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A Systems Approach for the Effective Adoption of Rapid Prototyping for SMEs

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Abstract

Rapidly changing global markets, unprecedented increase in product flexibility requirements and shorter product life cycles require more efficient technologies that can help reduce the time to market, which is considered to be a crucial factor to survive in today's highly volatile market conditions. Rapid prototyping technology (RPT) has the potential to make remarkable reductions in the product development time. However, its fast development pace combined with increasing complexity and variety has made the task of RPT selection difficult as well as challenging. This paper presents a conceptual framework that will facilitate a systematic selection and adoption of the RPT from strategic to operational level. The proposed framework will help the companies, especially SMEs, to make more realistic and economical decisions on the selection and adoption of the right RP technology.

Keywords: Rapid prototyping, technology adoption, SMEs

1. Introduction

The changes in the global economic scenario have posed considerable threats to many companies, especially SMEs to stay competitive in world markets. This change in paradigms demands more flexibility in product designs. These challenges combined with increased variety and very short lead time have a great impact on the business of small to medium companies in securing a significant proportion of markets in which they operate. The conventional approaches and technologies are struggling to meet the business needs. Consequently, the manufacturers are searching for more efficient technologies, such as rapid prototyping that can help embrace the challenges. A critical activity for the small companies is the decision-making on the selection and adoption of these advanced technologies. The SME's task becomes more difficult because of the absence of any formal procedures [1] . An advanced technology can be a great opportunity for a business but it can also be a threat to a company. A wrong alternative or too much investment in the right one can reduce the competitive advantage of a company[2]. The changing picture of the competition requires synchronization between business and new trends, which demands unique and effective solutions. These solutions should be designed by keeping in view the specific nature of SMEs and ought to be simple, comprehensive and more practical to support them so that they remain an effective part of the global value chain.

Technology selection is concerned with the selection of the best technology among a number of alternatives, leading to complex decision making due to increased complexity and range [3]. Selection of the technology on the basis of technical parameters only can limit the effectiveness of the adoption as the selected technology will have a direct impact on different business functions. Therefore, the link between technology and business functions must be considered carefully before selecting a particular option. The situation poses more difficulties when the decision-makers find themselves unable to integrate the theory and practice because they lack the ability to match their exclusive problem with the applicable theory to devise an effective solution [4].

This paper contributes to the engineering profession by proposing a new system based approach for the adoption of RP technology for small to medium companies. The proposed approach is an integrated adoption model, which links the selected technology with all business functions of the company to ensure an effective and more realistic decision. It systematically identifies the issues and challenges, and then combines the technology drivers with the business functions for a seamless technology penetration.

2. SMEs Role and Issues

The strategic importance of small and medium enterprises in the development of the economy is widely accepted in both developing and developed countries [5]. The SMEs play an important role in the development of national economy of any country. UK economy is 99 % SMEs, so out of the 4.8 million UK businesses less

than 1 % are large corporations i.e., corporations with over 250 employees [6]. The share of SME employment accounted for 70% of total employment and the product share for over 46% in South Korea [7]. In Malaysia, SMEs accounted for about 48% of manufacturing establishment [8]. There are about 118,648 SMEs in Thailand representing around 98% of the total firms in manufacturing sector [9]. China is fast becoming the largest economy in the world and SMEs are key element in China's economy accounting for 99% of total number of firms and 69.7% of overall employment [10]. The above statistics clearly shows the role of SMEs in the economy of the country and their contribution in labor absorption, poverty alleviation and revenue generation.

2.1 Management Issues

It is imperative to consider the unfolding dimensions of the SME infrastructure before moving into any technology related issues. The main reason is that any solution suggested may lose its effectiveness if made without considering the environment in which they are going to be implemented. This is particularly important for SMEs as they differ from that of large companies in many respects and any solution designed for large companies may not fit to the small companies [11]. There are number of reasons for that; (a) Education level at SMEs is very low (b) Most managerial positions are acquired based on experience and they often lack professional qualifications (c) R&D culture is absent due to financial constraints [12]. Most of these issues are common in many countries. In Malaysia, management abilities, R&D and technological capability in particular are constraints on innovation and high value added activities in small and medium sector [13]. SMEs in Korea are economically weak units facing lack of technical competitiveness, money, skilled labor force, management and market awareness [8]. Management problems in SMEs are largely due to the fact that many of their entrepreneurs lack high levels of education and professional training and they perform poorly in many areas of production and quality control [5] .

