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Evaluation of the Implementation of Business Practices and Advanced Manufacturing Technology (AMT) in Saudi Industry

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Abstract. The need to improve the performance of Saudi Industries to be more productive and competitive worldwide is well known and accepted. This paper draws the current situation of business and manufacturing practices, and the level of adoption of AMTs in Saudi manufacturing companies. It investigates the level of importance of manufacturing strategic objectives, current practices in the different organizational and technical industrial functions, the level of adoption of AMTs, and obstacles and expected benefits of these advanced technologies. The surveyed companies are well aware of the manufacturing strategies and they showed best business practices that are related to cost and production operation functions. However, activities related to marketing and product/manufacturing design are of less practice. Moreover, companies practice implementation of AMT related to CAD/CAE and MRP much more than CIM, FMS, CAPP, and IT technologies. Hence, the implementation of AMTs in Saudi industries is still at early stages and does not take full momentum for development to achieve the expected benefits from using AMTs. The surveyed companies do not feel that they have major difficulties or obstacles challenging the implementation except mainly those of cost and lack of labor skill.

1. Introduction

In order to be successful in today's competitive environment, manufacturing companies must be capable of manufacturing products of high quality, at low cost and providing an improved customer service. Many companies have responded to these competitive demands by adopting new manufacturing technologies to improve quality, delivery, productivity and flexibility to meet customer needs.

Manufacturing companies recognize that the best business practices and adopting Advanced Manufacturing Technologies (AMTs) have become very important competitive methods for success. Saudi Industries have an important role to play in Saudi Arabian economy, both in terms of employment and contribution to gain a market place. In Saudi Arabia, there are more than 3,652 manufacturing establishments, with SR 255 billion capital investment, employing nearly 280,000 people (MCI, 2004). Many of these establishments are small to medium sized companies. The majority of these companies could benefit from upgrading their production techniques and procedures. Among the actions needed to improve their performance to meet the ever increasing demand for Saudi products are better marketing, design and investment in new manufacturing technologies. The national manufacturing industry will continue to be a vital to Saudi Arabian economy bending considerable pressure to improve its performance and competitiveness.

Companies using Advanced Manufacturing Technologies (AMTs) such as CAD/CAM, CAPP, and CNC are able to achieve higher productivity and efficiency. These new technologies provide an opportunity for profitable growth in output and new job opportunities. Rapid growth in worldwide application of AMTs is providing new opportunities for products, production processes, and manufacturing planning & control. The crucial importance of AMT to industry was underlined in many recent reports (see, for example, McGaughey and Roach, 1997; Ramesh *et al.*, 1990; Barad and Nof, 1997; Browne *et al.*, 1988; Kosturiak and Gregor, 1995; Rembold *et al.*, 1993; Groover, 1994;

Singh, 1996; Gunasekaran *et al.*, 1994; Kaltwasser, 1990; Kochan and Cowan, 1986; Bedworth *et al.*, 1991; Al-Ahmari, 2002).

This paper aims to establish the framework in which Saudi Manufacturing Industries are operating with emphasis given to current practices of business manufacturing parameters. The AMTs are also evaluated and the level of obstacles and expected benefits of these technologies are considered. The research is based on designed questionnaire and visits/interviews with decision makers in Engineering Industries in Saudi Arabia. The results of a survey of 93 Saudi Manufacturing Companies are presented in three major sections, namely; strategic objectives, current business and manufacturing practices, and advanced manufacturing technologies.

2. Literature Survey

AMT is usually used to refer to any computer-based technological system used in industries. AMTs include computer aided design (CAD), computer aided manufacturing (CAM), computer integrated manufacturing (CIM), computer numerical control (CNC), automated material handling (AMH), automated storage & retrieval system (AS/RS), and automated guided vehicles systems (AGVS) (Abdul Ghani *et al.*, 2002).

In addition to machine tools for design and manufacturing, AMTs include computer-aided techniques for plant management such as management information system (MIS), computer-aided process planning (CAPP), material requirement planning (MRP), artificial intelligence (AI), and so on. The current state of expectations is that CIM will ultimately determine the industrial growth of worldwide nations within the next few decades. Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Flexible Manufacturing Systems (FMS), Robotics together with knowledge and Information Based Systems and Communication Networks, are expected to develop to a mature state, to respond effectively to the managerial requirements of the factories of the future that are becoming highly integrated and complex.

Many applications have been reported by researchers and practitioners of AMTs. Meierhoefer (1997) examined the process of technology adoption and productivity within manufacturing firms, and built two models of technology use and productivity, for manufacturing establishments in Georgia. He used a technology adoption measure varied from 0 to 12, counting the use of seven "hard technologies" and five organizational, or "soft technologies".

Youtie (1997) assessed manufacturing needs, practices, and performance of the Georgian Manufacturing Extension Alliance for the period 1994 to 1998. The survey went to all Georgian manufacturing firms with 10 or more employees. More than 1,000 responses were received and weighted to reflect the actual distribution of manufacturers by industry and employment size.

Milling (1997) questioned a total of 550 German industrial firms to gain a comprehensive and reliable picture of the situation of the applications of CIM technologies in German corporations. The corporations utilize different production techniques with varying degrees of flexibility and both centralized and decentralized systems, for production planning & control, at the same time.

