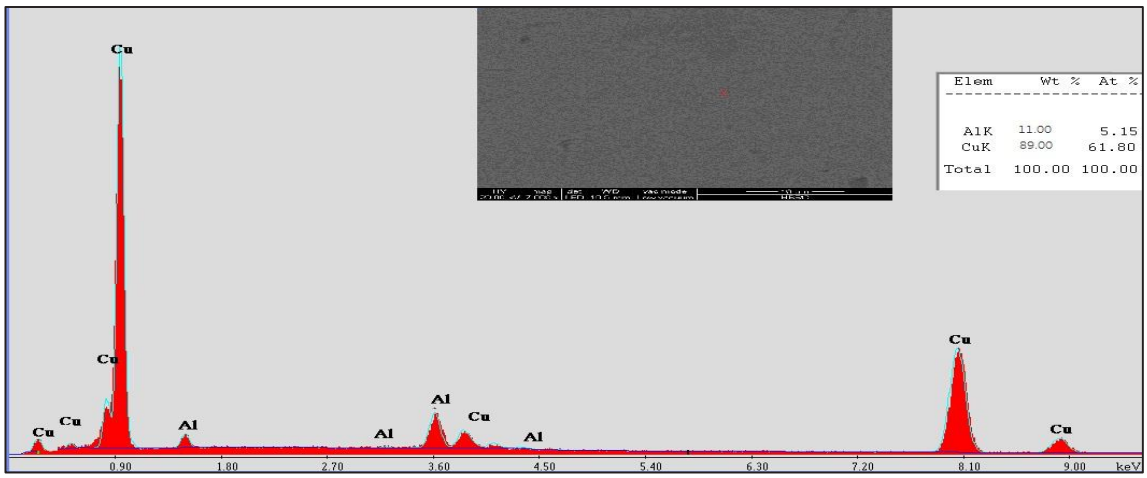

Fig. 1 SEM of aluminum-bronze matrix composite and EDS analysis.

3.2 Microhardness

The microhardness of the n- Al_2O_3 particles and CNTs incorporated in Aluminum bronze matrix composites measured by Vickers micro hardness tester, as exhibited in Fig. 5. As cleared, the hardness increases with blending the matrix by n-Al2O3 particles or CNTs. In addition, when n- Al_2O_3 together with CNTs are incorporated, the hardness of composites will be equal 230 HV, which is around 2.3 times higher than that of an Aluminum bronze matrix without existing n-Al_2O_3 particles or CNTs, as obtained in Table 1. According to previous investigation, when the CNTs/metal or CNTs/ceramic nanocomposites are manufactured by the atomic level process, the synthetic holding framed between the CNTs and the matrix particles gives homogeneous conveyance of CNTs and also high interfacial quality [27]. Subsequently, it is confirmed that such significant improvement of hardness is resulting from the high interfacial quality of CNTs and n-Al_2O_3 particles/aluminum bronze interface, the homogeneous dissemination of CNTs and n-Al2O3 particles inside the aluminum bronze matrix and accomplished high relative densities. In this manner, it can be demonstrated that the mechanical properties of CNTs and n-Al_2O_3 strengthened in nano composites are normal when the outside load can be shared by homogeneously circulated CNTs and n-Al_2O_3 through the heap exchange from matrix to CNTs and n-Al_2O_3 particles by sound interfacial quality of n-Al_2O_3/matrix and CNTs/matrix.

