Integrated decision making and optimization model for robot technology from planning to implementation

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Abstract: Advanced Manufacturing Technology (AMT) plays a major role in quality and flexibility improvements in Small and Medium Enterprises (SMEs). Advanced manufacturing technologies provide a great potential for improving manufacturing performance to compete in the global markets. Proper decision making in pre-implementation and implementation of Robot technology as one of the types of AMT plays an important role in the success of its implementation. A robot Decision Support System (DSS) which is included of two main parts is proposed to facilitate the proper decision making. The first part, decision making model, can support companies in pre-implementation by providing models for successful implementation prediction, robot selection and robot supplier selection. The second part, Optimization model, can support companies in implementation by providing robot-based assembly line balance & sequencing optimization.

Keywords: Advanced Manufacturing Technology (AMT), Small and Medium Enterprises (SMEs), Decision Support System (DSS)

1 INTRODUCTION

Advanced Manufacturing Technology (AMT) plays a major role in quality and flexibility improvements of Small and Medium Enterprises (SMEs). Since 1980s, firms have introduced and implemented Advanced Manufacturing Technology (AMT) to improve profits and competitive advantages. Apparently, the purpose of implementation of AMT is to achieve technical ability and market profits, but the appliance level and implementation effects of AMT are not perfect (Friscia, 1990). The implementation of Advanced Manufacturing Technology (AMT) requires not only substantial investment in the technology, but also changes in the culture and organizational structure of the organization. It requires careful planning at all levels of the organization to ensure that the implementation will achieve the intended goals. It is a complex process with many factors to be considered before the full benefits of AMT can be realized (Yusuff, Yee, and Hashmi, 2001). The statements of the problems for AMT success implementation are, high costs of purchasing a new robot technology from one side, finding the potential of the companies in applying new robot technology from the other side, highlights the need for a predictor on the success or failure of the robot technology to be implemented. Different types and categories of robot technologies in today’s market make it difficult to select among them. Additionally selecting the robot technologies suppliers among large number of suppliers is a cumbersome and complicated task for managers. Even though after predicting the success of the new robot technology, selecting that new robot technology and its supplier, still in order to implement the new robot technology it must adapt to existing system. This adaption makes a new problem in balancing it in existing production line. Three main parts of AMT are
included: Pre-implementation, Implementation and, Post-implementation. For successful implementation in SME companies decision maker needs, in pre-implementation part, predict the percentage of implementation success probability, selecting the robot technology and selecting robot technology supplier. In implementation part managers need to adapted robot technology with existing system and re-balance the line. Figure 1 illustrates the integration frame work, the first part decision making model, can support three parts of pre-implementation such as: successful implementation prediction for robot technology, robot technology selection and robot technology supplier selection. The second part, optimization model, can support Robot assembly line balancing problem (RALBP). Hundreds of authors have already investigated about Advanced Manufacturing Technology (AMT) prediction model, Technology selection, Technology supplier. However, none of them has explained how to combine these concepts is able to predict AMT implementation, select technology and select technology supplier, also none of the have explained how to combine these concepts specific for the robot.

Figure 1: Conceptual frame work

Pre-implementation leads to AMT selection which is categorized into Hard and Soft AMT. The latter leads to integrated systems, branching into: Logistic related technology, Computer integrated manufacturing, and flexible manufacturing technology. Hard AMT has two parts: Intermediate which is Automated Inspecting, and Material handling, where as Stand Alone is divided into: Design and Engineering, and Machining – fabricating and assembly. All the above sub-divisions have their own abbreviations, as indicated in Figure 2. Of the above, the intermediate sub-divisions are: AITS; and ASRS/AMHS, while far stand alone, CAPP and CAD, for Design Engineering, and MWL, NC/CNC and Robot for Machining-fabricating and assembly. Robots are classified into: Small, Low pay load, medium pay load, High pay load and heavy duty; with ramify in variety of robots 1… (n).

Figure 2: Classification of a different kind of AMT specific Robot
Industrial robots are increasingly used by many manufacturing companies. The number of robot manufacturers has also increased, with many now offering a wide range of robots (Khouja & Booth, 1995). Robots are now used in many industrial applications, such as assembly, finishing, machine loading, material handling, spray painting, and welding (Khouja & Booth, 1995).