Millen and Sohal (1998) surveyed a number of American Companies with regard to their investment in CIM technologies. All respondents indicated that there had been more than one CIM investment in their company in the past three years. Although the percentages are not directly additive, it appears that the rank order of investments is in computer hardware, computer software, and plant & equipment. The most common investments in plant and equipment were computer-controlled testing equipment (41% of respondents), automated assembly (37%), and automated warehousing/order picking (36%).

Abdel-Kader (1998) reported the results of a survey investigation of investment decision making practices of large U.K. manufacturing companies, especially in relation to investments in CIM technologies. Seven types of CIM systems are frequently referred to in the literature: CNC, robotics, AMH, FMS, CAD, CAM and CIM. Based upon Meredith and Suresh (1986), these systems were categorized into three groups according to the level of integration. The first level comprised stand-alone systems such as CNC and robotics, the second level comprised linked systems such as CAD, CAM, and AMH, and the third level comprised integrated systems such as FMS and CIM. In their study, 76 companies were surveyed. 77% had invested in CIM. Most of these had invested in several different CIM applications. It was found that CAD systems were most widespread while the relatively lowest percentages were for FMS and CIM.

Baldwin and Sabourin (1999) considered the growth in advanced technology use that has taken place over the last decade in Canadian manufacturing establishments. They presented the percentage of plants that use any one of the advanced technologies studied and how this has changed between 1989 and

1998. They also investigated how the growth rates in the 1990s have varied across different technologies in specific functional areas, such as design & engineering, fabrication, communications, integration and control. Multivariate analysis is used to investigate the joint effects of plant size, foreign ownership and industry type on the incidence of technology adoption, and how these effects have changed over the last decade.

Kotha and Swamidass (2000) investigated the complex relationships among strategies of advanced manufacturing technology (AMT) and performance, using survey responses from 160 U.S. manufacturing firms. The survey included 19 items of CIM technologies. These items have been used extensively in previous studies. Respondents were asked to rate how frequently a particular technology was used in their firm on a five-point Liker-type scale. A factor analysis of the responses was then conducted to establish meaningful patterns in the data and for grouping the 19 items into factors.

Sun (2000) presented the findings of a survey about the pattern of current use and future tendency of CIM technologies. Empirical data came from a project on "International Manufacturing Strategy Survey (IMSS)" which covered 18 countries. It was found that CAD, MRP, LAN, and CNC machines are the most popular CIM technologies used by now. It seems that there is a sequence for adopting CIM technologies, namely from simple to complicated. Green field and fully integrated CIM systems seem to be rare. In three years, the uses of CAPP and shared database were significantly increased, which indicate the increase in the integration level of manufacturing system. However, the main configuration of manufacturing will be stand-alone islands of automation and limited integration. Fully computerized integration in manufacturing system will unlikely be the main model in the near future.

Baldwin and Lin (2001) used survey data to investigate problems that firms in the Canadian manufacturing sector face in their decision to adopt advanced technology. The survey collects information on 22 advanced manufacturing technologies. Abdul Ghani *et al.* (2002) found in their study that CIM technologies have been introduced in Indian manufacturing industries to have a competitive edge in the global market. Despite the claims that attractive benefits can be accrued through the use of these technologies in manufacturing firms, only modest benefits are reported. The productivity of CIM organizations is found to be low even after several years of implementing CIM. One of the reasons attributed for low productivity is the organizational structure that remains mechanistic and not compatible with the new technology in most of AMT firms. They presented a framework to implement CIM technologies in an existing environment, with organic structure to achieve superior performance.

Arvanitis *et al.* (2002) evaluated the effects of the Swiss governmental program to promote the diffusion of CIM technologies from 1990 to 1996.

Recently, Al-Ahmari (2007, 2008) used Analytic Hierarchy Process (AHP) and FAHP for the evaluation of advanced manufacturing technologies industry.

3. Problem Statement

It is widely believed that the successful implementation of best business practices and AMTs offers many benefits and resolve many problems in manufacturing industries. Nowadays, the industry in Saudi Arabia is believed to be the best strategic choice for the future of national economy. Unfortunately, these sectors do not receive much of research work in particular, the current business practices and the technological side. Therefore, there are several important questions required to be answered such as: what are the major strategic objectives of Saudi manufacturing companies? What are the level of business and manufacturing practices in the different activities of these manufacturing companies? What are the levels and types of current AMTs used in Saudi industries? What are the major obstacles of AMTs in this country? And, what are the expected benefits when the manufacturing companies adopt the AMTs? Unfortunately, to the author's knowledge there is no single existing study that has been conducted for consideration of the above critical issues and their impact on Saudi Industries.

4. Research Method

In this research, a questionnaire is designed and used to collect the required data from manufacturing companies. The design of the questionnaire is based on the international literature and recent developments in the subject area and guidelines taken from case study research (Burgess, 2003; Oppen-heim, 1992). The questionnaire is split into three major sections, each section addresses separate issues.

