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THE ISSUES FOR THE IMPLEMENTATION OF RECONFIGURABLE MANUFACTURING SYSTEMS IN SMALL AND MEDIUM MANUFACTURING ENTERPRISES

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ABSTRACT

Reconfigurable manufacturing system (RMS) is a new manufacturing paradigm to address fast changing market and mass customisation. The adoption and implementation of RMS involves major investment that needs considerable attention. Therefore, issues influencing RMS implementation should be generated to address properly the milestones. This paper focuses the study on the implementation of RMS in small and medium manufacturing entreprises (SMMEs). In this paper, the result of study from three sources is discussed. First, SMMEs characteristics which show general performance of SMMEs as well as the SWOT analysis. Second, recommendations from survey studies of the implementation of advanced manufacturing technology (AMT) in SMMEs. Third, general approaches for the justification of AMT. Based on these sources, the issues are grouped into five categorises, i.e. performance measurement, strategic issues, economic issues, technological issues and operational issues.

Keywords*: reconfigurable manufacturing systems, advanced manufacturing technology, implementation, SMMEs*

INTRODUCTION

Manufacturers have been challenged with customised market requirements. Developments on product design, information technology and supply chain management enable customers to order products with individual specifications as needed. This trend first emerged in personal computer industries, such as Dell and IBM. Berman (2000) reported that Dell manufactured their products based on orders from customers with different specifications for each customer. Following the trend, other industries such as car manufacturers, clothing, eyeglasses and farm machinery also produced more product varieties to meet customers' orders. Customers' unique requirements have changed manufacturers' practices, from producing large volumes of products in mass production to personalised demand fulfilment in mass customisation. Consequently, improvements of methods to manufacture mass customised products effectively became essential.

Koren et al. (1999) proposed a novel manufacturing paradigm, namely rconfigurable manufacturing systems (RMS), as the solution to address the limitations of the existing systems. The RMS has the ability to reconfigure its components to adapt to changes in the market environment. The reconfiguration will enable rapid adjustments of production capacity in response to the fluctuation of customer demands. Moreover, the system allows quick adaptation of functionality changes as and when needed. It is also designed to be upgraded simply by adding new technologies to gain better performance.

All manufacturing industries are facing the same conditions, not only large manufacturers but also small and medium manufacturing enterprises (SMMEs). The reason is that many SMMEs play a role as an ancillary industry for large companies. Indeed, SMMEs become subcontractors to produce parts and components for large companies' main products which are not produced internally in their plants. Since SMMEs have limited resources and peculiar manufacturing environments, a general approach to implement RMS in SMME may not be achievable. Therefore, a study to generate what issues should be addressed for the introduction and implementation of RMS in SMME is needed. This paper is therefore focused on generating the issues to cover the milestones when introducing RMS to SMMEs. The main goal is to enable an SMMEs to possess a responsive manufacturing system in unpredictable market changes. As a result, SMMEs will be able to produce a large variety of products with fluctuating demand in cost-effective ways, providing high quality products and better services to customers.

However, SMMEs often find difficulty to compete with large enterprises due to insufficient resources. To achieve more competitive advantages, they need to improve their manufacturing ability by

adopting new technologies such as RMS. In order to conceptualise this need, the issues faced on the implementation of RMS have to be identified first. This paper, therefore, discusses what issues should be addressed to implement RMS.

LITERATURE REVIEW

Reconfigurable manufacturing has gained more attention as a priority area in manufacturing research. RMS has ability to reconfigure its components to adapt to changes in the market environment. The reconfiguration enable rapid adjustments of production capacity in response to the fluctuation of customer demands. Moreover, the system allows quick adaptation of functionality changes as and when needed. It is also designed to be upgraded simply by adding new technologies to gain better performance.

Five key characteristics of RMS are established to achieve the desired aims. There are: (1) modularity (2) integrability (3) diagnosability (4) customisation and (5) convertibility (Koren et al., 1999; Mehrabi et al., 2000; Inman, 2006). The first three are aimed at reducing time and effort, while the other two are aimed at reducing cost.

Modularity is the ability of RMS to enable adding and removing of the components required to perform a specific process by means of a product family. Therefore, an RMS consists of modular components.Integrability is the ability of RMS components to be integrated, both machine modules and control software. As RMS consists of modular components, machine modules and the software controllers are designed with an interface to enable integration. Diagnosability is the ability of RMS to identify predictable and unpredictable errors and problems regarding quality and reliability issues. For example, changes in machine hardware or program software should be monitored in real-time to avoid errors. Convertibility is an RMS ability to adjust its function rapidly between production batches including changes in tools, fixtures, materials to process and the software.

