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Rapid Prototyping Technology Roadmapping For SMEs: Issues, Challenges & A Pragmatic Implementation Approach

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In the advanced era of globalization, the changing demands of customers and trends of the market have changed the business world. The changing scenario of the global village has an indelible impact on Small and Medium Entrepreneurs (SMEs) but these small business firms are incapable to tackle all these challenging issues and maintain the market positions due to limited human resources and technological infrastructure. Though Rapid Prototyping technology has a great potentiality to address all these challenging issues, yet there is not much application of this technology in the large proportion of SMEs. This paper highlights the key barriers, their impact on competitive capabilities and introduces a practical roadmap. It also discusses its implementation mechanism through industrial case studies for the understanding of the market dynamics, competitor's ability and internal business analysis to facilitate the RP technology link with the challenges they are facing, to ensure an effective adoption process.

Key words: *Rapid Prototyping; SMEs; Global Value Chain; Competitiveness; Technology Adoption*

1. Introduction

The manufacturing industry is the backbone of the country, which plays a central role in industrial development, the effectual indicator of a robust economy, and the growing prosperity of the country. The role of the manufacturing industry is very significant to enhance the employment ratio in the multifarious private as well as public sectors to put the country on a

prosperous path. SMEs comprise countless manufacturing firms, playing a contributory role in boosting up the country's economy on higher levels. The small and medium enterprises are important to fulfill the growing demands of the customers in the domestic as well as global markets, the fruitful sources of inputs in the progress of the big industries.

In the global marketplace, the unpredictable demands of the customers have pressurized the manufacturers extremely with the extraordinary rate of product flexibility with the minimum bulk. SMEs, demands to be leaning towards creating competitiveness and business productivity that is competitive in global, national, and local markets (Surya et al., 2021).

In the advanced era, the earlier business tactics have been replaced with innovative ones due to the immediate shift of market drivers, a long journey of product development from the standardization to mass-customization, focussing on the customers individually, and launching products in the most befitting marketplace with short lead time. SMEs have undergone extreme pressure due to the rapid changes in the business methods, focussing on the development of managerial as well as technical competencies in order to fill up the gap among the external demands and internal capacities, which is essential for incorporating all emerging changes in the domain of the business world. The manufacturing firms should focus on technological development to manufacture the multifarious kinds of products in accordance with the growing trends of the markets in the view of the emergent complexity of products, which has reduced the product life-cycle and time of launching products in the marketplace (Australia, 2009). According to the organization of Economic Corporation & Development (OECD), SMEs are encountering some barriers which include managerial as well as technological capacities, embracing the innovative and competitive business model, potentiality of innovativeness, due to all these barriers, they are incapable of tackling all challenging problems (Storey, 2004). In fact, SMEs are incompetent to respond to these modifications, jeopardizing the survival of the small and medium enterprises due to wider gaps among the external as well as internal environmental demands and potentialities.

This research paper demonstrates all possible challenging issues and barriers encountered by SMEs. Rapid Prototyping (RP) Technology plays a pivotal role in developing a significant linkage among all possible issues of SMEs and the development of technology to overcome all challenging threats practically as the previous studies are inadequate to sort out all such problems faced by SMEs. The practical implementation of the technology, Rapid Prototyping (RP) was done based on the findings, applying practically to the different case studies of SMEs. This practical approach would be a roadmap for SMEs to adopt RP (Rapid Prototyping) effectively.

2. Globalization & SMEs

In the economy of any country, SMEs are the main source of creating countless jobs, comprising a greater proportion of the industrial sector. In order to develop the economy of

any country, SMEs play a vital role strategically to create jobs and flourish businesses profitably. China is one of the rapidly flourishing economies of the world where SMEs are a substantial component, consisting of 99% of overall business firms and creating around 67% of employment (Low et al., 2007). According to the statistical reports of the Australian Government, the actual figure of SMEs was approximately 2051085, which are operating their businesses in Australia till June 2009 (Clark et al., 2011). Figure 1 shows that the small business composes 96%, medium-sized firms constitute around 4% while big business firms consist of less than 1%.

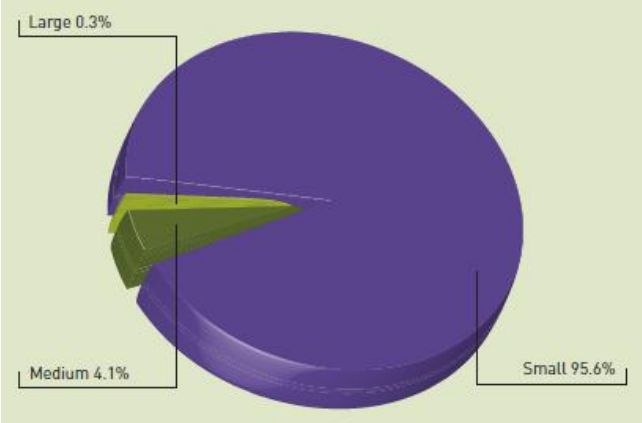

Figure 1: Statistical Report of the Industrial Sector in Australia
Source: ABS Cat. No. 8165.0 Cited from the Department of Innovation, SME Statistics Department (Clark et al., 2011)

Lukacs elaborated the significance of SMEs as (Lukács, 2005):

- SMEs provides a diversity of products and services which are not available by other big business firms due to some specific reasons
- SMEs offer unique kind of services and products which are not provided by other large firms to satisfy the potential customers

Kongolo demonstrated the contributory role of SMEs, which follows as (Kongolo, 2010) :

- SMEs is the central source of employment, composing rural as well as urban workforce
- The employment of a larger number of people is dependent on SME in the direct as well as an indirect way

In the advanced era of the telecommunication and internet, the world has become a global village where the process of the designation and manufacturing of products has been continuing simultaneously, developing Global Value Chains (GVC). Global Value Chains (GVC) encompasses wide-ranged activities, including conception, designation, production, and shipment to the customers, and all kinds of business firms, situated in different regions of the

world perform such kinds of activities (Nations, 2007). OECD demonstrated a number of problems encountered by SMEs and highlighted the significant role of SMEs in Global Value Chains (GVC) OECD, which are discussed here (OECD. et al., 2008):

- To develop awareness and understanding about the competitiveness and value chain dynamics for the business firms
- Unavailability of technological resources and incapability to upgrade overall systems of the businesses
- To launch innovativeness and quality compliance systematically

The growth of SMEs has been jeopardized, encountering a number of challenging issues in the developed as well as developing countries. In the era of globalization, there is no exemption of adopting megatrends for the business firms, particularly, SMEs have been influenced by the challenging issues developed by globalization in the world, which focuses on the radical changes by implementing innovative methods (Hwang, 2007).

3. The Real-Time Challenges

In order to avail of all kinds of advantages and opportunities presented by the GVC, there is a need to harmonize the capacity and responsiveness of SMEs and the changing demands of the global markets. These promising opportunities will be converted into high risks and threats if there is no harmony among the constantly changing scenario of markets and capacity-building of the SMEs to respond. According to International Trade Forum (ITC), the competitiveness of any organization can be determined on the basis of some factors, including requirements of buyers, standardization and regulations of markets, and market conditions (ITC, 2003). Synchronization requires developing an understanding of the changing market trends by enhancing the capacity and adaptability of the firm to adopt new technological tools and techniques and upgrading the internal system of operations to synchronize internal as well as the external system of operations of the organization. It is necessary to resolve such technical issues of SMEs by finding out the appropriate solution from the previous research-oriented literature that is relevant to highlight the complex solutions based on the practical experience of SMEs. There are the following basic questions of this research work which should be answered to sort out the pertinent solution of the challenging issues encountered by SMEs:

- Are SMEs capable of understanding how the changing demands of markets are influencing the GVC?
- What are the potentialities of SMEs to identify the drawbacks of the current operational and technological systems to achieve the desired targets of productivity?
- What are the skillful knowledge and resources of SMEs to enhance competitiveness?
- How are the practical solutions to the challenging issues of SMEs obtainable with the support of Governmental agencies or previous research works?

In the marketplace, business firms may obtain a competitive edge by having a unique design and development of the product (Ahmad et al., 2012). The process of product development initiates from the acquisition of the demands of customers and fulfillment of the customers' demands, which are translated into the final product. This process of product development is continued by involving many activities, finally, the agreement between the customer and firm is signed to initiate the manufacturing process of the final product. Prototyping is one of the most significant phases of the product development cycle, representing the final product according to the customers' expectations. This phase of the product development cycle is also an evaluative phase where it is determined to what extent the demands of the customers are fulfilled by identifying all manufacturing requirements to develop the final product. In order to develop the final product, the process of product development has undergone many kinds of recapitulations. The whole process of product development is essential and considered a doorway for the customers and the markets. Prototyping is a critical phase of product development to evaluate the capacity of the organization to meet the expectations of the customers and current trends and demands of the market as this whole process is connected with the total expenditure of the entire project and the pertinent time period to launch a product in the relevant marketplace. If some errors occur at this phase, prototyping, the product wouldn't meet the desired demands of the customers and resultantly, there is a need for rework which would increase the cost of product development and time of launching product in the market, moreover, it would disappoint the customers and distort the brand image of the firm. Such type of erroneous process of product development is widely continued in SMEs of the developing countries; the main factors involved in this rework are the application of out-dated technologies and conventional techniques, incapacity to understand the rapidly changing demands of the customers and market trends, low-quality infrastructure due to the low level of education, small business culture, owned by the family and less aptitude of R& D culture, making the entire business scenario more complicated (Ayyaz et al., 2008).