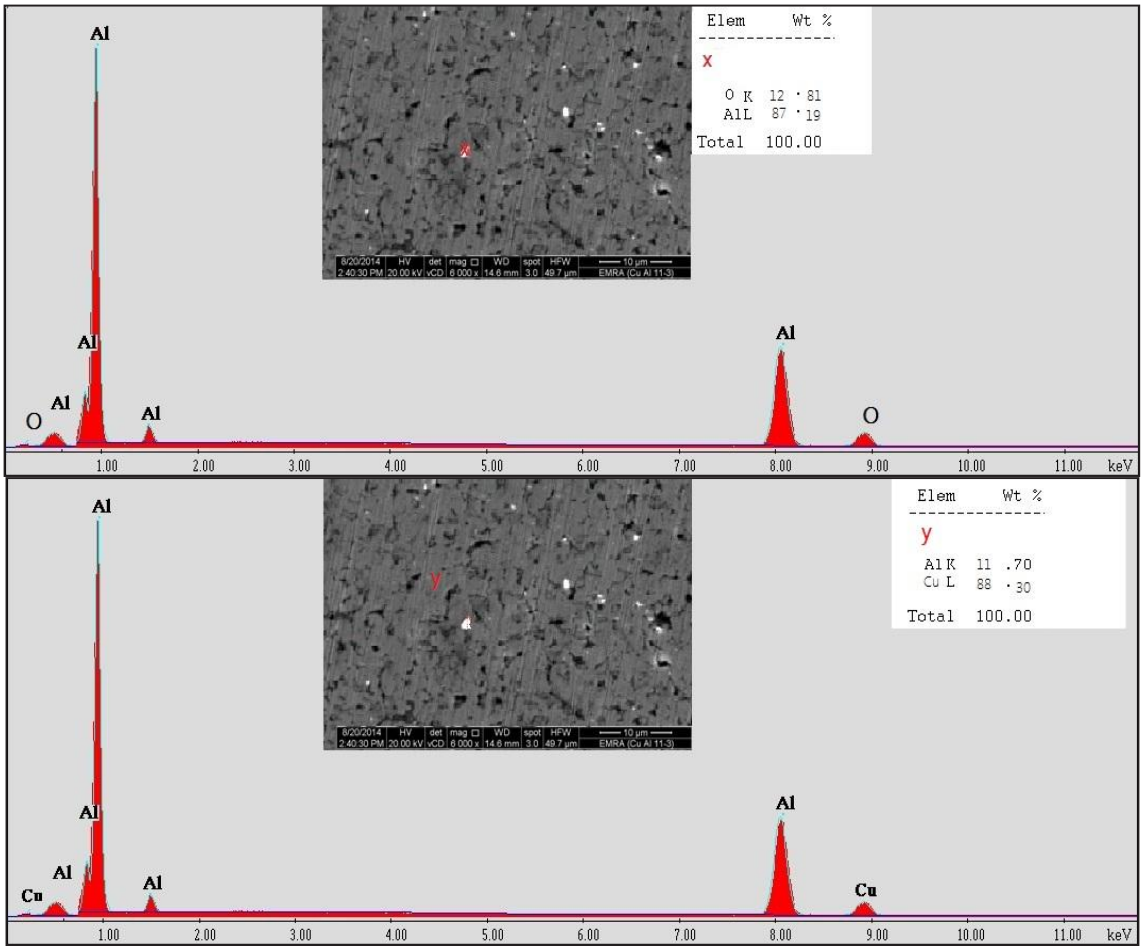

Fig. 2 SEM and EDS of aluminum bronze- 2 wt.%Al_2O_3 composite.