An RMS consists of reconfigurable machining tools (RMT), reconfigurable controllers (both hardware and software). Some of them are supported by reconfigurable inspection machine (RIM), reconfigurable assembly system (RAS) and reconfigurable material handling system (RMHS) as technology enablers. In addition, RMS operations begin with grouping parts/products into their corresponding families, then configuring or reconfiguring the system (both mechanical hardware and control software) and managing its capacity. From the concept of RMS, other supporting systems are developed such as changeable manufacturing, reconfigurable process planning, reconfigurable supply chain management and reconfigurable manufacturing execution systems.

The main benefit of RMS is its ability to adapt quickly to unpredictable market changes of various production requirements in a cost effective way. An RMS combines the benefits of a dedicated manufacturing system (DMS) to produce a specific part and a flexible manufacturing system (FMS) to produce a large variety of parts. An RMS is installed where exact production capacity and functionality is needed and it allows for changes in the future. Expandable capacity enables RMS to adapt quickly with fluctuation in demand. On the other hand, adjustable functionality enables the production of many product varieties in the same system. Accordingly, RMS is expected to have cheaper production costs than FMS or DMS.

Improvement on communication technology and networking facilities has encouraged SMMEs to enlarge their operation from traditional orientation, which focuses on local market, to global market. In fact, SMMEs play an important role for economic development in many countries. They succeed by providing high levels of responsiveness and personalised service. Additionally, they offer lower priced products compared to other large enterprises. This is because SMMEs have less overhead and located closer to the market (Raymond, 2005).

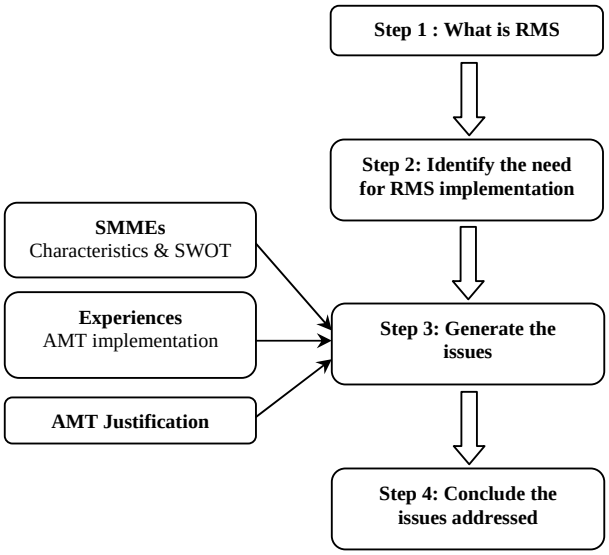
Mass customisation and rapid changes of market conditions further accentuate the need to improve manufacturing systems to adapt quickly to the challenges. The systems must combine cost-saving efficiencies in mass production and more value-added products for specific customers. Current manufacturing systems, such as cellular manufacturing systems (CMS), DMS and FMS, all have limitations in response to the above conditions. The current manufacturing systems take a long time to be modified when changes are required. For these reasons, a new manufacturing system which provides fast changing of its system should be developed, i.e. RMS. RMS in industries will attain significant competitive advantages when the systems are impemented properly. However, the adoption and implementation of this system involves major investment that needs considerable attention from all department levels within a company.

RESEARCH METHODOLOGY

Figure 1 shows the flowchart of methodology used in this research. In order to generate what issues should be addressed, four steps are arranged. The first step is to answer the main question “What is

RMS?", therefore RMS concept and its benefits will be described. The second step is to identify the need for RMS implementation. The purpose of this step is to specify whether a SMME is critical to implement RMS or not. The third step is to generate what issues should be addressed prior to implementation of RMS. For this purpose, three main sources in the literature are explored. Those sources are SMME characteristics including the SWOT analysis, recommendation from several survey studies of AMT implementation in SMME, and AMT justification methodologies. In this paper, those three groups of sources are discussed further. Finally, the issues on the implementation of RMS in SMMEs are concluded.

This research is conducted mainly based on the study of literature. The literature is used to collect findings on the development of the RMS concept and advanced manfacturing technology (AMT) implementation.