The word ROBOT was coined in 1920 by the Czech author K. Capek in his play Rossum's Universal Robots; it is derived from the Czech word robota, meaning “worker”. An industrial robot is commonly defined as a reprogrammable multifunctional manipulator, designed to move materials, parts, tools, or other devices by means of variable programmed motions, and to perform a variety of other tasks. In a broader context, the term robot also includes manipulators that are activated directly by an operator (Raoa, 2006). As Robots are expensive, an investment in robot system and the selection process is an important function for many advanced manufacturing companies. Improper selection of robots will adversely affect a company’s competitiveness in terms of productivity of its facilities and quality of its products (Goh, 1997). Thus for the sake of improving efficiency and quality and at the same time for performing repetitive, difficult and hazardous tasks with total precision, many manufacturers use robots extensively (Parkan, 1999). There are more than 90 robot manufacturers and some 200 different robot styles have been reported in U.S.A. (Wang, 1991). Robotic selection, being an important, as well as, ambiguous and crucial task in today’s highly competitive environment, robot technology ranking tool is very important to the success of any company. The decision to select which robot is made more complex because robot performance is specified by as many parameters as there is robot as yet there is no industry-wide standards. Ranking robot technology, have varied strengths and weaknesses, requiring careful scrutinizing in their assessment. However it helps decision makers to select the ideal one among a vast source of evolving robot technologies (Farzipoor Saen, 2006). Advanced Manufacturing Technology (AMT) and supplier selection (SS) of new technology has become one of the most important issues in group decision-making. The benefit of the AMT model is reduced new product design lead time, increased customer service and reduced overall setup time. The importance of the Supplier Selection (SS) model is to select a suitable supplier's new technology which considers both quality and quantity criteria. The world of business is changing rapidly. The winds of globalization have pushed SMEs to grapple with the changing needs of their customers. The customer of the 21st century demands products and services that are fast, right, cheap and easy. AMTs have been heralded as a new way for manufacturing companies to gain a competitive advantage. One of the ways by which SMEs can achieve a competitive advantage in manufacturing is through the implementation of AMT.

The significance of this research is to propose combine robot technology model from planning to implementation for SME companies. The benefit of the AMT model is increase the success probability in implementation, and reduces overall technology setup time with optimizing the product cycle time, which is to be performed by precise computer programming and simulating.

2 LITRUCHER REVIEWS

Since the arrival of many AMTs in the 1980s, there has been a slowly rising tide of research into their successful implementation. Voss (1985) and Chen (1994) studied various companies that implemented shop floor automation and found that top management support, vendor relationships, product-process dependence, employee participation, and manufacturing strategy were key reasons for AMT success. In recently research, Hofmanna and Stuart (2005) studied the average time taken to implement Advanced Manufacturing Technology (AMT) investment and the benefits provided by AMT investments to large German manufacturers. The findings of this research have, the respondents typically took between 3 and 12 months before making the final decision to invest, irrespective of the department generating the idea for the AMT and a further six months to implement the AMT.

The objective of a robot selection procedure is to identify the robot selection attributes, and obtain the most appropriate combination of the attributes in conjunction with the real requirements. A robot selection attribute is defined as a factor that influences the selection of a robot for a given industrial application. These attributes, which are objectively and subjectively considered, are presented in Table 1. The
objective criteria are: Velocity, Load capacity, Repeatability, Purchases cost, and Manipulator reach, whereas the Subjective ones are: Reliability, programming Flexibility, and man–machine interface.