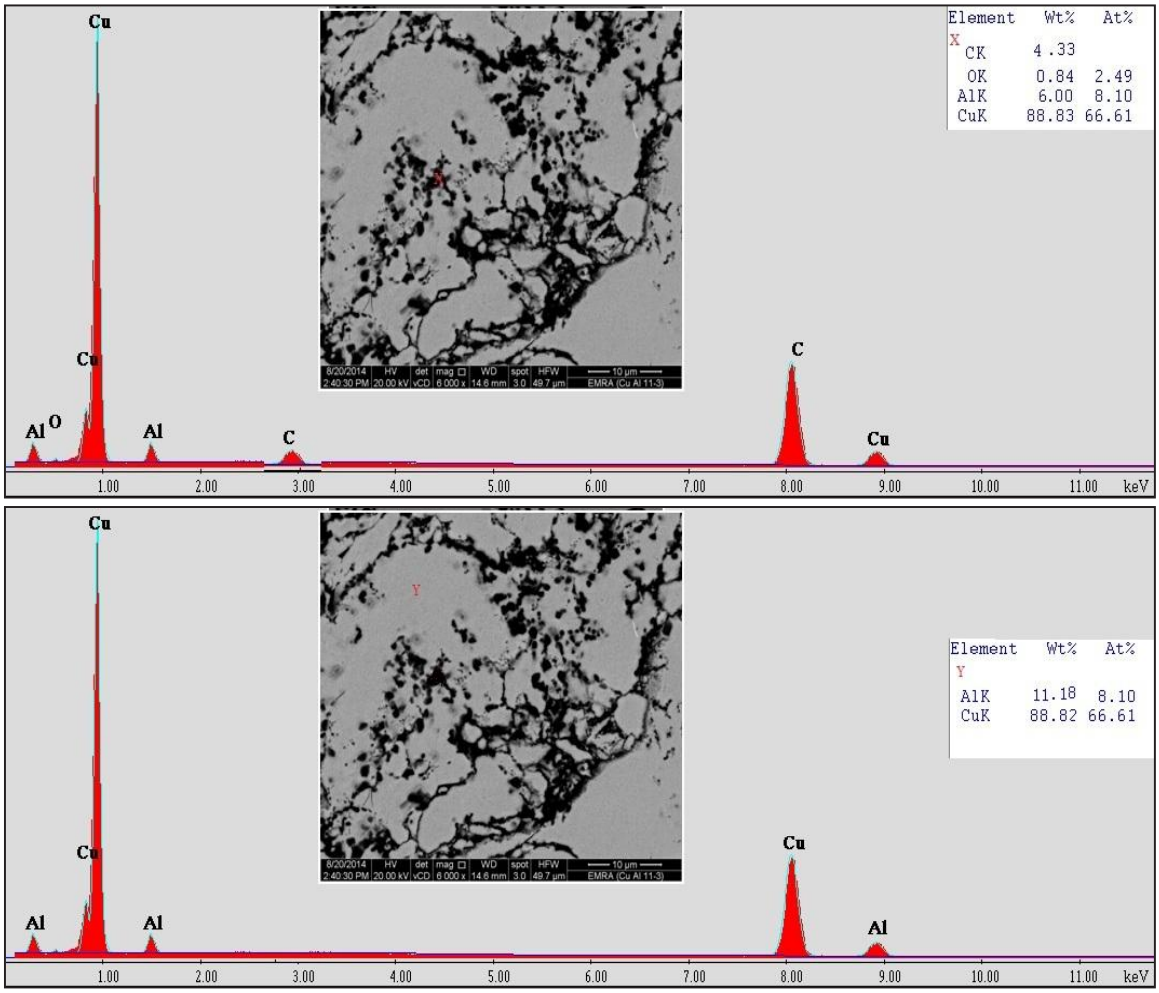

Fig. 3 SEM and EDS of aluminum bronze-2 wt.% CNTs composite.

Table 1 Microhardness values of the examined specimens.

Composite	Hv
Aluminium Bronze	100
Aluminium Bronze-2% CNTs	170
Aluminium Bronze-2%n- Al2O3	200
Aluminium Bronze-1%n- Al2O3+1% CNTs	230