According to the reports of The Economist Times of India, the Indian SMEs have to designate the product according to the requirements of the customers. There is no room for innovativeness and the latest technology implemented in Indian SMEs. There is a need for up-dated knowledge, skills, and accessibility to the latest technology for sponsoring SMEs in India (Karla, C, 2009). Commonly, SMEs have their own craftwork, which should be promoted on the industrial level to develop unique products that would be the future investment (Svensson & Barfod, 2002). In Malaysia, SMEs encounter many challenging issues like change in the mode of businesses due to globalization and the capability of technology management (Saleh & Ndubisi, 2006). The impact of advanced technologies and restrictions on launching innovation within minimum time puts pressure on the managers to take effective and appropriate decisions based on technological knowledge and competitiveness with a quality business approach (Phaal et al., 2006).

In low-income countries, it is challenging to shift SMEs from conventional standard operations to advanced and novel technological operations to enhance productivity with specialized expertness. Innovation implies technological advancement as well as organizational development by implementing the dynamic strategies of marketing management (Altenburg & Eckhardt, 2006).

4. Product Development Revolutionalisation through Rapid Prototyping (RP)

Rapid Prototyping is the latest technology that has revolutionized the process of product development, which was in vogue in the old times. It is known as an Additive Manufacturing (AM) technology entirely different from its antecedent, CNC, a subtractive technology to produce overlapping layers of the parts by having commands from 3D Design Software. Ping Fu Advisor to US President on Innovation, described in a BBC program Hard Talk, "3D printing is as big as Internet; as big as steam engines" (BBC, 2013). The advent of Rapid Prototyping technology presents distinctive features that are useful for providing appropriate solutions and a set of strategies. American Society of Testing and Materials (ASTM) developed a standard designation with the support of document, F2792-12, published in March 2012. Additive Manufacturing (AM) is defined by the F42 committee on Additive Manufacturing as "A process of joining materials to make objects from 3D model data, usually layer upon layer as proposed to subtractive manufacturing methodologies"(ASTM, 2012)

5. Rapid Prototyping Technology & SMEs

The in-build capacity of RP technology has enhanced its featured contents for developing different and complex parts by applying wide-ranged techniques like Form-Fit Analysis and Functional Testing Approach, which can be implemented to utilize the produced parts as end-products, made of different materials and equipment. The advantageous role of RP technology has brought revolutionary impacts on the design manufacturing cycle, having significant influences on the lead time and cost of the product, which helps enhance the productivity of the manufacturing firm. By implementing this innovative technology of Rapid Prototyping, it would bring about unpredictable modifications in the business environment, threatening to current and prevalent business operations with high risks, therefore, this technology would be used by considering market turbulence. In the era of globalization, extraordinary pressure is placed on the manufacturing firms of every industrial sector and the innovative RP technologies have provided supportive tools for the manufacturing firms to develop designs of the products in a short time(Onuh & Hon, 2001). There are many advantages of RP for the mega multinational firms and small enterprises that authenticate the significant reduction in a design-prototyping cycle with the use of RP Technology, enhancing the quality of the products (Wohlers, 1995).

Rapid Prototyping has gained immense popularity and numerous technological articles and blogs highlight the significance of this emerging technology in the print media. The all-

embracing applications of this technology have been used by different organizations like NASA, implementing this technology to develop space programs while BMW, applying this technology for automotive manufacturing operations. Nearly all leading and prominent manufacturing firms are getting benefits from the applications of a particular technology. On the other hand, in SMEs of developing countries, the rate of applying this latest technology is very low. The emerging technology has been launching rapidly in this advanced era of globalization where the rate of application of the novel technologies is still at the minimum level, increasing the gap among the users as well as to non-users. There are many cases of such firms, especially the even in the credible size of SMEs, there is no adoption and application of the latest technology that's why the impacts of the certain technology were indisputable. It is estimated that approximately 20% of the design and product development is done through the applications of Rapid Prototyping. If specific technology is too useful, why are manufacturing firms not applying it in the manufacturing units to immediate and advanced product development (Grimm, 2004)?

6. Low RP Adoption Challenges & Causes

Despite the extensive range of potentialities, RP technology has an effectual impact on the product development cycle, and numerous SMEs are still not applying this technology to improve the quality of products. the adoption of AM in SMEs is presently inadequately understood, as the majority of the literature concentrates on large firms(Martinsuo & Luomaranta, 2018). A survey report of 262 UK firms described that approximately 85 % of these firms are not using this RP technology, due to a lack of exact knowledge and understanding about the useful applications of this technology for improving the growth rate of the overall businesses, they are not interested in implementing RP technology(Grenada, 2002). It is the deplorable state of business firms where the engineers and production departments are not aware of the technological development of the firms through the usage of Rapid Prototyping (Laar, 2007). Regardless of the all-embracing features of RP Technology, SMEs are not implementing this technology which may address the challenging issues including the limited capacity of the manufacturing firms for design and product development and prolonged lead-time cycle (Ahmad et al., 2009). The author had worked with UNIDO (United Nations Industrial Development Organisation) to promote the Cluster Development Programme in Pakistan for almost two years (2005-2006). The main objective of this Cluster Development Programme was to boost up the overall productivity of SMEs and exclusive market shares by utilizing the resources and capabilities of each other. The stakeholders of this programme were the chief policy-making organizations, comprising PSIC (Punjab Small Industries Corporations), SMEDA (Small and Medium Entrepreneur Authority), and EPB (Export Promotion Bureau of Pakistan). A survey report presented by SMEDA highlighted the main problems encountered by the largest Automotive Cluster, which were the limited time for novel products and product development capacity. The inability of the cluster to resolve these issues brought about the reduction of market shares for these small enterprises. By having

consultations with the key representatives of all SMEs, it was revealed that no single feature of RP Technology was applied in the cluster. It was really an alarming condition of SMEs. In the current times, the rapid advancements in applications of Rapid Prototyping Technology and accessibility of the RP equipment at the minimum rate have not succeeded in ensuring the diffusion and adoption of this technology in the industrial sector of Pakistan.

6.1 *Obliviousness of RP Technology and its Impact*

Before taking the initiative in the domain of technology, it is unnecessary to understand the latest technology and its influences upon the business operation and competitive edge of the firms. After reviewing the unpredictable beneficial roles of the latest technology, adoption and diffusion of technology are the immediate actions on the industrial levels(Hall & Khan, 2003). Koen highlighted technology planning in these words:

"Technology planning is often a journey into uncharted areas of customer needs, competitors, capabilities and requirements. However, many begin this journey with no clear idea of terrain and obstacles. The path is poorly communicated, and technology staff gets lost and are focusing their expertise in the wrong direction**"** (Koen, 1997).

According to the viewpoints of Narain and Sarkis, the highest value of the capital investment is indispensable for purchasing RP on the initial stage which is out of the affordability range of SMEs (Narain & Sarkis, 2006). Since, the inception of technology, It is a valid reason how the cost of adopting technology at the initial stage is really unaffordable for small enterprises. Over time, the rate of 3D Printer is about $5000 compared with the old prices, which were about $100,000 at the introductory stage of technology, yet still, this impression of the expensiveness of adoption of technology is embedded in the industrial sector. The incapacity of SMEs to resolve these issues is another factor to adopt technology even if the technology is available at the minimum level of investment. Terry Wohler demonstrated the logical reasons in his reports that the value of the capital investment is not a big issue but there is a need to evaluate other problematic factors that cause complex problems with manifold challenging issues. It demands a detailed analysis which can be simply elaborated here:

"WIIFM ÷ WWIHID where

WIIFM = What's in it for me

WWIHID = What will I have to do"

Source: Wohler's Report 2002 (Wohlers, 2002)

An additional "W" is the reason for low adoption, raising this question repeatedly by the industry and academics, "Why we use this technology?". There is a need for a comprehensive

answer, denoted by "W". Another question raised was, "What I need to do?" in the case when a business firm or individual is influenced by technological development. This single question comprises myriad issues that would be discussed in the next section.