Research methodology

RESULTS

Step 1 and Step 2 of the research methodology have been discussed on the previous sections. This section discusses Step 3 how the issues are generated and Step 4 the conclusion of what issues should be considered on the implementation of reconfigurable manufacturing systems in small and medium manufacturing enterprises.

The issues influencing RMS implementation generally are similar to the issues on AMT implementation. In order to generate issues facing RMS implementation in SMMEs, results from previous studies available in the literature regarding SMME are explored. First, the literature on SMME characteristics in general, such as lack of financial support and technology, is discussed. Second, literature on AMT implementation, including surveys on the implementation of AMT in three different countries is examined; as is, finally, literature on justification approaches and techniques for AMT implementation. The next parts discuss further each of these sources.

SMME characteristics

The competition in global markets has motivated SMMEs to offer better performance and better service to customers by providing high quality products at affordable prices. Their managerial culture and manufacturing systems have gained more attention and become a focus of research in literature. However, many SMMEs still perform in terms of traditional characteristics. Garengo et al. (2005) reviewed SMME characteristics that have been identified by many authors. Some of those characteristics are briefly described below.

- Lack of human resources
  The number of people working in an SMME is strictly limited. Almost all employees are busy with their own daily activities and have no extra time for additional work. Consequently, it is difficult to focus on developing ideas for improvements including AMT implementation.

- Lack of managerial capacity and formalized management
  Many SMMEs are operated by nature. They have no formal managerial systems or tools. In fact, some employees occupy different positions with different responsibilities involved at the same time.
- Limited capital resources
- Reactive approach
  Many SMMEs do not apply good strategic planning. They are run by nature and are reactive to market, with a short-term orientation.
- Lack of performance measurement
  Many SMMEs are not aware of the importance of measuring performance to evaluate and improve their competitiveness.

Beside these characteristics, a SWOT analysis of SMME as described in Table 1 also shows the nature operations of SMMEs. Many SMMEs are still described by the characteristics listed above; therefore, when implementing RMS as advanced systems, these characteristics should be considered.

SWOT analysis of SMMEs
(Dangayach&Deshmukh, 2001)

STRENGTHS	**WEAKNESSES**
• Flexibility to absorb new technology, new processes and new design with minimal cost • Quick decision making due to minimal layer in management • Favourable capital output ratio, low level capital per unit output • Close relationship and cooperation amongst manager and employees	• Lack of advanced technologies due to lack of funds • Lack of infrastructural analysis • Lack of financial strength and depend largely on the bank for finance.
OPPORTUNITIES	**THREATS**
• The role as ancillary industry for large companies • Interaction and partnership with global companies	• Acquisition and merger of large companies that may affect SMME business • Government policies and global competition may threaten their existence

AMT adoption in SMMEs

Many researchers have proposed approaches to adopt advanced manufacturing technologies which can be implemented in SMMEs. These systems include concurrent engineering (Usher, 1996), computer integrated manufacturing (CIM) (Marri et al., 1998; Vassel, 1999) cellular manufacturing (Boughton&Arokiam, 2000), flexible manufacturing systems (Petroni&Bavilacqua, 2002), advanced engineering environment (Fenves et al., 2003), and advanced manufacturing technology (Thomas, et al., 2008). Each researcher has proposed a particular approach to enable different systems implementation. However, they have adopted a general approach concerning SMME limitations. To explore the results found from these studies, a few of the studies are presented below.

Marri et al. (1998) studied the implementation of CIM in SMMEs. The requirements for CIM implementation are to computerize a product design using computer aided design (CAD) system and to integrate it with computer aided manufacturing (CAM). The managers of SMMEs believe that implementing CIM will improve their ability to face growing international competitive pressure, but the study found that SMMEs frequently lack strategies, expertise, capital and time to upgrade their manufacturing operations. Also, many SMMEs lack capability and face problems in implementing better quality control, improving workforce training and introducing new technologies and methods. The reasons for this are:

- Lack of top management support and skills available in CIM
- No support systems for system integration
- No strategic alliances and networking between government, universities, and SMMEs
- Lack of a long-term relationship between SMMEs and large-scale industries.

- Lack of a framework on the size, modularity and low-cost solution for a successful implementation of CIM

Other researchers, Thomas et al. (2008), Marri et al. (2007), and Raymond and Croteau (2006) studied the AMT implementation in SMMEs. They studied the trend of AMT implementation in UK, Pakistan and Canada respectively.