Table 1: Explanation of Robot selection factors

<table>
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<tr>
<th>Criteria</th>
<th>Criteria Explanation</th>
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<tr>
<td>Velocity</td>
<td>• Which is the maximum speed a robot’s arm can achieve. • How fast the robot can position the end of its arm. This may be defined in terms of the angular or linear speed of each axis or as a compound speed i.e. the speed of the end of the arm when all axes are moving. • This is measured in m/second or inch/second and indicates the quickness of response. • Often enough a Robot is fuzzily described as being _fast’ or _slow’ on the shop floor. • Which is the maximum weight a robot can lift?</td>
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<tr>
<td>Load capacity</td>
<td>• This is measured in kg or lbs and is defined as the operating range (or limit) of the Robot payload capacity. • Often enough a Robot is fuzzily described as being capable of handling _heavy’ or _light’ loads. • Which is a robot’s ability to repeatedly return to a fixed position? The mean deviation from that position is a measure of the robot's repeatability. • How well the robot will return to a programmed position? This is not the same as accuracy. It may be that when told to go to a certain X-Y-Z position that it gets only to within 1 mm of that position. This would be its accuracy which may be improved by calibration. But if that position is taught into controller memory and each time it is sent there it returns to within 0.1 mm of the taught position then the repeatability will be within 0.1 mm. • This is measured in ± mm or ± inch and is defined as the measure of the ability of a Robot to return to the point of reference (or command) repeatedly.</td>
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<td>Purchase Cost</td>
<td>• The cost of a robot includes its purchase, installation, and training costs. • An industrial robot is comprised of a robot manipulator, power supply, and controllers. The robot manipulator can be divided into two sections, each with a different function: ✓ Arm and Body - The arm and body of a robot are used to move and position parts or tools within a work envelope. They are formed from three joints connected by large links. ✓ Wrist - The wrist is used to orient the parts or tools at the work location. It consists of two or three compact joints.</td>
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<td>Mane-Machine interface</td>
<td>• This is the probability that a robot will perform its specified mission according to stated conditions for a given time period. • The setup or programming of motions and sequences for an industrial robot is typically taught by linking the robot controller to a laptop, desktop computer or (internal or Internet) network.</td>
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<td>Programming Flexibility</td>
<td>• Flexible programming software: The computer is installed with corresponding flexible interface software. The use of a computer greatly simplifies the flexible programming process. Specialized robot programming software is run either in the robot controller or in the computer or both depending on the system design. • Programming flexibility refers to the robot's ability to accept different programming codes.</td>
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<td>Man-Machine interface</td>
<td>• User friendliness of the user interfaces to the new system determines the degree of the acceptance of operating staff to related Robot technology.</td>
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Table 2 illustrates ten studies, on tangible and intangible critical success factors for robot selection between years 1988 to 2008. The summary of the studies is as follows: A decision making algorithm, using utility theory for the selection and evaluation of robots, for electronics assembly, was developed by Nnaji et.al.,(1988) choosing: velocity (m/s), load Capacity (kg), repeatability Error (mm) and reliability (R) as the critical success factors. A decision support system, applying fuzzy set method for robot selection was presented by Wang et.al., (1991). The system uses marginal value functions with objective factors: (load Capacity (kg), repeatability Error (mm) and purchase Cost ($)), and a subjective factor (programming Flexibility). A two-phase robot selection model, involving data envelopment analysis application (DEA) in the first phase, and a multi attribute decision making model in the second phase was presented by Khouja and Booth (1995) with the objective criteria: Velocity (m/s), Load Capacity (kg), Repeatability Error (mm) and Purchase Cost ($). Another research by Khouja and Booth, (1995), use the same criteria with a computerized Fuzzy Clustering Procedure for selecting robots from twenty seven alternatives. Analytic Hierarchy Process (AHP) method was employed for robot selection: Velocity (m/s), Load Capacity (kg), Repeatability Error (mm) and Purchase Cost ($) as objective factors by Goh (1997). A decision making and performance measurement model with applications to robot selection was presented by Parkan (1999). Particular emphasis was placed on a performance measurement procedure called operational competitiveness rating (OCRA) and a multiple attribute decision making method,
TOPSIS. The final selection was made on the basis of rankings obtained by averaging the results of 
OCRA, TOPSIS, and a utility model. For this purpose the criteria weightings factors of Velocity (m/s), 
Load Capacity (kg), Repeatability Error (mm) and Purchase Cost ($) were applied. Bhangale e.t al. (2004) 
listed a large number of robot selection attributes, and ranked the robots using TOPSIS and graphical 
methods, comparing the rankings given by these methods. However, the weights assigned by the authors 
to the attributes were not consistent. The criteria used are Velocity (m/s), load capacity (LC), 
Repeatability Error (RE), and Manipulator reach (mm). A decision making model, using Fuzzy AHP 
theory for the selection and evaluation of Robots, was developed by Kapoor (2005) based on Velocity 
(m/s), Load Capacity (kg), Repeatability Error (mm) and Purchase cost (PC). A methodology based on 
digraph and matrix methods for evaluation of alternative industrial robots was proposed by Rao and 
Padmanabhan (2006), using Velocity (m/s), load capacity (LC), Repeatability Error (RE), and Purchase 
Cost ($) criteria factors. A robot selection index was proposed that evaluates and ranks robots for a given 
industrial application. The index was obtained from a robot selection attributes function which was in turn 
obtained from the robot selection attributes digraph. The digraph was developed based on robot selection 
attributes and their relative importance for the application considered. Technology ranking based on DEA 
method, and tested with numerical example was suggested by Farzipoor Saen (2006) using the objective 
criteria factors of Velocity (m/s), Load capacity (LC), and Purchase Cost ($) with alternative 27 Robots. A 
review, comparing objective criteria factors of Load capacity (LC), Repeatability Error (RE), and 
Purchase Cost ($) with subjective factors Programming Flexibility and Man-machine interface was 
conducted by Rao and Venkata (2007) to analyze a variety of methods. Fuzzy Analytic Hierarchy Process 
(FAHP) based on the objective criteria factors Load capacity (LC) and Purchase Cost ($) was developed 
by Anand et.al. (2008) to select an ideal robot system.