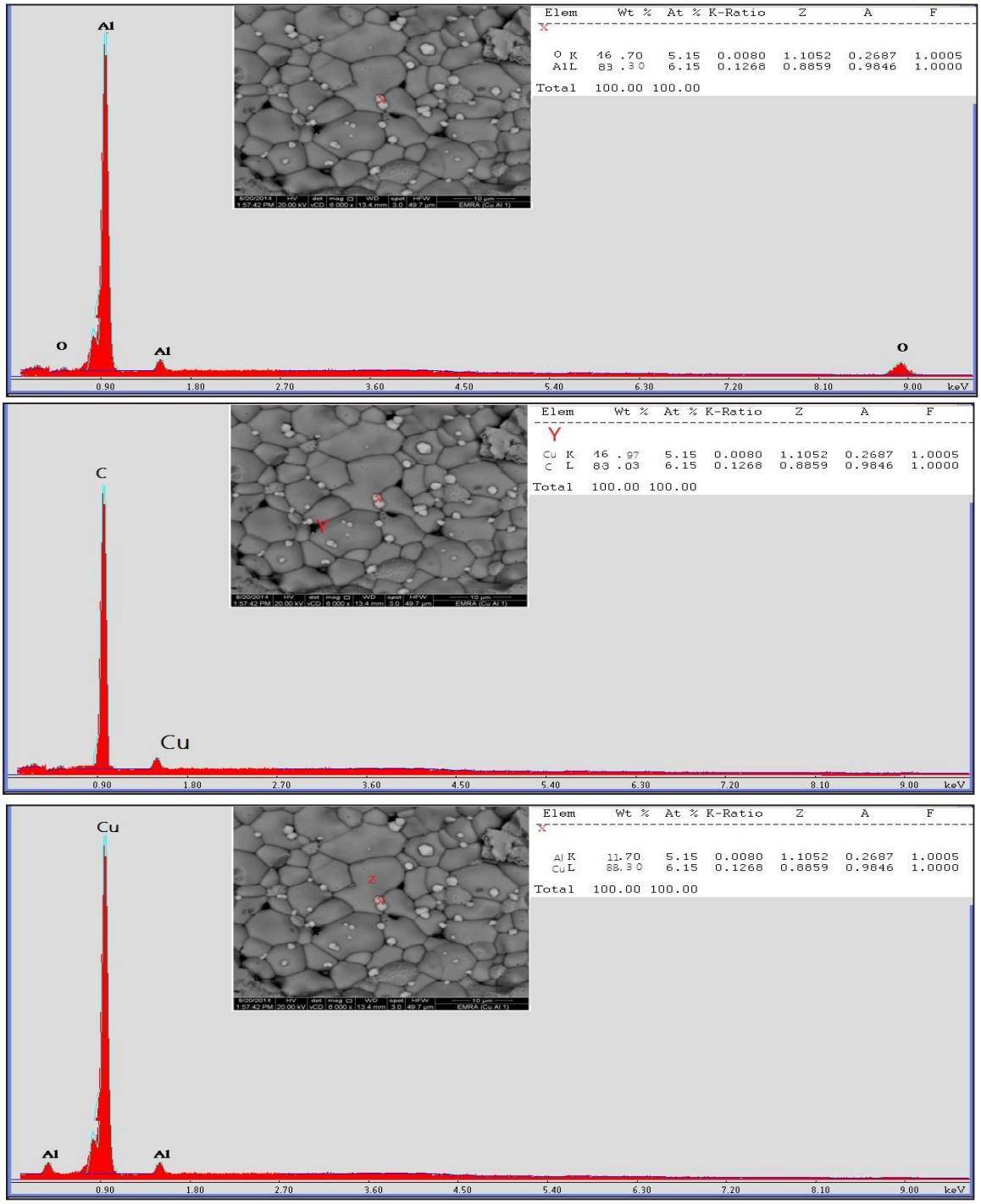

Fig. 4 SEM and EDS of aluminum bronze- 1 wt.%Al2O3-1 wt.% CNTs composite.

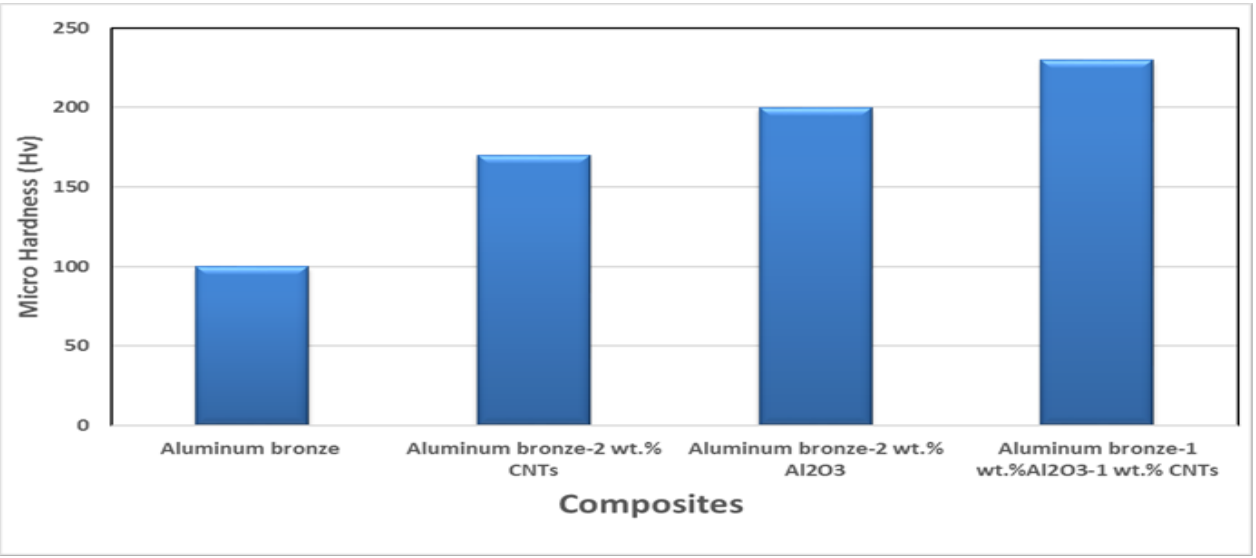

Fig. 5 Hardness of composites and aluminum bronze matrix.