1. *The general information section*: This section provides statements to obtain information on the industrial establishment. This includes the company manufacturing activity, capital, labor

and employees, and their type of business. Also, the company strategic objectives given in Fig. 1 are measured.

2. *The industrial and business practices section*: This section contains the surveys the following business functions practices:
   a. Management functions which are measured by activity statements shown in Fig. 2.
   b. Marketing and product design functions which are measured by activity statements shown in Fig. 3.
   c. Production operation function which is measured by activity statements shown in Fig. 4.
   d. Cost function which is measured by activity statements shown in Fig. 5.
3. *AMT section*: This section contains the following:
   a. The present technologies of the establishment and the level of applying AMTs in Saudi Industry are measured according to statements given in Fig. 6.
   b. The different obstacles and expected benefits of AMTs from the view point of Saudi manufacturers are surveyed according the statements given in Fig. 7.

Requirements of implementing and developing advanced technology, information on the application of advanced technologies, its obstacles and the expected benefits are measured according the statements given in Fig. 8.

The questions statements for strategies, the functions of business activities, AMT implementation, obstacles and expected benefits are weighted by experts. To measure the opinion of the manufacturers, these questions statements are answered based on rated values from (1) to (5) representing low to high values.

The findings are analyzed using SPSS (statistical package for social sciences) as follows:

- At the beginning, the questionnaire is tested for: (a) validity where Pearson's coefficient of correlation between statements of each question are obtained as shown that all statements in the questionnaire are validated with significance less than 0.01 and assure that the inter-correlation between statement are valid, and (b) reliability for internal consistency where Cronbach's alpha coefficient are obtained for each question and shown to be between 0.83-0.89 which indicate on the consistency and the result of the questionnaire can be used with good reliability.
- Hence, the weighted average of the statements of each question are determined to give simple index of importance to indicate the strength or weakness of the measured questions (i.e. less than or equal 2.5 low, larger than 2.5 to 3.5 below average, larger than 3.5 to 4.0 average, larger than 4.0 to 4.5 high, and larger than 4.5 very high).

In order to improve the questionnaire, a pilot study was carried out where 10 manufacturing companies are selected for this pilot study. After preparing the final form of the designed questionnaire, it is distributed to 412 Saudi manufacturing companies in the sector of Engineering Industries, along with several visits to some companies. 131 questionnaires are collected. It is found that only 93 questionnaires are fully completed by the surveyed companies. Therefore, the data analysis is based on the completed group (93 questionnaires).

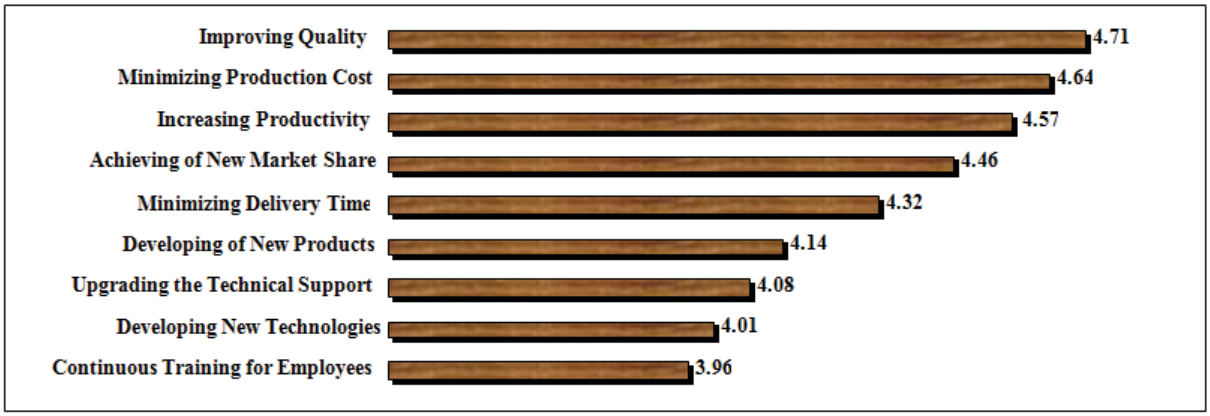

Fig. 1. Level of importance of strategic objectives.