2.2 Technical Challenges

Emerging technologies and markets present tremendous challenges and opportunities to firms seeking a competitive edge from them [14]. Design and development of the products is one of the critical activities, which largely determine the success and position of the company in the market. A typical product development cycle is shown in Figure 1, where the prototyping is placed at the heart of the complete cycle. This is a gateway to the customers and manufacturing at the initial stage and requires several iterations before the formal manufacturing can be started. A greater control and success at this stage ensures not only a satisfied customer with all the requirements incorporated but also reduces reworks and time to market at later stages. Compression of time with complete customer satisfaction at this stage increases the ability of the firm to hold a reasonable share of market. Reliance on the traditional methods and inability of the small firms to recognize the benefits offered by the technology like rapid prototyping is holding back this sector to play a critical role in world markets, where several firms are worried about losing business with multinational corporations. Many large companies still import their components, rather than purchase from local SMEs supplies. The main reason is the high price and low quality of the locally produced components [5]. A recent UN document stresses that production capacities should be placed at the heart of national policies. There are number of obstacles faced by firms which limit their growth and relations with the global value chain and one of them is the ability of SMEs to compete [15]. The Institute of Engineers Australia describes that the long term success of manufacturing requires attention on both markets and technology[16]. Emerging technologies can play a considerable role in this regard.

Rapid prototyping is an additive manufacturing, which builds a part layer by layer in contrast to previous methods which use subtractive methods, by using material like wax, metal, several types of plastics, paper etc. The inherent capability of this technology has made it an ideal candidate for producing prototypes using a range of materials available. The developed parts can be used for a wide range of applications like functional testing; form-fit analysis or even the parts produced can be used as end product, based on the material and equipment used. Stratasys exposed that 32 of the parts on its large format fused deposition modeling (FDM) system were produced via FDM(from another RP machine) resulted in saving of $100,000 of tooling cost and reduction in lead time up to six weeks [17]. Another great advantage of the technology is direct tooling application and all these benefits have great effect on the design-manufacture cycle with a significant impact on the lead time and the cost of the product which leads towards the increased capacity of the company.

RP technology is not for large firms only, it also offers tremendous potential for SMEs to pursue and create new opportunities [18]. Despite the common thread between the problems of these companies like limited design and manufacturing capabilities and the benefits offered by the technology, still only a small proportion of industry currently use this technology and this is particularly true for small to medium size companies [11]. The general consent is that less than 20% of the design and product development community use rapid prototyping. In the manufacturing engineering discipline the level of use is far less. Keeping in mind its immense potential, it is difficult to understand why few companies use it [19]. There are many reasons for this low diffusion but the one

which largely contributes towards the problem is the lack of awareness of how to successfully adopt this technology. The absence of a complete adoption mechanism is one of the major reasons for SMEs being unaware of the strategic benefits offered by this technology.