3.3 Wear

Fig. 6 illustrates the wear loss of aluminum bronze, n- Al_2O_3/aluminum bronze, CNTs/aluminum bronze composites, and CNTs + n- Al_2O_3/aluminum bronze composites assessed by pin-on-disk wear test. Under dry sliding wear condition, the wear loss of CNTs + n- Al_2O_3/aluminum bronze composite is decreased to one-third compared with those of aluminum bronze matrix. Consequently, this composite shows three circumstances higher wear resistance by an expansion of CNTs+ n- Al_2O_3. It was reported that CNTs presented to the well-used surface amid wear process can go about as a greasing up carbon film inferable from its low wear coefficient [10]. Hence, the wear loss of CNTs + Al_2O_3/aluminum bronze composites is surprisingly diminished because of the impact of homogeneous circulation of CNTs in aluminum bronze and low corrosion coefficient of uncovered CNTs on the well-used surface. The hardness and wear resistance of the cross composites were better than that of the network material. Similarly, it was reported that the hardness of the composites containing SiC and Al2O3 was higher than that of the composites with SiC and Gr because of the consolidated sticking impact of SiC and Al_2O_3 and the higher hardness of Al_2O_3 to that of the Gr [26].

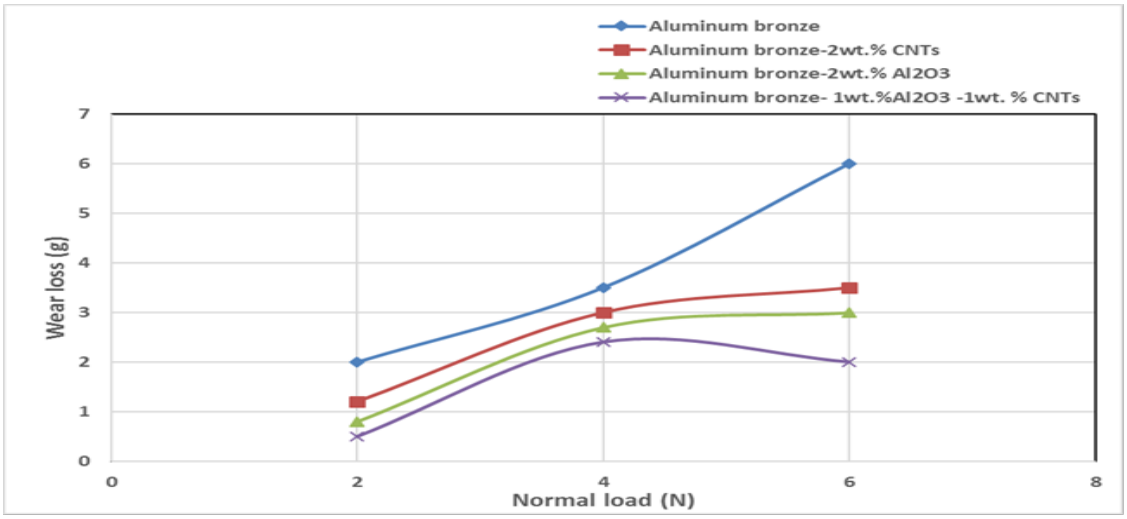

Fig. 6 Wear loss in (g) of the aluminum bronze and composites.