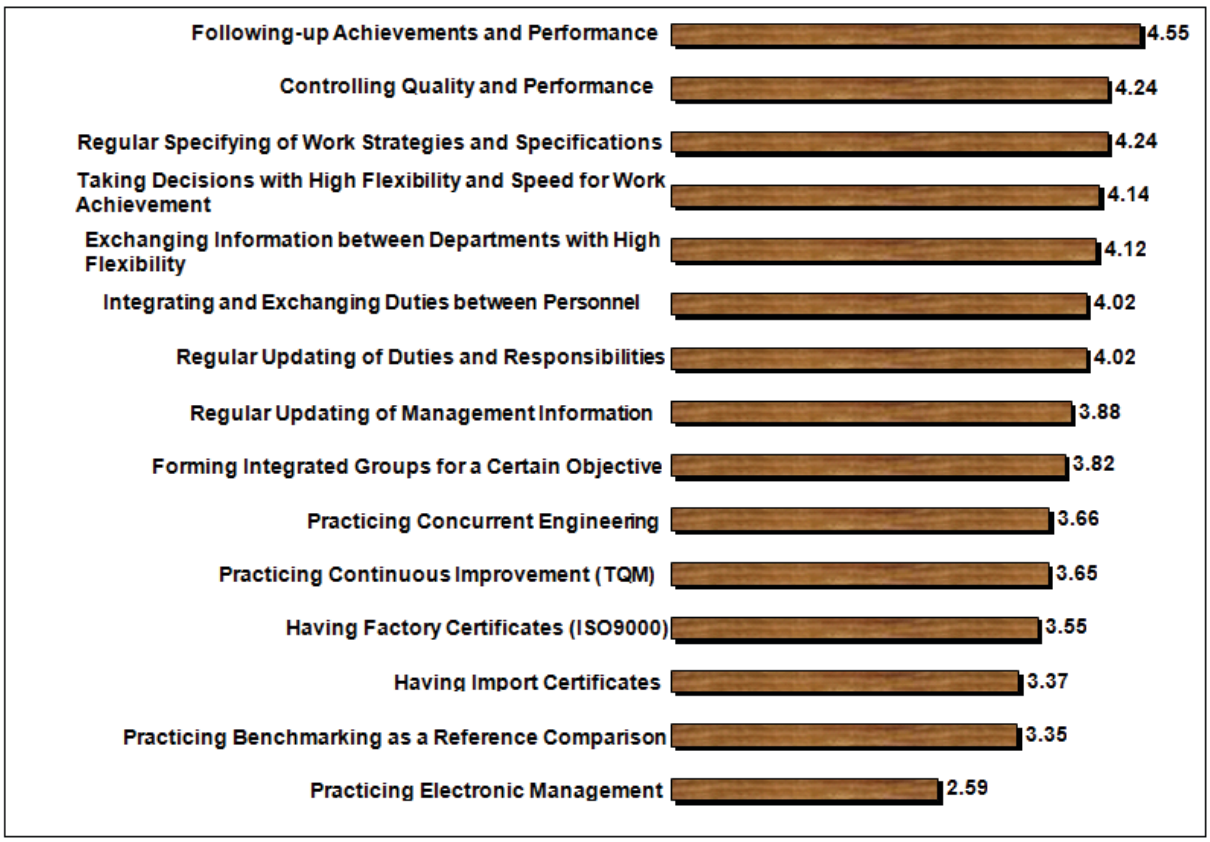

Fig. 2. Level of practicing management activities.

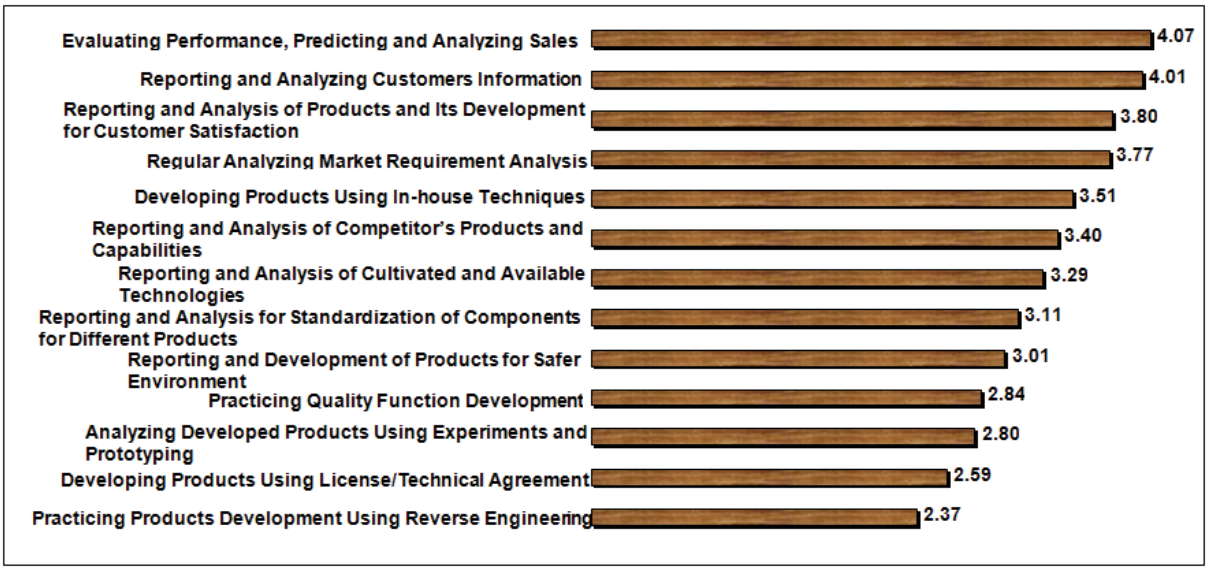

Fig. 3. Level of practicing marketing and product design activities.

Fig. 4. The level of practicing production activities.