6.2 Practicality Issues

There is a need for skillful knowledge and information on the external as well as internal levels of the organization for the effective adoption of technology. In order to take technology-based initiatives, it is necessary to develop an understanding of the essential parameters and drivers of technology, their capability to impact the business products, current strategies and methods of production, and knowledge or expertise in the view of technological development.

Effective Technology Adoption (ETA) demonstrates a comprehensive mechanism to manifest all technology features, embedded in all possible functions of the business firms after adopting the chosen technology. The OECD defined a new terminology, Constructive Technology Assessment (CTA), whose main objective was to cut down the blunders and decisions on the basis of erroneous calculations regarding the investment (OECD, 1988).

RP is an emergent technology, having mythical concepts due to a lack of understanding about its capacities and impacts on how it would be befitting for the business operations and technological requirements. There are more complex and worst conditions due to several managerial as well as infrastructural issues when SMEs are willing to adopt such advanced technology. Resultantly, they would have either reliance on the conventional production process or the wrong technology utilization. Fleischer elaborated that emergent technologies jeopardize the existence of the classical methods of technology by having considerable challenges of a classical technology evaluation and the decision-makers need to have authentic information related to the potential consequences of the adoption of the latest technologies before they are applied on a large scale (Fleischer et al., 2005)

Grimm argued in his article, " Industry has failed to recognize the latent opportunities which are offered by the Direct Digital Manufacturing technology(Grimm, 2006). Ordoobadi and Mulvaney highlighted the issues of operationalization as sometimes, the model needs to be activated by implementing some recommendations in order to obtain more good productivity with the help of the decision-makers (Ordoobadi & Mulvaney, 2001). There is a need for an integrated solution that may provide complete guidelines practically for the potential adopters of the technology on the strategic as well as operational levels. It is not sufficient to develop a framework for adopting technology for addressing the complex challenges but there is a need for practical application of all operating procedures.

7. Existing Research Related to Technology Selection& Assessment

Technology Assessment is comparatively an emerging approach founded in the 1960s in the USA with the slogan, Modify the standards of living with the implementation of technology. Regardless of its emergence over the six decades, the efficient methods of technological development and assessment have still undergone a process of innovation (Tran & Daim, 2008). Technology Selection is related to the best choice of technology out of numerous alternatives, developing a complex decision-making process due to wide-ranged and complex features of technology (Ruder et al., 2008). When the technology is selected based on the specific technical parameters, it would restrain the effectiveness of adopting the chosen technology, having direct influences upon the business functions. That's why it is necessary to understand a close linkage between technology and business functions before selecting a specific technology. The condition becomes worse when the decision-makers are incapable of integrating theory and practice as they have no capability to incorporate the exclusive problem with the applicability of theory for obtaining the most productive results (Tate & Nordlund, 1996). In order to resolve the problematic situation, new terminology was founded on the basis of the previous literature, known as "Effective Technology Adoption" or ETA. The main objective of any ETA is to develop a close linkage between technology and all possible business functions and operations to resolve real issues.

A business comprises a set of all different functions and every business function is required to be improved for the overall improvement of the business. As all these functions are technology-based, developing a strong bond between technology and business. The main contents of the ETA plan are described here:

- To develop a comprehensive and accurate understanding of all drivers externally as well as internally to evaluate the capacities of the competitors and overall global trends
- To evaluate internal capacities accurately and pinpoint the gap among the internal capacities and external demands, determining a technology-strategy link
- To choose the feasible equipment which may meet the requirements of the specific organization on the strategic, operational, and financial level
- To develop a set of guidelines, including all appropriate tools and methods for addressing all the problems mentioned above. These guidelines should have capability and practicability of mechanism for implementing all techniques effectively

Grieves pinpointed the issues of unavailability of perfect adoption solutions, implementing the point solutions that put restraints on the beneficial role of Direct Digital Manufacturing, which is not effectual as an integrated solution (Grieves, 2006). Huang and Mak concluded after surveying almost 100 British Manufacturin Firms that the poor change management is the result of inappropriate selection and adoption of technology, showing the incapability of the organization to identify the close linkage of the technology and business in the broader

spectrum (Huang & Mak, 1999). Naik and Chakravarty described that it is obvious from the previous literature how innovative technology justification studies are incapable of illustrating all pertinent attributes of the system in an evaluative manner. A poorly-developed system with little knowledge and expertise would be disastrous(Naik & Chakravarty, 1992).

According to the Business Enterprises and Regulatory Reform (BERR) UK, it is an important barrier to invest in developing innovative products, particularly for small business enterprises, due to the high costs of launching new technology or production system in the manufacturing firms (BERR, 2008).

Practical implementation involves the practicability and availability of tools and techniques that would support management decisions. There is a need for conceptual frameworks and processes to sort out the problematic challenges of businesses with effective guidelines for technology management (Phaal et al., 2006). This statement authenticates the fourth point of the ETA charter, having a specific emphasis on practicality.

8. Incongruity of the Technology Selection Studies for RP Adoption

Rapid Prototyping is a pioneering and emerging technology which have changed the way of businesses in the world. The RP technology provides a set of solutions and strategies which are innovative present several benefits of the technology. Specific and dedicated solutions are needed, which can be applied and integrated. According to the previous literature, it is shown how technology is incapable of diffusing in SMEs despite having a greater potentiality of RP. There are some reasons for the low diffusion of technology in SMEs, which are as follows:

- The incapability of the previous studies is to pinpoint the diverse kinds of RP drives, focusing on AMTs, an emergent technology.
- Lack of an integrated approach which may provide guidelines for the strategic as well as operational perspectives.
- Difficulty in selecting the right RP technology according to the particular requirements of SMEs, therefore, the selection of the right RP equipment is considered a big adoption barrier as there is no tool or technique implemented for selecting the right RP technology.
- Unavailability of all-inclusive and exclusive procedures with the effectual tool kit provides technical support to SMEs for the effective diffusion and adoption of technology as they are novices in this regard.

The frameworks are rather generic, which are developed previously. The framework proves to be inoperative due to a lack of knowledge of the decision-makers about the innovative technology and the incapability of the individual to develop an understanding of the complexity of the interrelated decision factors. There is a need for a hands-on approach to implementation,

described as the collective process of rapid prototyping with action research that will permit a prototype of best practices to be created that can even exhibit the downsides to evade in the implementation process (Cook & Crawford, 2008).

9. Rapid Prototyping Technology Adoption Framework

Manufacturing strategy is the crucial one in determining the competitive edge of the firm in the marketplace, having direct linkage with the external environment (customer, competitor, and market) as well as the internal environment (technological capacities, business operational methods, and human resources). Cil and Erven asserted that the manufacturing strategy is neglected with growing concerns linked with management principles about the manufacturing of the product, deploying organizational resources within the designed infrastructure (Cil & Evren, 1998). Platts and Gregory stated that a strategy could be devised or it arises out of the changed circumstances, therefore the decision process should be postponed till the most pertinent information is received as the strategy is related to uncertainty and unpredictability of the events (Platts & Gregory, 1990). Similarly, in RP adoption, where unpredictable and uncertain elements are involved, it is incredible to forecast manufacturing strategy for SMEs particularly. In the white paper of CIM data, Grieves elucidated how RPT can restrain several issues that negatively impact the effectiveness of manufacturing firms(Grieves, 2006). However, it is mandatory to develop such procedural tactics aligned with the capacities of RPT to obtain diversified advantages on the maximum level.

According to the author, there is a need for an integration solution rather than point solutions that are commonly implemented, resulting in a small proportion of RPT benefits. In the context of the inadequate technological methods of RPT adoption, a comprehensive and integrated RPT adoption framework is developed, based on the model of Farooq and O'Brien (Farooq & Brien, 2010) to resolve challenging issues in adopting RPT effectively as it is shown in figure 4.

10. RP Technology Roadmapping (TRM)

The diffusion process of the latest and emergent technologies like RP is unusually very slow. The uncertain environment for technology adoption, lack of understanding about the beneficial role of new technologies, identification of changing market dynamics, corresponding with the technology drivers, and validating the adoption of technology based on both operational as well as financial parameters which is a very crucial and complicated task. The extravagant information available on the internet, useless, irrelevant, and impractical solutions compel SMEs to maintain the status quo. The unfeasible selection and adoption of technology wouldn't be productive for the SME community.

The absence of a comprehensive adoption solution and resistance to changing work procedures leads to the incessant use of out-dated technologies and operational procedures. Technology

Roadmapping (TRM) is the most prevailing tool, having a capacity to resolve these issues by applying pertinent solutions. A document of the US department of energy elucidates TRM in these words:

"Roadmapping is comprehensive, considers the impacts of all interfaces of the overall system and identifies the key elements and functions that must be integrated in a selected pathway to achieve a timely and successful end point"(DoE, 2000)

Koen elaborated several impediments in the domain of technology planning due to unexpected requirements of customers and unexplored competencies of the competitors, creating the situation more complex and challenging for the business firms (Koen, 1997). Resultantly, the efforts and expertise are put into practice wrongly and there is a need for graphical direction for mapping all processes in the field of technology implementation. The Australian Engineering organization members valued Technology Roadmaps as the most significant factor for formulating National Manufacturing Policy effectively (Engineers Australia, 2009).