Table 2: Critical success factors for Robot selection

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<tr>
<th>Tangible factors (Objective)</th>
<th>Intangible factors (Subjective)</th>
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keys:
1. Velocity (m/s) = (V) 4. Purchase Cost ($) = (PC)
2. Load Capacity (kg) = (LC) 5. Manipulator Reach (mm) = (M)
3. Repeatability Error (mm) = (RE) 6. Reliability = (R)
7. Programming Flexibility = (PF)
8. Man-machine interface = (MI)

3 METHODOLOGY

The integration of predict of robot implementation success, selecting the robot technology and selecting 
robot technology supplier is becoming Multiple Criteria Decision-Making (MCDM) problem. A MCDM 
problem is affected by several conflicting factors so a decision maker must be able to analyze the trade off 
among the several criteria. MCDM techniques support the decision-makers (DMs) in evaluating a set of 
alternatives. The Fuzzy can be very useful in involving several decision-makers with different conflicting 
objectives to arrive at a consensus decision. The objectives and scope of this project were formulated 
followed by detailed literature review related to Advanced Manufacturing Technology (AMT). In order to 
simulation for this research comply with collecting quantitative and qualitative data, a basic steps are 
going to be used to insure successful implementation.
Step 1: To develop robot technology implementation prediction model.
Step 2: To develop a robot technology selection model.
Step 3: To develop a robot technology supplier selection model.
Step 4: To develop a robot assembly line balancing optimization model.
Step 5: Developing the Software with C++ programming.

Objective of these models is replying to these questions?
- “Whether Robot technology implementation will be successful or not?”
- “Which kind of Robot technology is suitable to be selected?”
- “Which Robot technology supplier is suitable for purchasing?”
- “How can Robot adapt to existing system and the new production line be balanced?”

According to the five steps in above, to achieves the developing module in each step, identify criteria for AMT (4 module) and required data was collected based on the consideration of literature. Developing the new model is need to selects firms with AMT implementation from the Malaysian manufacturing. This study adopts for collect data apply of questioner and interviews. To analysis and simulating the data applies C++ programming. Senior managers or supervisors with responsibility to fill the questionnaire. Finally interviewed and tested the software is required.

4 CONCLUSIONS

An attempt has been made in this paper to present a conceptual model for the pre-implementation and implementation of AMT in SMEs. The significance of this paper is proposing an integrated decision making and optimization model for robot technology from planning to implementation for Small and Medium Enterprise (SME) manufacturing companies. The Fuzzy and Genetic Algorithm (GA) approach are proposed to develop this model.

5 REFERENCES