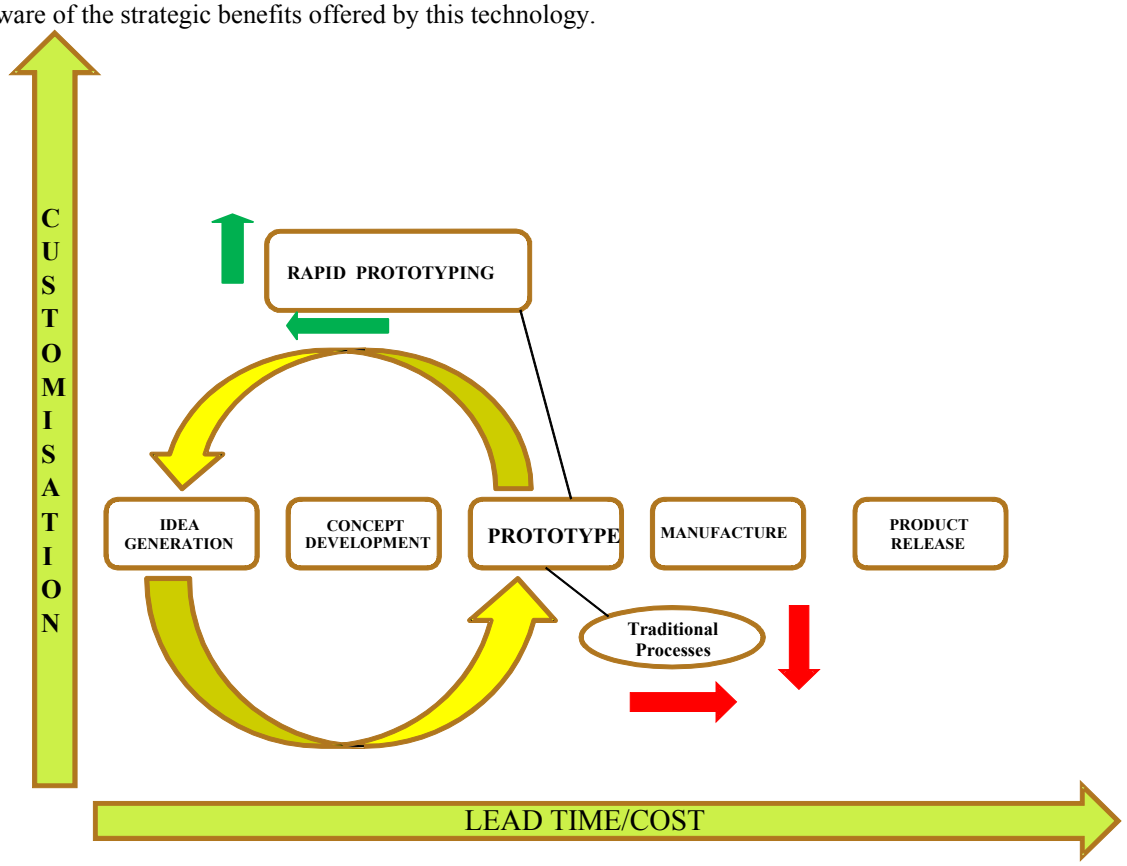

Figure1: Role of RP in product development cycle

3. The Existing Frameworks

Technology selection is concerned with the selection of the best option from the number of available alternatives. The selection and justification involves a number of factors, which are decisive for the growth of the business in increasingly demanding circumstances [3].

A data structure and a decision model which consolidates both the qualitative and quantitative variables was proposed by Kengpol and Brien [20].The model provides a technology selection mechanism by providing technical, manufacturing and financial parameters. It integrates the cost benefit analysis with the decision making model and provides some models to quantify the benefit loss due to early/late launch of the product and is more inclined on financial gains. Ruder, Pretorius and Maharaj [3] propose a technology selection framework which links core competencies with the selection of the technology. It identifies the core competencies first and then links them with the technology selection process. Another framework which uses the filter concept is described by Shehabuddeen and colleagues [21]. The model incorporates the filter concepts and uses several outer and inner organizational factors for the selection of the technology which also includes financial and regulatory parameters.

There is an abundance of work in the selection of advanced manufacturing technologies, like robotics, flexible manufacturing systems etc. Due to the high cost involved, these frameworks are based on the economic considerations or conventional investment justification methods and are designed for large companies. Moreover, they target the specific selection process only and lack an integrated and systematic approach for the effective adoption [21]. On top of that, there is no clear academic tradition of study of the total process of implementation [22]. The author also adds that most practitioners and researchers concentrate only on the technical aspects of the technology selection and do not capture market and business information. Management need to understand how the technology manifests itself in the business process and what impact it can have on the manufacturing as a whole [23]. Most of the information available to managers regarding technology selection is in segmented form rather than integrated form [24].