Technology Roadmaps can play a central role in the adoption of RP technology, an emergent and latest technology, which can be done by sorting out a comprehensive and hands-on adoption solution on the strategic as well as operational level. The value of such a roadmap is enhanced when the capacities of the potential firms are unsure of the adoption of technology.

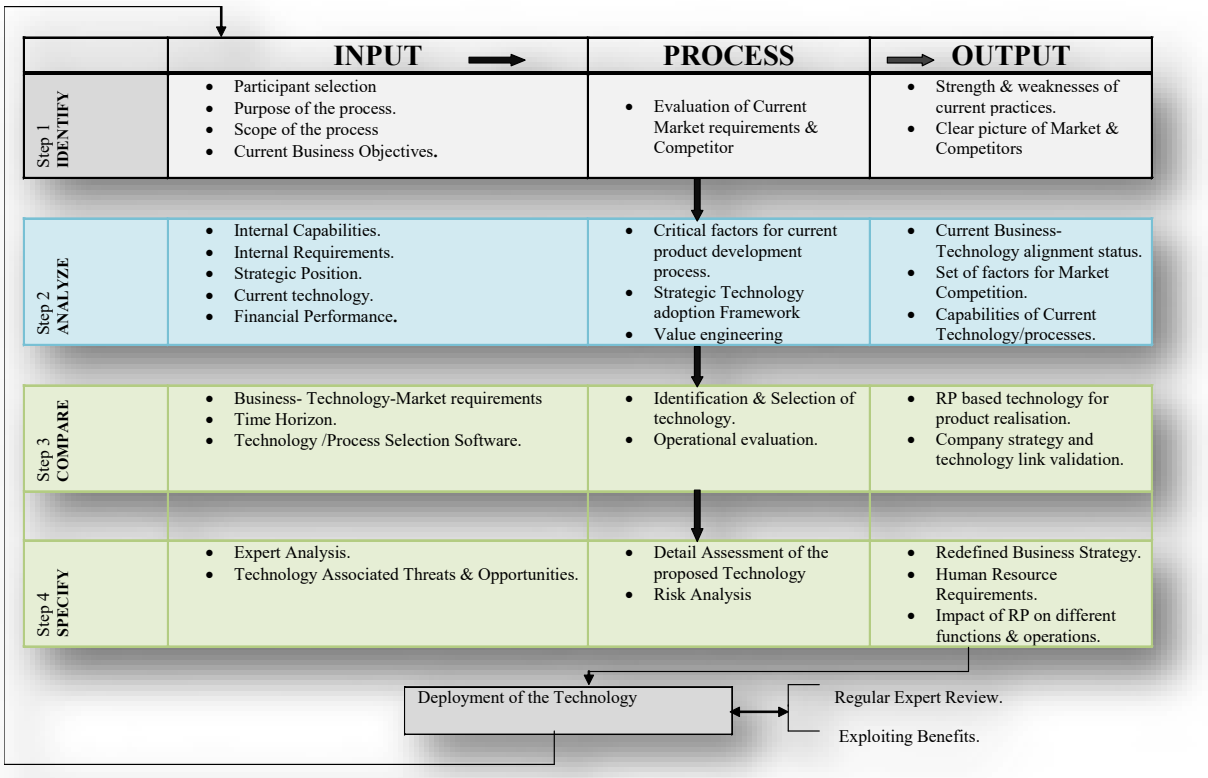

Figure 4. Proposed Rapid Prototyping Adoption Framework(Ahmad et al., 2012)

11. TRM through Action Research

Action Research is conducted by individuals to sort out the solution to an immediate problem and improve the productivity of the business firms. It requires active participation on the organizational level to follow an innovative course of action. Action Research is very significant in solving real-world problems practically. In the words of Reason and Bradbury, action research is defined as follows:

"Action research is about working towards practical outcomes and also about creating new methods of understanding since the action without understanding is blind, just as theory without action is meaningless" (Reason & Bradbury, 2001).

Koshy demonstrated the main features of Action Research briefly: (Koshy, 2005)

- emerging and hands-on
- supportive in resolving actual problems
- improving the way of business
- involving in the process of reflection, evaluation, and analysis
- facilitating the change in an inquisitive manner

Clark argued that action research resembles experimental research but is applied in the real world by applying a small-scale intervention in the real-world operation and the impact of such intervention is closely monitored and ready for application (Clarke, R, 2005).

12 Industrial Involvement/Introduction of Companies

It has been identified that the lack of a practical guide is one of the biggest barriers, requiring guidance step by step. The main objective was to evaluate the current practices and capacities of the technology to meet the current challenges and issues. It was necessary to expose technological development to SMEs at a large scale that does not prefer to adopt technology and consider it impertinent to them. In order to develop a roadmap for the practical adoption of RPT, two medium-sized firms were selected, one from a developing country and the other from a developed country, so that the developed framework, tools, and techniques would be applied.

12.1 ALPHA*/Company A*

Alpha/A company was taken from Pakistan, which is a medium-sized enterprise for about thirty years and the founder of fiberglass products in the country. Company A is known as one of the largest telecom infrastructure providers countrywide, having experience in manufacturing products for decades, which include altitude shelters, precision fit luggage, steel towers, alarm

systems, electric distribution boards, chemical plant equipment, tube-well pipes, aerospace equipment, monopoles, and cold chain products, etc. The general manager and production manager of the company were the focal persons and with their reference, design and operational engineers were also in contact for consultation and instructions whenever required.

12.2 Bravo*/Company B*

Company B was chosen from Australia, a leading manufacturing firm in the production of the vehicle system and specific engines. This company is experienced in providing engine and vehicle technologies with alternative fuel solutions. It also provides consulting services and also involves in business activities like Sprint system and Autogas.

13. RP Adoption Framework Implementation

As shown in Figure 4, there are four stages of the operationalization or implementation process, developing an all-inclusive and practical roadmap that can provide perfect adoption solutions on the strategic and operational level. The main aim is to illustrate the technology strategy linkage, evaluating the impacts of RP technology by developing a widespread adoption process of technology in the documented form.

13.1 External Environment Analysis

The external environment analysis is conducted by evaluating the competitors and markets. At this stage, the main objectives of the study, advantages of RP technology, and potential impacts of RP technology on SMEs were discussed in detail with the technical as well as business managers of both firms. The significance of the external evaluation approach was highlighted and all relevant queries were answered at this initial phase. The managers were informed about criteria selected for market and competitor evaluation. Market Evaluation Questionnaire was handed over to the managers of both firms to take an overview of the market and customer demands while having an interview. The responses of both firms are displayed in Table 2.

Table 2: Company A and B Market Evaluation Response

	Criterion	**Response**	
		Company A	Company B
1)	Nature of Market	Medium Standardization	Medium Standardization – Differentiation
2)	Product Customization Level	Moderate	Moderate – High
3)	Product Complexity Levels	Medium	High
4)	Product Flexibility Demand	Moderate	Moderate – High
5)	Time to Market Requirement	High	Moderate – High

	Criterion	Response	
		Company A	Company B
6)	Market Condition	Turbulent	Turbulent
7)	Product Volume Demands	Medium	Single Unit – High
8)	Most Important Business Outcome	Increased Market Share	Increased Market Share along with Lead Time reduction and Quality with Low Price
9)	Role of Technology	Critical	Critical
10)	Technology Selection Procedures	No Formal Process	In house and Customer reviews, capability analysis
11)	Critical Technology Selection Parameters	Return on Investment	Benchmarking Functional Requirements
12)	Document Procedures for Product Development	No	ISO 9000 Certified
13)	Formal Manufacturing Audit in Place?	No	Only at CEO & CFO Level

The responses from both companies A (developing country company) and B (developed country company) show how they encounter challenges. Both companies have similar challenging issues like unpredictable market demands and flexible behavior of the customers where standardization levels were medium-high. The exact time to launch products in the markets with enhanced market shares were the most common challenges of both firms. Technology played a central role in both companies but there were no formal procedures for selecting technology for both A and B companies. A manufacturing audit process was absent entirely, which plays a vital role in developing close linkage among the organizational goals and business operations, business strategy, and technology. It was authenticated through the responses of company B that the CEO and CFO only take an overview of such matters in the view of strategic parameters without having any formal evaluation procedure to develop linkage with business strategy and technology.