3.4 Density

The experimental and theoretical densities values of the composites containing different support rates are shown in Fig.7. It can be seen that the experimental and theoretical density values are nearer to each other for the separate composites, as shown in Table 2. Additionally, it was observed that the density of aluminum bronze matrix - CNTs or n- Al_2O_3 particles, and hybrid composites are higher than that of the base matrix. Obviously, the density of aluminum bronze - 2.0 wt.% CNTs has the higher density compared with the others examined composites. This increase in density of the aluminum bronze - 2.0 wt. % CNTs composite resulted from the higher density of CNTs than that of the Aluminum bronze. The density of the Aluminum bronze matrix increased by around 8.62% as the CNTs content was added to the matrix. The theoretical density of composite was calculated by the following equation:

$$\rho_c = V_p \rho_p + V_m \rho_m$$

Where ρ_c , ρ_m and ρ_p are density of composite, matrix and particles, respectively. V_P and V_m are the volume portion of particles and matrix, respectively.

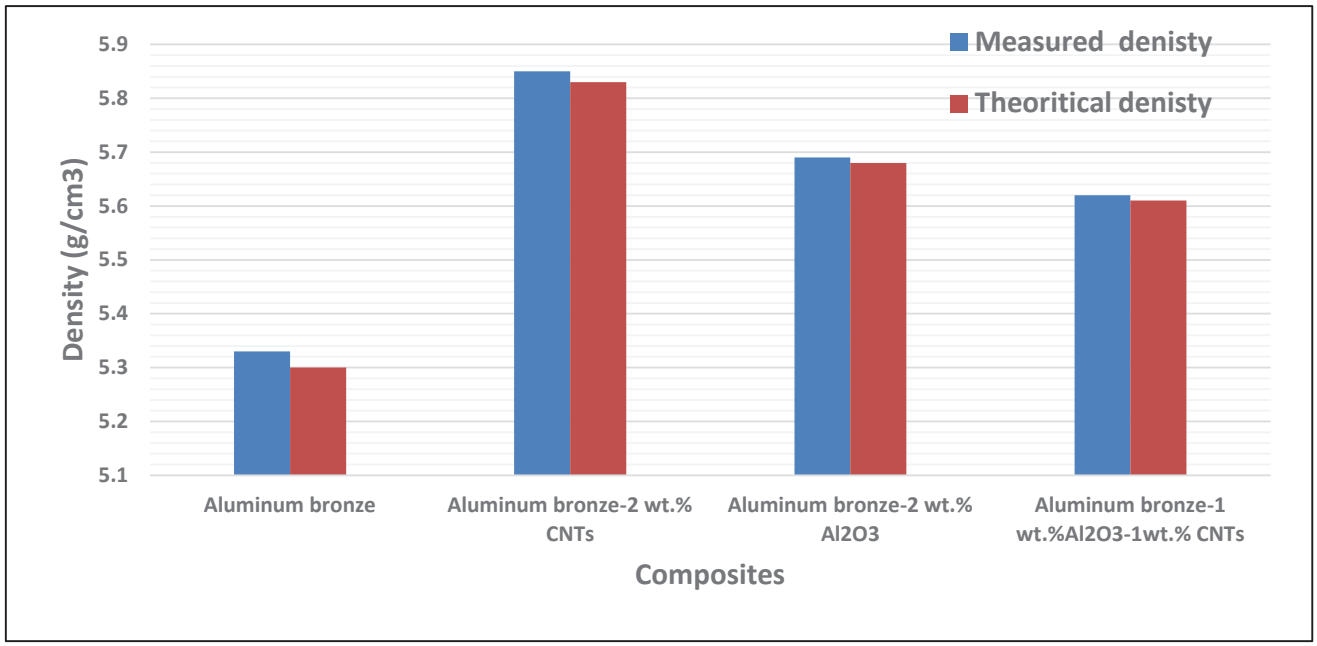

Fig. 7 Experimental and theoretical densities of aluminum bronze and composites.

Table 2 Experimental and theoretical densities of the examined composites.

Composite	Experimental denisty	Theoretical denisty
Aluminium Bronze	5.382351846	5.27
Aluminium Bronze-2% CNTs	5.724374853	5.71
Aluminium Bronze-2%n- Al2O3	5.691200755	5.58
Aluminium Bronze-1%n- Al2O3+1% CNTs	5.659537317	5.54

3.5 Electrical Resistivity

Fig. 8 shows the variation of electrical resistivity with different composites. It was observed that the average electrical resistivity of the aluminum bronze 2 wt.% CNTs composite decreases about 25% compared with the matrix. This shows that the addition of conducting CNTs in good conducting matrix phase severely affect the electrical resistivity. From results, it is clear that CNTs are homogeneously dispersed in aluminum bronze matrix. However, the addition of ion-conducting n- Al_2O_3 particles in good conducting matrix phase does not severely affect the electrical resistivity. Notable from the results, the electrical resistivity of the hybrid composite is lower than the matrix.