Emerging technologies pose significant challenges to classical technology assessment [25]. Different technologies offer different competitive advantages and for an effective adoption, technology drivers must be identified first, which should match later with the business and market requirements. The technology planning is a trip of unfamiliar customer needs, competitor capabilities and many begin this trip with no idea, the complex path is poorly communicated and technical staff get lost or focus their expertise in incorrect directions [26]. There seems no work done which is specifically designed for SMEs that can be utilized exclusively and effectively for the RP adoption. This creates the need for the design of a systems approach for the RP adoption, which is simple, easy to understand and can be utilized by small companies to solve their particular problems.

4. Proposed RP Adoption Framework

A study [27] concludes that wrong technology or even the right technology but poorly implemented can be disastrous. A complete acquisition process is very critical for the effective technology adoption. A conceptual framework for RP adoption is presented which also considers the models proposed by Farooq and Shehabuddeen [21, 28]. The structure of the framework is based on the critical factors which play a major role in technology selection process. These factors have been extracted from literature and assessed and refined by getting expert opinion from industry and academics. The common factors are grouped together to form the building blocks of the framework. Four key elements have been identified namely identify, analyze, compare and specify.

The developed framework has the capability to cover all aspects that need to be considered in the implementation process as urged by Voss [22]. These include pre-installation planning and justification as well as purchasing, commissioning and evaluating the technology under consideration. The description of the phases identified can be seen in Figure 2.

4.1 Identify

The framework begins by first evaluating the markets and competitors. This provides an excellent starting point, by giving an overview of the current strength and weaknesses of business, real challenges and the requirements of the current and future markets. Wheelwright and Clark [29] identify competitor comparison as a critical starting activity which helps to benchmark where you stand as compare to your competitors and to set goals for the future by overcoming the current identified gaps.

4.2 Analyze

Once the competitor and market position are determined, this information serves as input to the second phase which deals with the analysis of the internal capabilities, requirements, strategic position and current link of the technology with the strategy, assessment of the current performance, operational and cost parameters. A framework to link the marketing strategy and the current and potential technology can be a great tool at this stage for an integrated business plan.

4.3 Compare

Abundance of technological alternatives and complexity of the receiving company have made the technology selection a complex task. Selection of the technology is a critical task, which involves a lot of information from inside and outside of the organization. Limited knowledge of the user company makes this task much more difficult especially in the case when technology is emerging. This step evaluates the technology based on financial and operational parameters identified in the earlier stages. Analytical Hierarchy Process (AHP) is a significant tool, which can provide a means for integrating economic and noneconomic, qualitative and quantitative factors and has an enormous potential to devise a solution based on the necessities of the user company.

4.4 Specify

Once a technology has been identified in the previous step, the evaluation of the selected technology and its link with the manufacturing strategy of the company is established. It also includes the detailed risk analysis and opportunities it can offer. Adjustment of the business strategy, impact assessment of the technology on the business operations and human resource requirement are the critical points to consider at this phase before a technology deployment decision is taken. The cycle continues with the regular expert reviews and exploitation of the benefits after the deployment of the technology. This can create a new world of opportunities which are even not realized during the initial phases.