After evaluating the customer demands and market challenges, it is necessary to evaluate the competitive status of company A through competitive position modeling quantitatively. There are several steps of this process, which are discussed here:

13.2 Problem Modelling

Analytic Hierarchy Process (AHP) is known as Expert Choice, based on microcomputer application used to evaluate competitors by rationally integrating assessments and individualistic

values, very similar to human brains to choose the best alternatives for decision-making. At the initial stage of competitor evaluation, it was mandatory to organize all goals, criteria, sub-criteria, and the number of competitors hierarchically, as displayed in Figure 5. The overall criterion was developed after having discussions with the managers and references from the previous literature.

Figure 5: Competitor Evaluation Hierarchy

13.2.1 Pairwise Comparison of Criteria with respect to Goal

It was necessary to estimate the priority level of every criterion for every defined goal as all the criteria described in the former step cannot be equalized due to the diverse weights. To achieve the ultimate goals, it is important to determine the exact amount of each weight against each goal or sub-objective records. The managers were requested to equate the objectives in

correspondence with the goals and a paired comparison of every sub-objective against others on the node was done, which was at a higher level. All-inclusive weighted hierarchy is displayed in Figure # 6.

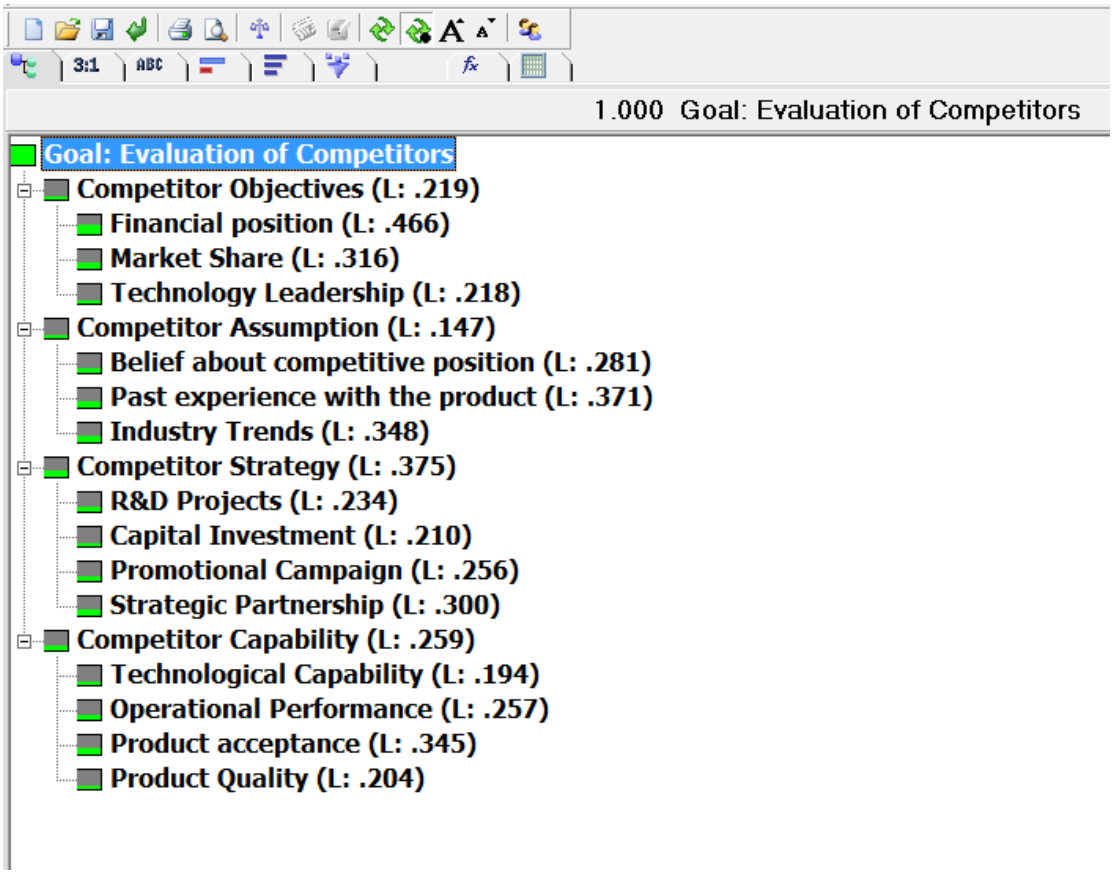

Figure 6: Weighted Hierarchy of Competitor Evaluation

13.2.2 Competitor's Rating

The managers were asked to choose options from 1-7(where 1= poor & 7=extremely good) against each criterion for rating the competitors. During this process of rating, the results are shown in Table 3.

Table 3: Company A Competitor's Rating

	Critical Success Factors	Company 1 Rating	Company 2 Rating	Company 3 Rating	Company A Rating
1)	Financial Position	6	5	4	5
2)	Market Share	6	5	3	5
3)	Technology Leadership	5	5	3	5
4)	Belief about Competitive Position	6	4	3	4
5)	Post Experience with the Product	5	4	3	4
6)	Industry Trends	6	5	4	3
7)	R&D Projects	5	4	3	3
8)	Capital Investment	6	5	4	4
9)	Promotional Campaign	4	3	4	4
10)	Strategic Partnership	1	1	1	1
11)	Technological Capability	5	5	3	5
12)	Operational Performance	6	5	4	7
13)	Product Acceptance	6	5	4	5
14)	Product Quality	6	5	4	6

The next step was to develop a rating scale formula whose aim was to give numerical values and equate alternatives against a standard scale. Every company was appraised against every single criterion on the standard scale. In order to illustrate, the ratio of companies against 4 out of 14 criteria is demonstrated in Figure 7.

AID	Alternative	Total	RATINGS Competitor Assumption Past experience with the product (L: .371)
A1	COMPANY1	.663	.660
A2	COMPANY2	.523	.490
A3	COMPANY 3	.379	.330
A4	ALPHA/A COMPANY	.470	.490

AID	Alternative	Total	RATINGS Competitor Assumption Industry Trends (L: .348)
A1	COMPANY1	.663	.830
A2	COMPANY2	.523	.660
A3	COMPANY 3	.379	.490
A4	ALPHA/A COMPANY	.470	.330

AID	Alternative	Total	RATINGS Competitor Strategy R&D Projects (L: .234)
A1	COMPANY1	.663	.660
A2	COMPANY2	.523	.490
A3	COMPANY 3	.379	.330
A4	ALPHA/A COMPANY	.470	.330

AID	Alternative	Total	RATINGS Competitor Strategy Capital Investment (L: .210)
A1	COMPANY1	.663	.830
A2	COMPANY2	.523	.660
A3	COMPANY 3	.379	.490
A4	ALPHA/A COMPANY	.470	.490

Figure 7: Ratings of the Competitors against Defined Criteria

13.2.3 Synthesis

After having a pairwise comparison and rating of the alternate criteria, the next phase was the synthesis, which was done through the multiplication of each ranking on the basis of the priority level of its criteria or sub-criteria. The calculated synthesis values are demonstrated in Figure 8.

Level 1	Level 2	Alts	Prty
Competitor Objectives (L: .219)	Financial ...	COMPAN...	.023
		COMPAN...	.019
		COMPAN...	.014
		ALPHA/A ...	.019
	Market Sh...	COMPAN...	.016
		COMPAN...	.013
		COMPAN...	.007
		ALPHA/A ...	.013
	Technolog...	COMPAN...	.010
		COMPAN...	.010
		COMPAN...	.005
		ALPHA/A ...	.007
Competitor Assumption (L: .147)	Belief abo...	COMPAN...	.011
		COMPAN...	.006
		COMPAN...	.004
		ALPHA/A ...	.006
	Past expe...	COMPAN...	.012
		COMPAN...	.009
		COMPAN...	.006
		ALPHA/A ...	.009
	Industry T...	COMPAN...	.013
		COMPAN...	.010
		COMPAN...	.008
		ALPHA/A ...	.005
Competitor Strategy (L: .375)	R&D Proi...	COMPAN...	.021
		COMPAN...	.015
		COMPAN...	.010
		ALPHA/A ...	.010
	Capital In...	COMPAN...	.019
		COMPAN...	.015
		COMPAN...	.011
		ALPHA/A ...	.011
	Promotion...	COMPAN...	.020
		COMPAN...	.014
		COMPAN...	.020
		ALPHA/A ...	.000
	Strategic ...	COMPAN...	.000
		COMPAN...	.000
		COMPAN...	.000
		ALPHA/A ...	.000
Competitor Capability (L: .259)	Technolog...	COMPAN...	.010
		COMPAN...	.010
		COMPAN...	.005
		ALPHA/A ...	.010
	Operation...	COMPAN...	.014
		COMPAN...	.011
		COMPAN...	.008
		ALPHA/A ...	.017
	Product a...	COMPAN...	.020
		COMPAN...	.016
		COMPAN...	.012
		ALPHA/A ...	.016
Competitor Capability (L: .259)	Product Q...	COMPAN...	.012
		COMPAN...	.009
		COMPAN...	.007
		ALPHA/A ...	.012

Figure 8: Synthesis of Competitor Evaluation

The global priority calculation was the last stage where all values were obtained through the process of synthesis of all local priorities. The conventional AHP approach was applied for an additive aggregation with normalization of the amount of the local priorities to unity (Ishizaka et al., 2009) by using the following formula:

$$P_i = \sum_j w_j . l_{ij}$$

The concluding ranking of all alternatives is presented in Figure # 9 on the basis of the calculations as mentioned above.