Thomas et al. (2008) performed a research survey with 300 SMMEs in the UK. The industries varied from aerospace industries to automotive, medical, electronics and construction. They found that 8% of the surveyed industries had implemented AMT but not in a structured manner and without an adequate planning process prior to the introduction and application of AMT. In addition, they also identified lack of top management commitment. Therefore, they developed a technology implementation model which focused on technology selection, purchase and implementation.

Marri et al. (2007) emphasized the role of top management in the implementation of AMT in SMMEs. They studied 24 SMMEs located in the Province of Sindh Pakistan. They found that lack of technology initiatives; time, money and support in upgrading their manufacturing operations were the problems in AMT adoption; most of the companies spent less than 1% of their total revenue on research and development. They also emphasised the importance to consider human factors in AMT implementation, including employee education and training to give them a deeper understanding of the principles and the benefits of AMT. In addition, motivation through incentive schemes, workplace safety, convenience and ergonomic tools were also significant in AMT implementation.

Raymond and Croteau (2006) performed a survey study of 248 Canadian SMMEs. Its aim was to assess the alignment between AMT implementation and business performance in terms of network, product and market development. They indicated the importance of product innovation and shifting business from local orientation to world-class SMMEs through market expansion and network extension.

Those main findings and recommendation for AMT implementation based on the survey studies described is included to generate the issues for RMS implementation in SMMEs.

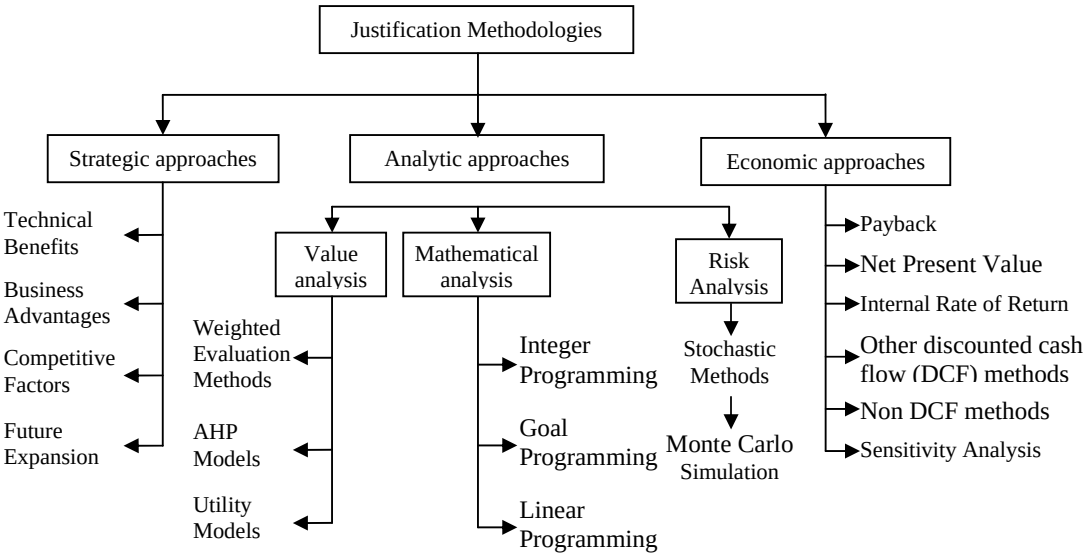
Justification approaches for the implementation of AMT

Each company uses a different approach to justify its new technology investment. Investment evaluation methods become a crucial for manufacturing firms to improve competitiveness in global markets. Many researchers have identified and discussed issues regarding the implementation of AMT (Thomas et al., 2008; Sambasivarao&Deshmukh, 1995; Small &Yasin, 1997) and integrated them through a conceptual framework. It is a well known fact that implementing AMT is a challenge as it needs high investment. Manufacturers should pay attention to the issues and problems regarding the implementation to avoid faulty operations and exceeding capacities.

To identify the factors influencing AMT implementation decision, the recommendations and results from previous studies are presented. Meredith & Suresh (1986) categorized justification approaches of investment in new manufacturing technology into three groups: economic, analytical and strategic. Other researcher proposed integrated approaches by considering multi-criteria decision making.