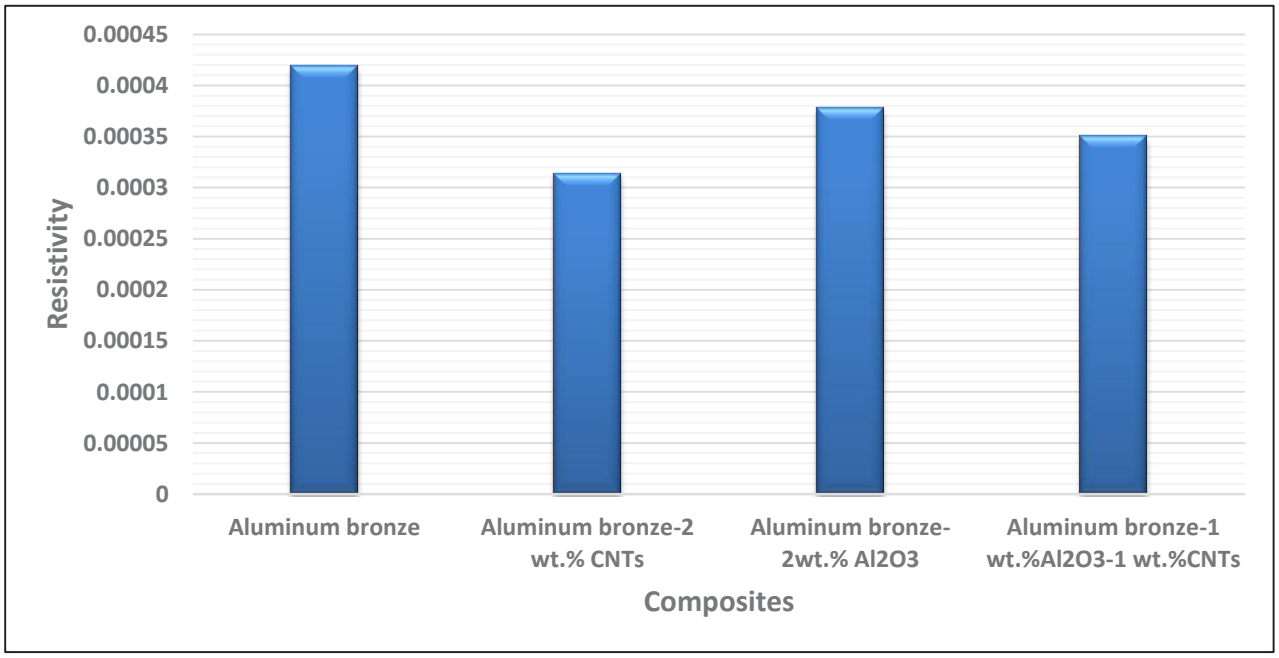

Fig. 8 Electrical resistivity of aluminum bronze and composites

4. Conclusions

In this study, the effect of reinforcing n-Al2O3 NPs and/or CNTs on the microstructure characterization, microhardness, wear, density and electrical resistivity of in Al bronze matrix was studied. The results are summarized as follows:

(1) Hybrid Al bronze matrix reinforced with CNTs and n-Al2O3 particles were prepared successfully using sintering process.

(2) The characterization of n- Al2O3 particles and CNTs dispersed in Al bronze matrix composites were studied using SEM with EDS analysis. The result indicated the presence of CNTs and n- Al2O3 particles in the Al bronze matrix composites.

(3) Inclusion of CNTs and/or n- Al2O3 in the metal matrix composites improved the microstructure and the properties of the composite material.

(4) The hardness and wear resistance of manufactured CNTs + n-Al2O3/aluminum bronze composite were significantly the highest compared with the others composites.

(5) It has observed that the density of the matrix increased by around 8.62% as the CNTs was reinforced. In addition, results showed that the typical electrical resistivity of the aluminum bronze CNTs composites increased around 25%.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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