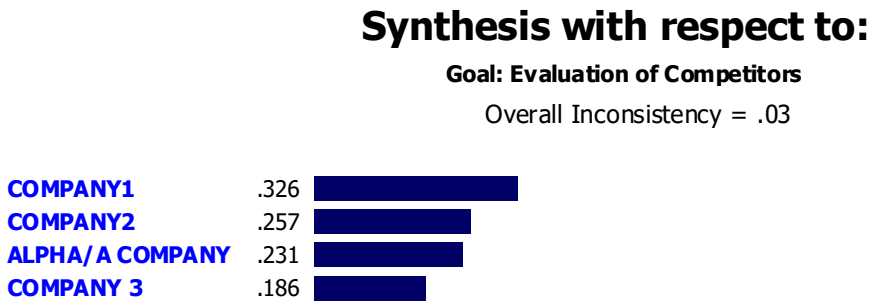

Figure 9: Competitors Ranking Results

The overall ratio of consistency during the evaluation process remains 0.03, which is considered a good figure as the acceptable value is 0.1. It is concluded through the results that the evaluation process is consistent, highlighting the general position of the company in view of the customers. The position of the company against any criteria or sub-criteria can be calculated to observe the performance of the company according to any single criteria. Similarly, the methodology was applied to evaluate Company B. The managers of two companies valued them as the main competitors and the degree of the ranking of the companies was displayed in Table # 4.

Table 4: Company B Competitive Rating

	Critical Success Factors	Company 1	Company 2	Company B
1)	Financial Position	5	5	3-5
2)	Market Share	5	2-3	3
3)	Technology Leadership	5	2	3-4
4)	Belief about Competitive Position	6	3	5
5)	Post Experience with the Product	6	6	3
6)	Industry Trends	5	2	5
7)	R&D Projects	5	2	5
8)	Capital Investment	5	2	5
9)	Promotional Campaign	5	3	2-3
10)	Strategic Partnership	5	2	5
11)	Technological Capability	5	2	5
12)	Operational Performance	3	2	3-5
13)	Product Acceptance	3	2	2-3
14)	Product Quality	2-3	2	2-3

The pairwise evaluation of the Critical Success Factors was executed to estimate the preference rating in accordance with the company B standpoints. In order to evaluate the competitive position of company B, the development of rating formulas and the process of synthesis was done. In Figure # 10, the ranking of the factors along with the rating of company B after synthesis is shown below:

Model Name: Competitor Evaluation Company B

Treeview

Alternatives

COMPANY1	.463
COMPANY2	.158
BRAVO/B COMPANY	.379

Figure 10: Company B Attribute Ranking & Competitor Evaluation

In the first phase, the framework evaluated the external environment comprehensively, which demonstrated the demands of the customers and trends of the market and the position of the companies against the competitors.

13.3 Market Evaluation & Competitor Analysis Results

The responses collected from both companies A and B for market evaluation exposed that both companies were encountering the same challenges like unpredictable market demands, high time to market, and high demands for customization of the products. Both companies were also

investing in their efforts to obtain the biggest market share. According to the collected data, discussions, and results, it was authenticated how these challenges prevail globally irrespective of the geographical boundaries. The results of evaluating the competitors of company A against 4 main and 14 sub-criteria are presented in Figure 11.

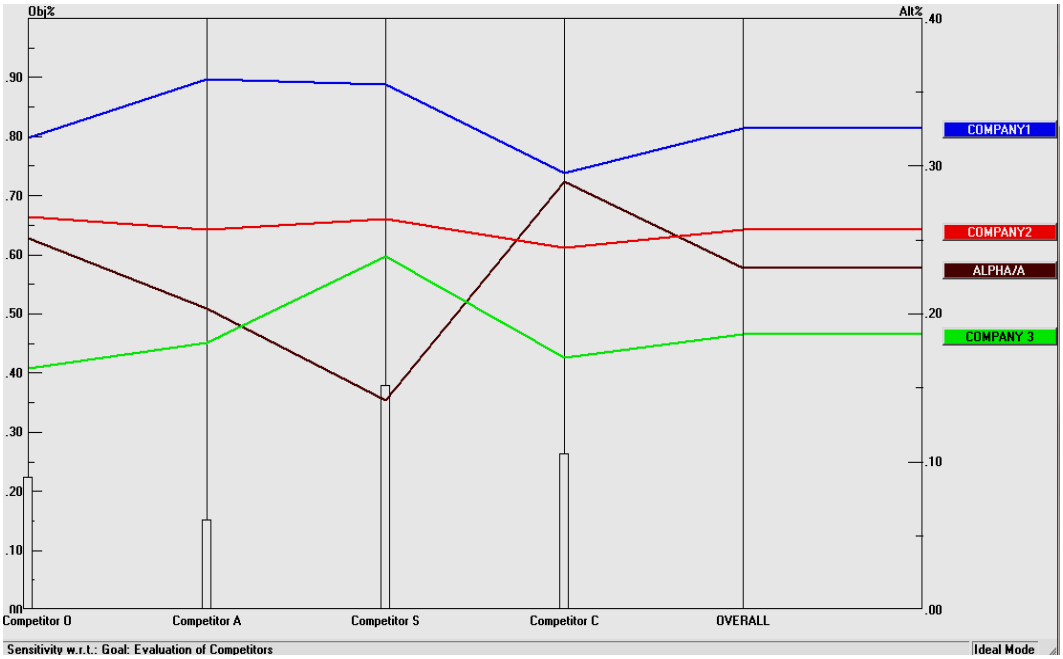

Figure 11: Competitor Evaluation Result Company A

It is obvious from Figure 11 that the strategy for competitors was principal and significant for the decision-making process with a contributory role of about 37.5% while competitor competence, assumptions, and goals were calculated as 25.9%,14.7%, and 21.9 %, respectively. In the context of competitor strategy, the performance of company A was calculated as too low figure up to the company, 1, 2, and 3 regardless of its crucial significance. The performance of the company was considered at the lowest level as compared with its two competitors and at a high level as compared with company 3. Figure 12 demonstrates the existing position of company A against its competitors.

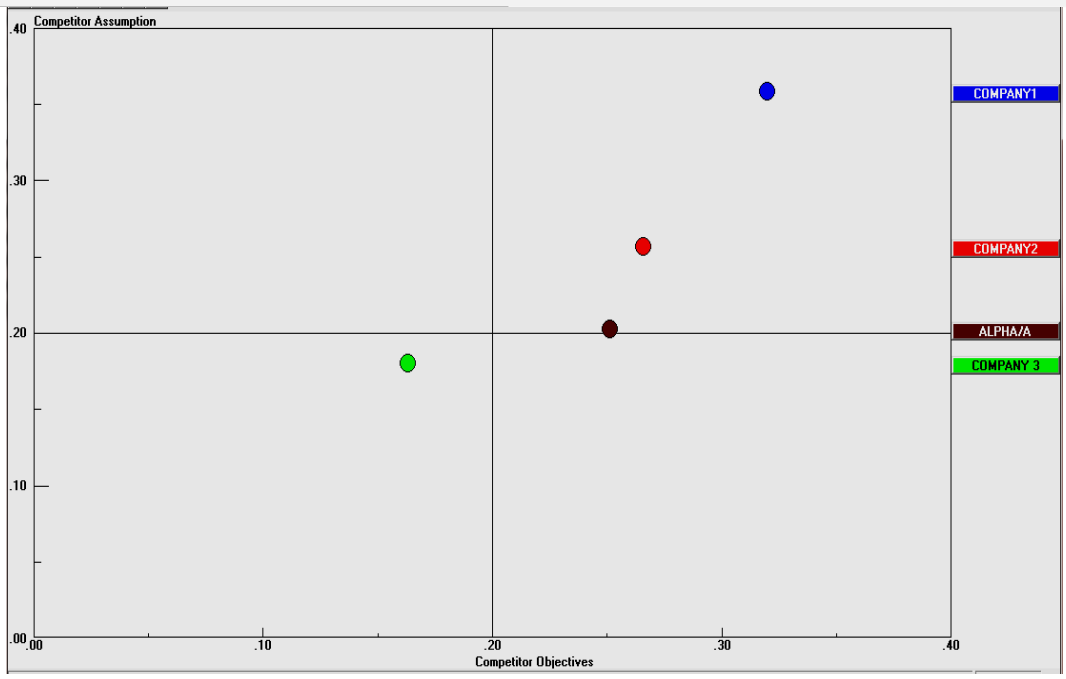

Figure 12: Competitive Positioning of Company A in the Market

The analysis provides directions to minimize the competitive gap by putting into practice all efforts and competencies. In view of the evaluation of company B, the competitor objectives weighted about 42.5% due to highly technology-intensive businesses. The significance of competitor strategy, assumption, and capacity was calculated as 29.2 % and 11.2%, respectively. In Figure 13, the results of competitor evaluation are shown below:

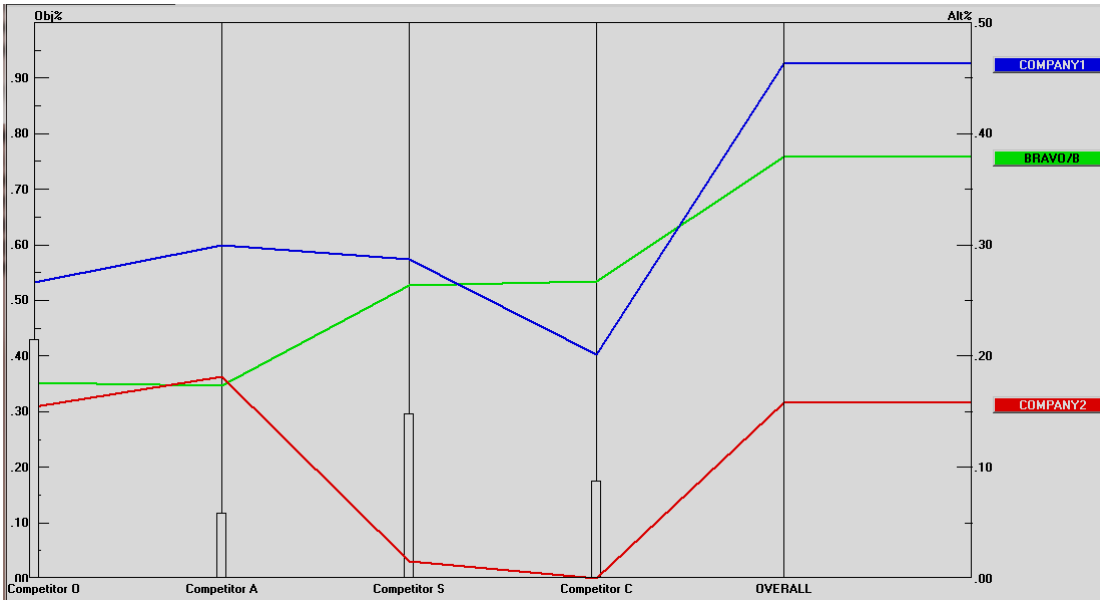

Figure 13: Competitor Evaluation Result Company B

It is obvious from Figure 13 that company B was poorer than company A in the perspectives of objectives and competitor capability. The overall performance of Company B was poor compared with its main competitor but it was better compared to other company 2. In Figure 14, the competitive position of company B is shown, whereas the performance of company A is shown on the outer line of the grid.

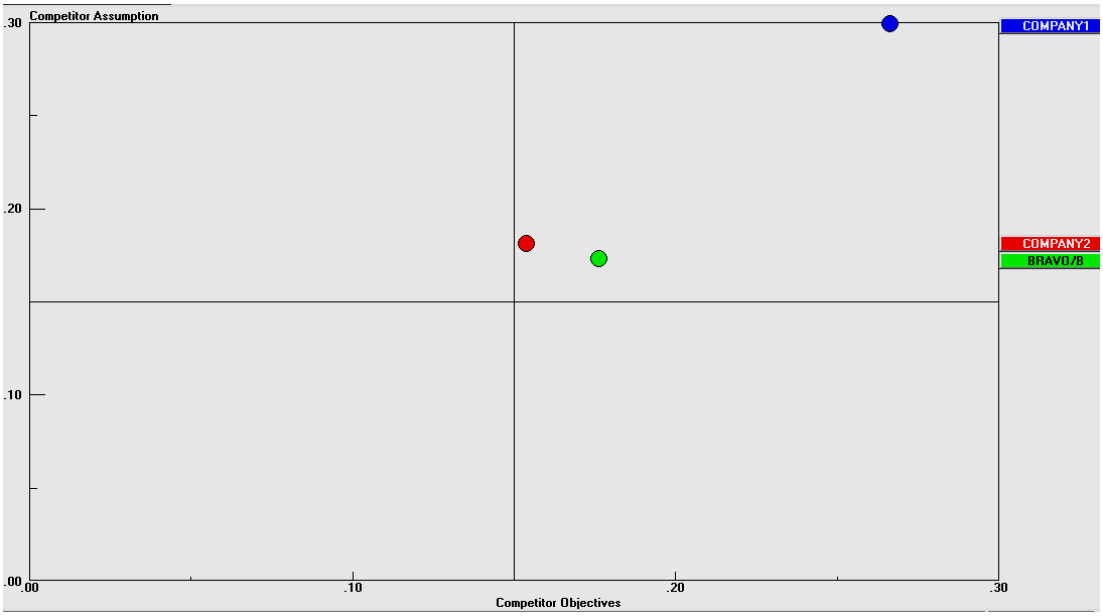

Figure 14: Competitive Position of Company B in the Market

The competitor evaluation of both companies pinpointed the strategic areas for further improvements to have better market positioning. Without strategic directions, it is useless to enhance the operational performance and ultimately, the results would be ineffective and unproductive.

14. Internal Business Analysis/Analyse

This procedure comprises many steps to examine the capacity of the current operations and processes using technology for delivering the required results through the External Environment Analysis.

14.1 Importance Performance (IP) Analysis

According to Martilla and James, it is difficult to translate research results into action and the research may be conducted after reviewing the one side of the customer acceptance, which would be importance-performance attributes rather than of both sides(Martilla & James, 1977). The researchers obtained the ratings on a four-point scale through the development of an importance-performance grid. Slack (1994) developed a nine-point scale that is entirely different from the four-point scale as developed by Martilla and James. The operational

performance was assessed on the basis of a nine-point scale, proposed by Slack (Slack, 1994). Approximately 33 criteria were pinpointed to check the influential role of RP.

To evaluate the performance of company A against the critical success factors, a detailed discussion was done with general managers and production managers of company A about the IP analysis questionnaire. Every item of the questionnaire was generally discussed as well, specifically in the context of the project. In Figure 15, the collected responses were plotted on an IP diagram as it is shown below:

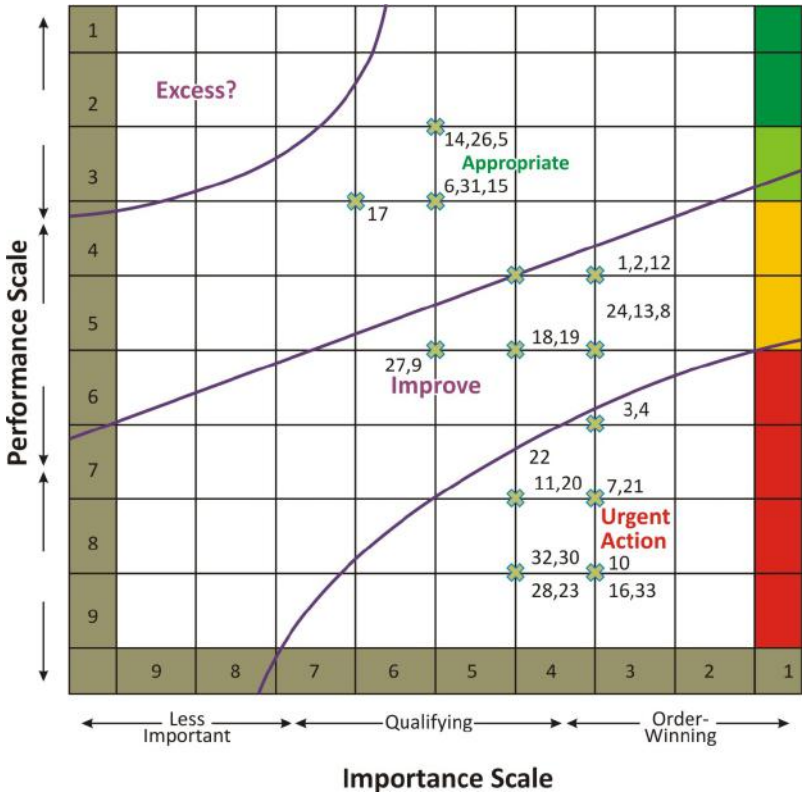

Figure 15: Importance Performance Analysis Company A

The IP analysis elucidates the operational performance of the company so clearly. The results of this analysis are described here:

There is a need for immediate action as order winning criteria is poorer than markets and competitors.

i) Time to Market, Improved Production, Short Life Cycle
ii) Reduce operational length, Redesigning Cost, Ease of operations
iii) Cost of waste, Rapid new production introduction, Quick Design change
iv) The complete product development cycle

Order winning criteria, similar to competitors but need improvement.

i) Process Flexibility, Cost-effective customization, Low inventory
ii) Increased synchronization, Low Cycle Time
iii) Design Freedom, Assembly Cost

iv) Better Product Performance & Product Return

Order Qualifying Criteria same as Competitors

i) Part count reduction, Reduce computing cost
ii) Supply chain cost, Variable order size
iii) Visual aid for toolmakers
iv) After-sale service

As shown in Figure 15, the specific parameters for time to market and launching new products are essential for gaining a competitive position like quick design and compressed development cycle, but the company was not performing well according to these parameters. Another area for improvement in the company includes design freedom, increased synchronization, and assembly cost. The company was performing well in the domain of chain cost, after-sale services, and part count reduction. The root cause of this poor performance was the cheap labor and obtainability of standard parts in the local markets.