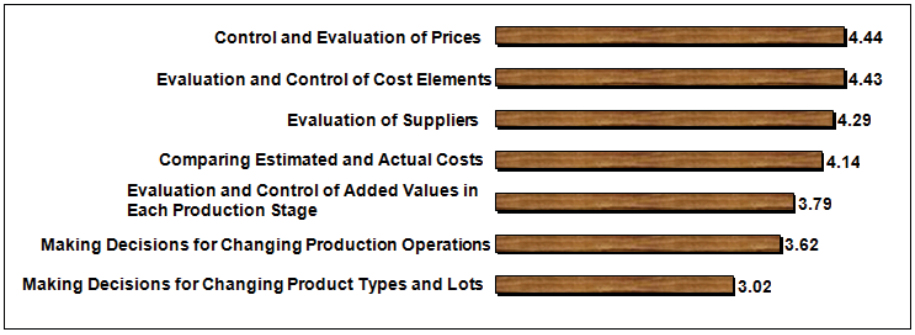

Fig. 5. Level of practicing cost activities in Saudi Engineering Industries.

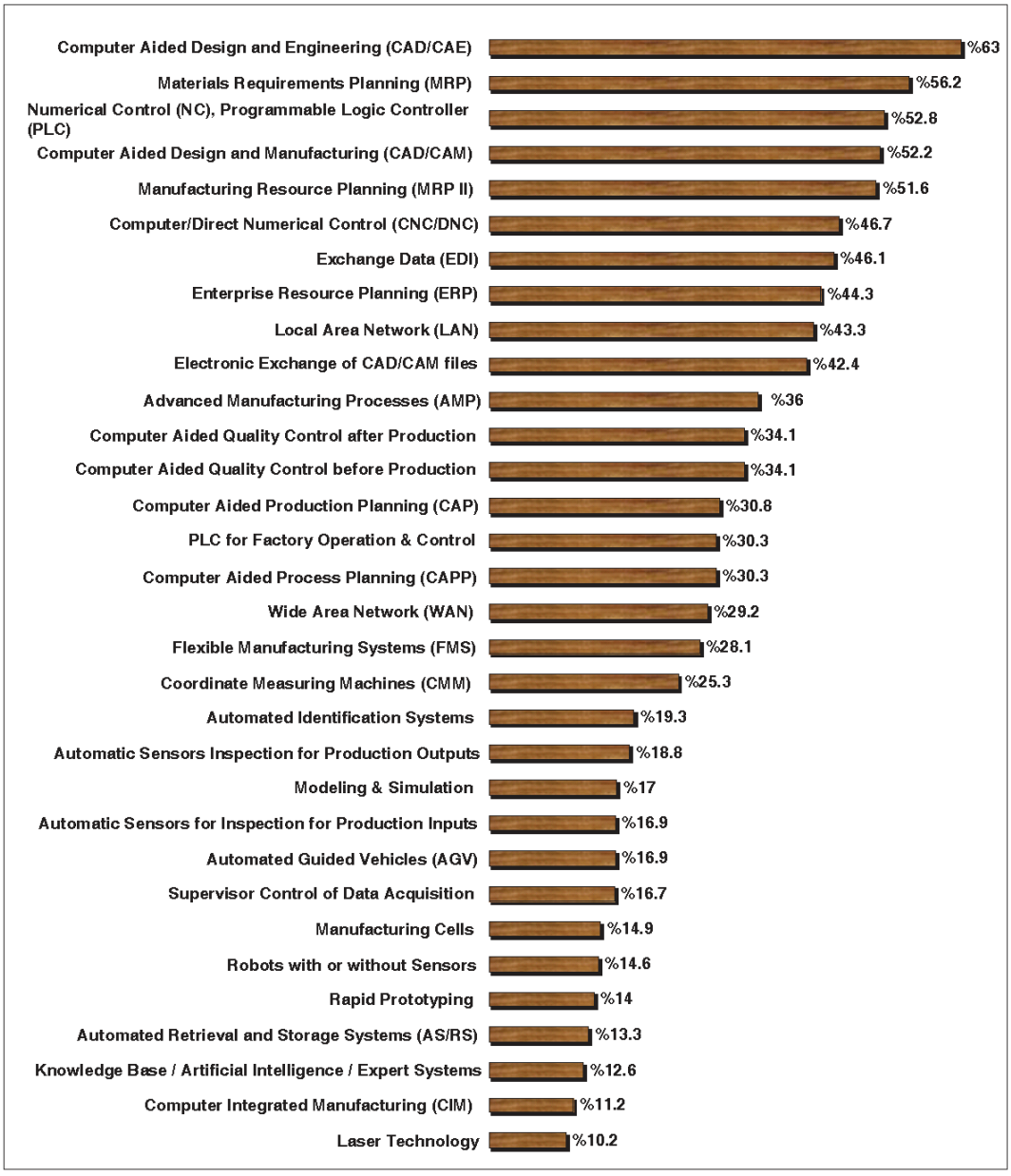

Fig. 6. Percentages of implementation of AMTs in Saudi Industries.