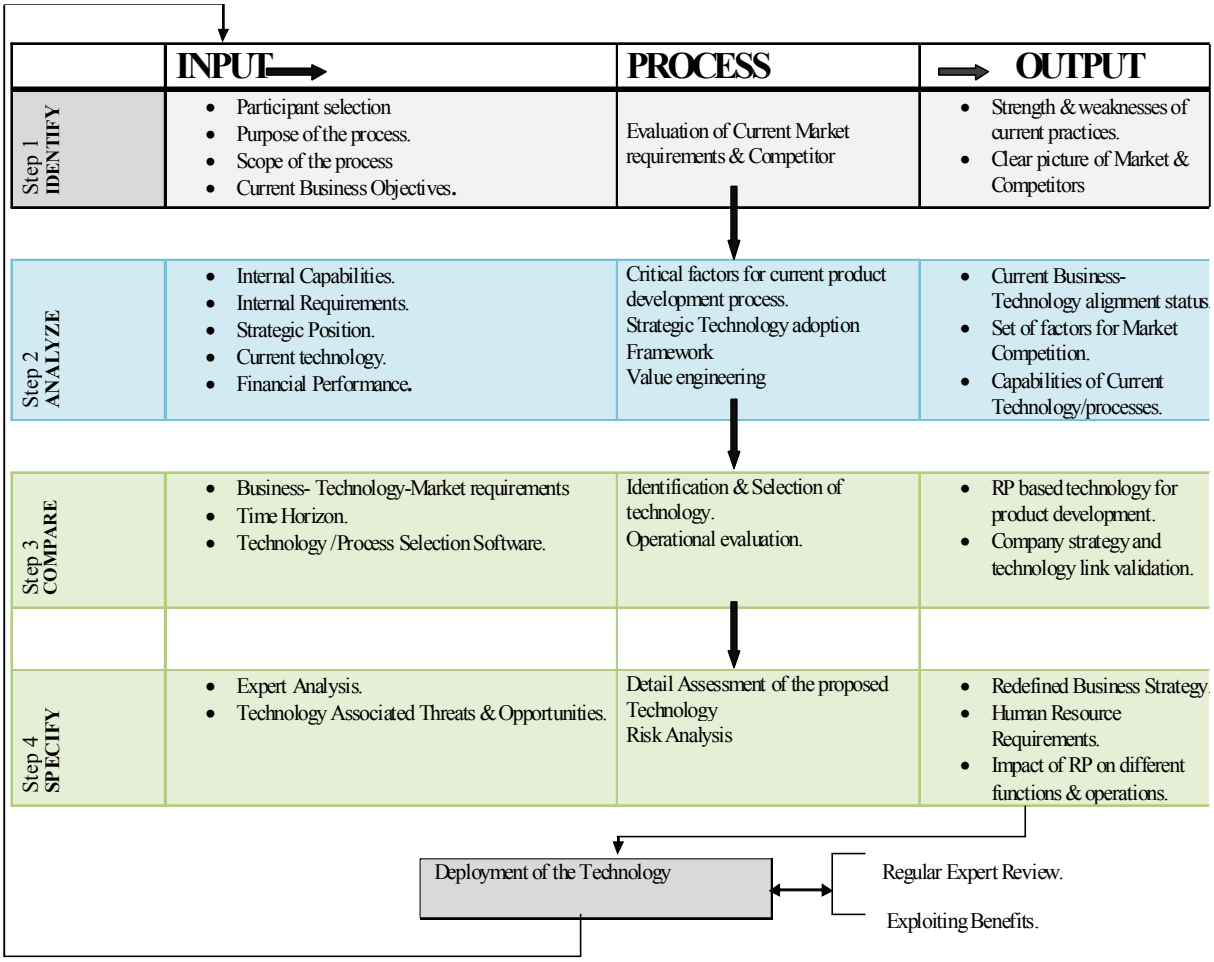

Figure 2: Proposed RP based technology adoption framework

5. Conclusion

The success of the technology selection and deployment is based on several factors, which must be identified during the implementation phase. These factors may be organizational, technical or operational. An effective technology adoption requires a lot of information about the technology, markets and business. The complete information is hard to find in the case of SMEs due to several reasons. Critical importance of this sector in the economy stresses on solutions which are exclusively designed for them by considering their resources and capabilities. Development of a system based technology adoption framework is one step forward in this direction which will add more practical solution at the later stage. The unstructured technology acquisition process, reliance on traditional processes and inability to meet the market requirement forms the basis of this development.

The proposed framework systematically identifies the business problems and links them with the selected technology attributes to ensure that the selected technology fully penetrates into the business and is completely exploited. The specific problems of this sector are identified at first stage, then suitability of the previous models for application in SMEs is studied and the factors which are not relevant or very complex to understand are eliminated. In particular there is limited focus on the financial justification, as the cost of the technology is much lower than the technologies mentioned in previous researches. A strong link between the technology and strategy is established to ensure the consideration of critical factors before a final decision can be made. This is very essential as most of SMEs have unstructured technology acquisition process.

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