Company B managers were also requested to fill the questionnaire. The main aim of this analysis was discussed here:

i) To pinpoint the significance as well as the performance of the company through the selected critical success factors
ii) How a company of the developing and developed countries identify such factors and how much the company has the capacity to tackle the pinpointed importance rating.
The response collected was plotted on an Importance-Performance Analysis Diagram as it is shown in Figure 16

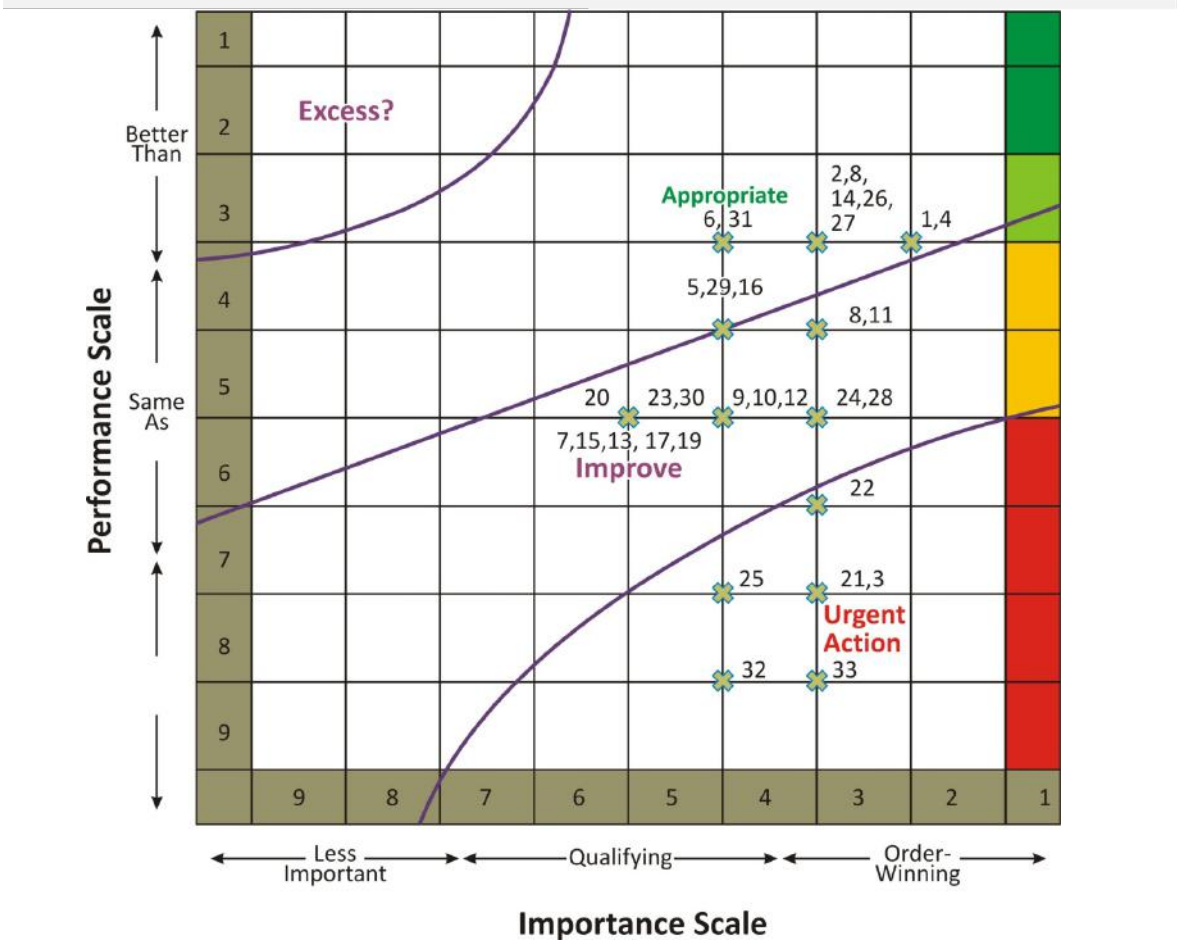

Figure 16: Importance-Performance Analysis Company B

The results of Importance-Performance Analysis of Company B are as follows:
Immediate action is required for order winning criteria as it was worse than competitors.

i) The cost associated with time to market
ii) Redesign cost
iii) Supply chain cost
iv) Low director labour, Product Development Cycle

Order winning and Qualifying Criteria, similar to the competitor but need improvement.

i) Low volume production and inventory, reduce operational length and cost
ii) Increase synchronization, low cycle time, assembly cost
iii) Ease of operations, cost of waste
iv) Production warranty, Rapid new introduction

Order winning and Qualifying Criteria same as Competitors

i) The cost-effective customization ability, fast response
ii) Low volume production, ease in innovation
iii) Better product performance,

iv) Setup time, variable order size

According to the data analysis of company B, the most significant order winning factors were the reduction of labor and supply chain cost, improved product development cycle, and time to market and there is a need to improve organizational performance in accordance with these factors as the performance of the company is not good. Other factors like ease of operation, reduced operational length and increased synchronization also require further improvements. In the context of IP analysis, both companies, A and B, have to encounter common challenges and incapable of handling them in both types of countries, developing and developed ones like time to market and short product development cycle, consisting of some other functions like short cycle time and improved synchronization, etc. Company B has to bear the high cost of labor and supply chain in the developed country as compared to company A. Launching new products within a short cycle time with the approval of the customers is one of the biggest challenges for both companies.

15. Conclusion

In previous studies regarding technology, there is no focus on developing an understanding of adopting the latest technologies and changing scenarios of the business requirements and customers' demands, particularly in the perspectives of SMEs. SMEs in developing countries are not capable of aligning with the changing scenarios of the Global Value Chain (GVC). Though SMEs have business relationships with the multinational firm, which are efficient parts of GVC, they are very competent and resourceful to tackle all such issues. There is a widening gap among the large companies and SMEs on the basis of the mismatched response levels, creating difficulties for SMEs to get maximum market share.

The companies fail to understand how to compare themselves with the potential competitors and evaluate the competitive position, considering the competitors as exceptional performers. Overall, all business firms are unaware of changing global value chain demands that's why these firms are incapable of getting a maximum share in GVC and avail the greatest opportunities. It is not necessary to compare with the potential competitors but to get ready to meet the changing demands of GVC in order to get more opportunities in the global marketplace.

In the previous literature regarding the selection of technology, it was assumed that the technology adopter has a complete understanding and knowledge about all possible features and capacities of the particular technology. In fact, it was revealed that the existence of merely a few RP systems was known academically at the public universities rather than at the organizational levels.

The Production Managers of Company A were unaware of such advanced technology when the advanced features of RP technology were introduced to them and it is very common in

SMEs. It is quite difficult to adopt and implement the latest technology at the workplace without knowing much about it just as if someone is forced to have a driving seat but not much aware of where to go and what is the destination. Resultantly, the journey would be in the wrong direction. Similarly in the case of adoption of RP technology in SMEs which should have a vivid understanding of the objectives and directions of the technology selection and adoption at the organizational levels.

In developing countries, the condition of SMEs is worsening as the managerial staff of Company A was unaware of the criterion set for IP analysis and Competitor Evaluation, it was indicated that there was no synchronization of the company with the changing demands of the market. Resultantly, company A was compelled to close all operations in 2012 due to the lack of business competitiveness despite its ruling over the market of fiberglass for about three decades. The cutdown in generating revenues of such companies can be calculated easily. The recommendations and suggestions should be effective and productive to improve the business operations of such companies practically.

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