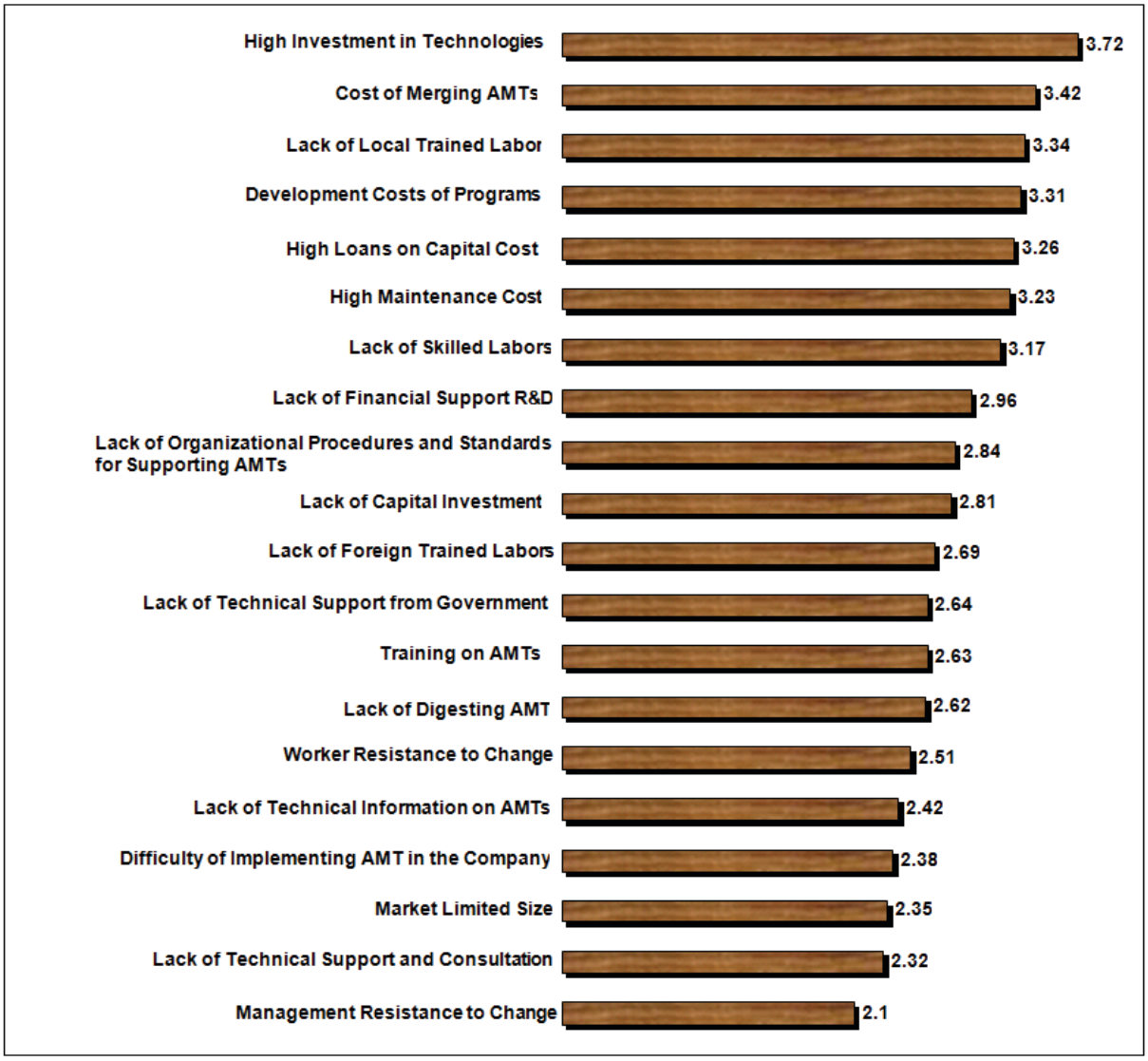

Fig. 7. Expected obstacles of implementation of AMTs in Saudi Industries.

Fig. 8. The expected benefits of AMTs.

5. Results and Discussion

Based on the responses to the fully complete questionnaire, the industrial practices and AMTs in which the Saudi Engineering Industries operate are investigated. The main results are as follows.

5.1. Level of importance of strategic objectives

Figure 1 shows the level of importance of various strategic objectives of the manufacturing companies.

It can be seen that the most important strategic objectives are: improving quality, increasing productivity, minimizing production costs, and minimizing delivery times. However, the mean value for all objectives is 4.32 out of 5.0 which means that there is awareness in these companies when preparing their strategic planning.

5.2. Level of business and manufacturing practices

The surveyed manufacturing companies are questioned about the level of practicing sets of business functions related to the activities of management, marketing, product design, production operations, cost, human resources, and environmental issues.

5.2.1. Level of management function practice

Figure 2 illustrates the level of practicing management activities in Saudi Engineering Industries. It is obvious from the figure that the level of the following management practices is high:

1. Following-up achievements and performance.
2. Controlling quality and performance.
3. Regular specifying of work strategies and specifications.
4. Taking decisions with high flexibility and speed for work achievement.
5. Exchanging information between departments with high flexibility.
6. Integrating and exchanging duties between personnel.
7. Regular updating of duties and responsibilities.

On the other hand, the level of practicing the following item is low and below average:

1. Practicing electronic management (IT).
2. Practicing benchmarking as a reference comparison.

This indicates that companies require improving IT and quality practices activities. However, management activities are carried on average since index mean value for all activities is 3.81 out of 5.0.