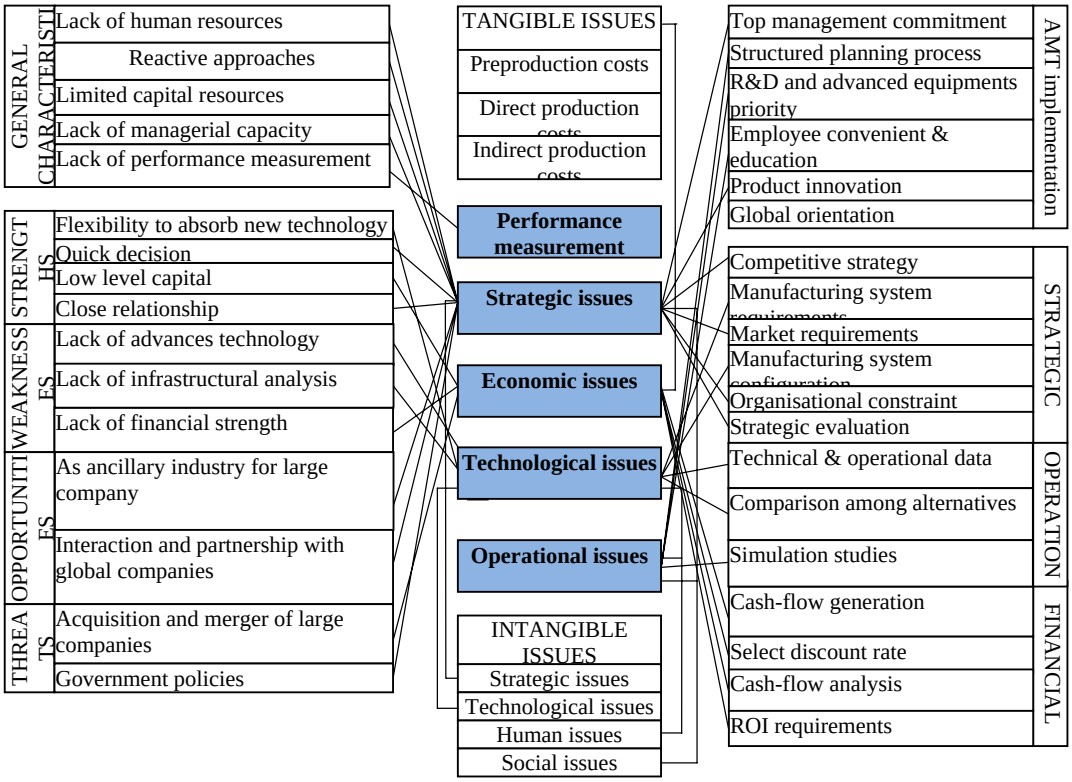
Raafat (2002) provided a comprehensive bibliography on justification techniques in investment of new manufacturing systems. He cited 231 articles published mainly between 1990 and 2001 and only some of them selected from articles prior to 1990. Naik and Chakravarty (1992), Chan et al. (1999) and Nagalingam and Lin (1997) have summarised the justification approaches and methodologies in AMT investment appraisal. Figure 2 illustrates the AMT justification methodologies summarised by Nagalingam and Lin (1997).

Another researcher, Sambasivarao and Deshmukh (1995), classified the AMT implementation issues into two main categories: tangible attributes and intangible attributes. Tangible attributes are quantifiable factors that can be analysed using economic calculation and represented as cost-borne figures. They include pre-production costs, direct costs and indirect cost. In contrast, intangible attributes are non-quantifiable factors that cannot be represented in figures but can be analysed using multi-attribute decision making. These attributes include strategic issues, technological issues, human issues and social issues.



AMT Justification methodologies

After the discussion of each sources on step 3, the next step is to find the general terms of the issues and linkage the main points or attributes adrressed on each sources into corresponding issues. Based on the literature study above, the terms used for the issues in RMS implementation are categorized into five main issues: (1) performance measurement, (2) strategic issues, (3) economic issues, (4) technological issues, and (5) operational issues. Finally, the attributes and their corresponding issues are shown in Figure 3.



Issues for RMS Implementation

CONCLUSION

This paper focuses on generating the issues considered in the implementation of RMS in SMMEs. The issues are generated from three sources. First, SMMEs characteristics which show general performance of SMMEs as well as the SWOT analysis.Second, recommendations from survey studies of the implementation of AMT in SMMEs. Third, general approaches for the justification of AMT. Based on those sources, then the issues are categorized into five main issues: performance measurement, strategic issues, economic issues, technological issues and operational issues.

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