5.2.2. Level of marketing and product design functions practice

Figure 3 illustrates the level of practicing marketing and product design activities. It is clear that reporting and analyzing customer's information and evaluating performance, predicting and analyzing sales are highly practiced in the considered manufacturing companies, while practicing products development using reverse engineering, developing products using license/technical agreement, analyzing developed products using experiments and prototyping and practicing quality function development receive low practice.

However, the index means value of the marketing and product design activities is 3.5 out of 5.0, which means that these activities are carried below average.

5.2.3. Level of production operation function practice

Figure 4 shows the level of practicing a set of activities related to production operations. It is noted that high levels of adoption of many production practices particularly those of:

1. Planning and follow-up of final product quality.
2. Control materials and product inventories.
3. Production control and following-up production operations.
4. Material requirement planning and control.
5. Planning and follow-up of raw materials quality.
6. Orders control and follow-up for optimum delivery.
7. Material supply planning and control.
8. Planning and follow-up of product standards and quality throughout production stages.
9. Balance and control of material supply production operations.
10. Planning and follow-up of labor loading and assignments.
11. Control inventory of tools and spare parts.
12. Planning and follow-up of equipment & tools requirement.
13. Evaluation and follow-up material handling, storage, manipulation and packaging.
14. Evaluation and follow-up defects and rejected products for improvement.
15. Planning production operations based on factory capabilities.
16. Analysis and control of production system performance, machines and efficiency.
17. Planning and follow-up of maintenance and repair activities.
18. Reporting and follow-up orders from receiving orders until delivery.

19. Evaluation and improvement of production lines flexibility.
20. Organizing equipment and production departments.
21. Human resources planning and control.

However, the production operations which have not much practiced are those of more advanced operation techniques as listed below:

1. Implementing simulation techniques.
2. Reporting, follow-up and improvement operations for safer environment.
3. Implementing Just in Time approach.

However, the index mean value of the production operation activities is 3.94 out of 5.0, which means that these activities are carried on average and approaching high level.

5.2.4. Level of cost function practice

Figure 5 shows that the surveyed manufacturing companies are highly practicing control and evaluation of prices and evaluation of control of cost elements in costing activities, while making decisions for changing product types and lots receives low level of practicing. However, the index mean value of the cost activities is 3.96 out of 5.0, which means that these activities are carried on average approaching high level.

5.3. Level of AMT practices

5.3.1. Level of implementing AMT

The surveyed AMTs are illustrated in Fig. 6. It is obvious from this figure that the adoption of AMTs in Saudi Engineering Industries is still in early stages. CAD/CAE, MRP, NC, CAD/CAM and MRP II are the most adopted technologies in Saudi with an average percentage of 55.7%, followed by the adaption of CNC/DNC, EDI, EPR, LAN, and CAD/CAM electronic change files with an average percentage of 44.6%, while the levels of adoption of other AMTs such as CIM, laser technology, FMS, cellular manufacturing, AGV are very low and their percentage on average is 22%.

5.3.2. Level of anticipated difficulties of implementing AMT

As illustrated in Fig. 7, the importance attached to each of the anticipated obstacles or difficulties at the time of adoption or implementation of AMTs in Saudi Engineering Industries, the figure illustrates the ranking of these obstacles based on the mean scores. This shows that there are first seven important difficulties as:

1. High investment in technologies.
2. Cost of merging AMTs.
3. Lack of local trained labor.
4. Development costs of programs.
5. High loans on capital cost.
6. High maintenance cost.
7. Lack of skilled labors.

Also, Fig. 7 illustrates the least important anticipated difficulties of implementing AMTs. These least important difficulties are:

1. Management resistance to change.
2. Lack of technical support and consultation.
3. Market limited size.
4. Difficulty of implementing AMT in the company.
5. Lack of technical information on AMTs.
6. Worker resistance to change.

However, the index mean value of the all obstacles is 2.71 out of 5.0, which is of low values. This means that the companies have the feeling that these obstacles do not represent a major challenge to change to AMTs

5.3.3. Level of expected benefits when implementing AMT

The surveyed companies are also provided with a list of possible benefits resulting from the implementation of AMT and are asked to indicate the importance at the time of assessment.

Figure 8 shows the ranking of the expected benefits based on the mean score levels. In general, the listed benefits are important or high impartment. The expected benefits which have high level of importance with index value of more than 4 are listed below:

1. Improving product quality and variety.
2. Improving performance of company.
3. Improving competition in international markets.

The expected benefits that have average level with index value of more than 3.5 to less than 4 are:

4. Improving quality.
5. Increasing market shares.
6. Improving competition in local markets.
7. Increasing profitability of company.
8. Increasing productivity.
9. Improving management and control.
10. Decreasing production costs.
11. Decreasing production times.
12. Increasing flexibility of orders fulfillments.
13. Decreasing defects ratios.
14. Increasing manufacturing flexibility and variety.
15. Improving manufacturing & assembly processes.
16. Improving safety standards.
17. Increasing labor utilization.
18. Decreasing marital order times.
19. Providing continuous technical support.

20. Minimizing setup times.
21. Improving skill levels.
22. Decreasing labor hour/product.
23. Increasing interchangeability of labor between machines.
24. Improving standardization level.
25. Reducing work in process inventories.
26. Supporting automation strategies.

The other 18 expected benefits are evaluated as below average. However, the index mean value of the all expected benefits is 3.59 out of 5.0, which is the average. This means that the companies have the feeling that the total expected benefits will achieve benefits on average and represent a major challenge to change to AMTs.

6. Discussion and Conclusions

The findings from the Saudi Engineering Industries survey of practicing business and manufacturing best practices, planning and implementation of AMTs are presented in this paper. The Sector of Engineering Industries in Saudi Arabia takes into consideration the strategic factors when planning for the future.

In general, the strategic issues have high or very high importance in the surveyed companies and these companies are well aware of them.

Best business manufacturing practices have different levels of importance, from one function to another in the surveyed companies. It is noted that the practices related to cost and production operation functions has more importance than practices related to management, marketing and design activities. This indicates that the industries need to develop their management, marketing and design functions to be more competitive to gain initiative and benefits of the business.

The surveyed companies are implementing on average AMTs more related to some high technical and organizational activities such as CAD/CAE, CAD/CAM, MRP, MRPII, and NC. Other very important AMTs have not been well adopted in Saudi Industries, while they are expected to achieve high level of factory characteristics, such as FMS, CIM, cellular manufacturing, CAQ, CAPP, material handling systems, and information technologies. The major difficulties or obstacles to the implementation of AMTs in the considered companies are mainly related to the high investment in technologies, operational costs, and lack of skilled labor. The surveyed manufacturing companies have good understanding about the effect of the AMTs of company performance. Hence, it can be concluded that the implementation of AMTs in Saudi industries is still at early stages and does not take full momentum for development even the surveyed companies expect benefits from using AMTs. They do not feel that they have major difficulties or obstacles challenging the implementation except mainly those of cost and lack of labor skill.

Therefore, the Saudi manufacturing companies require configuring long term strategies which takes into consideration the adoption of AMTs in their different organizational and technical activities.

There is no single best way to become successful AMT companies. More attention must be given to the integration of AMTs in the future of Saudi manufacturing companies. Investment in isolated AMTs such as CAD, CAM, or ERP, for example, which are used as stand-alone technologies, will have limited effects on factory performance. AMTs projects can be started with stand-alone components, but the high level of integration and automation is necessary to gain their full benefits.

The future work of the author is designing a proper methodology for a decision support system (DSS) to help decision makers in Saudi Industries to select the appropriate AMT based on their requirements, future plans, and the collected benefits of AMTs. In addition, this study could be extended to include other sectors of Saudi Industries.

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تقييم تطبيق ممارسات الأعمال وتقنيات التصنيع المتقدمة في الصناعة السعودية

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قسم الهندسة الصناعية، كلية الهندسة، جامعة الملك سعود،
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الكلمات المفتاحية: تقنيات التصنيع المتقدم، تكامل التصنيع بالحاسب، الصناعات السعودية، ممارسات الأعمال، وظائف التصنيع.

ملخص البحث. نظراً للحاجة الماسة لتحسين أداء الصناعة السعودية لتصبح أكثر إنتاجية ومنافسة عالمياً، تقدم هذه الورقة وصفاً لممارسات الأعمال وتطبيق التقنيات التصنيع المتقدمة في الحالة الحاضرة لشركات التصنيع السعودية؛ حيث تم استبيان مستويات تطبيق الأهداف الإستراتيجية الصناعية والممارسات الحالية للوظائف الصناعية الفنية والتنظيمية المختلفة ومدى تطبيق تقنيات التصنيع المتقدمة والفوائد المتوقعة عند تطبيقها ومعوقات التطبيق. وأوضحت نتائج الاستبيان أن الشركات التي تم استبيانها على دراية جيدة بإستراتيجيات التصنيع وأفضل الممارسات هي ممارسات وظائف التكلفة وعمليات الإنتاج، بينما الوظائف المتعلقة بالتسويق وتصميم المنتج والإنتاج أقل ممارسة. إضافة إلى ذلك فإن الشركات عند تطبيق تقنيات التصنيع المتقدمة تمارس التقنيات المتعلقة بالتصميم والتحليل الهندسي والإداري وتخطيط موارد المواد المساندة بالحاسب أكثر من التقنيات المتعلقة بالتكامل الصناعي والتصنيع المرن وتخطيط الموارد الصناعية وتخطيط عمليات التصنيع المساندة بالحاسب وتقنية المعلومات وغيرها من التقنيات؛ ولذا فإن تطبيق تقنيات التصنيع المتقدمة ما تزال في مراحلها الأولية ولم تأخذ الزخم الكامل للتطوير لتحقيق الفوائد المتوقعة من استخدام التقنيات المتقدمة كما تراها الشركات. وتشعر هذه الشركات بأنه ليس هناك صعوبات أو عوائق كبيرة في تطبيق التقنيات المتقدمة سوى ذلك المتعلقة بالتكلفة ونقص المهارات المكتسبة للعاملين.