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TECHNOLOGY DEVELOPMENT PROCESS AND MANAGING UNCERTAINTIES WITH SUSTAINABLE COMPETITIVE ADVANTAGE APPROACH

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Keywords: Sustainable Competitive Advantage (SCA), SCA risk level, knowledge and technology effect, manufacture strategy index, product and process development cycle

Abstract: The main purpose of this research work is to assist the decision-making process which is related to technology and knowledge factor within an organization. The data has been gathered and analysed from a particular multinational company that operates in the ceramic manufacturing industry within Malaysia. Four respondents were sought to answer the sense-and-respond questionnaire, including the part on technology sharing. The priority among technology types, including basic, core, and spearhead was decided by the maximum coefficient of the variance. The work has two main contributions: 1. It proposes and validates a tool for decisions and strategies related to technology focus in firms, and 2. expands the notion of technology types from focusing only on product development to one that focuses on both product and process development. The results of the study show that the proposed model which was previously applied in high tech start-ups and local medium-size enterprises is applicable in large industries involved in mass production.

1 Introduction

It is generally acknowledged that nothing is constant, especially in the competitive business environment, except for change. As such, change creates turbulence and uncertainty, along with affecting the respective dynamics and balances involved in any particular process. Complexity increases the danger of making wrong judgments in today's business world [1]. For instance, changes in Manoeuvring Characteristics Augmentation System (MCAS) software that was misaligned with Boeing’s 737 MAX sensor caused the entire fleet of 737s to be grounded internationally. These sparks global turbulence in the aviation industry, especially after two of the aforementioned aircrafts crashed. Turbulence thus leads to a shorter product life cycle (PLC), and thus emphasizes the importance of sustaining a competitive advantage in the overall business environment. Indeed, the real goal of any business endeavour is to attain SCA, instead of momentary business advantages. One approach to gauge and attain SCA is via the Resource-Based View (RBV) approach. Through RBV, firms are treated or seen differently, even though they are competing within a similar industry. This perspective is indeed valid and acceptable because, in the RBV, firms are viewed from their respective internal resources. There are few methods to assess and analyse SCA in business environments, such as the Critical Factor Index (CFIs), Sense-and-Response (S&R) method, and manufacturing business strategy.

Ranta and Takala introduced CFIs in 2007 for manufacturing managers to make decisions on allocating and/or reducing critical resources necessary to their respective business processes that were affected [2]. CFI allows decision-makers to sense which business attributes require their response and actions, and this is derived from the experiences and expectations of the firm’s employees, business associates, and customers. Methodologically, the CFI later evolved and redeveloped into the BCFI and so on. This article introduces the grounding theory and its respective literature of SCA and related findings onto the case study of a ceramic manufacturing firm. Subsequently, the discussion and conclusion based on the research's results will also be presented.

2 Theory background

2.1 Competitive advantage

Competitive strategy means being different and having a unique niche within the business environment. Explicitly, "it means choosing a different set of activities to deliver unique value" [3]. In today's' business world, a company can win over its competitors if it can create marketable differences and manage to preserve them. Based on Miles and Snow typology, there are four strategic positions in which a company should consider taking: Prospector, Analyser, Defender, and Reactor [4]. Once a strategic position of the company is set, all the activities and processes should be built upon and aligned with that. Specifically, the concept of sustainable competitive advantage is based on 1. Finding a unique competitive position for the company, 2. Tailoring activities and processes based on the strategy, 3. Making trade-offs, 4. Fitting across activities, 5. Attaining operational effectiveness. In terms of strategy and sustainable competitive advantages, there are occasions where managers just emulate what their competitors have successfully developed. As such, they might chase each new technology without evaluating its suitability with their main strategy. Although both external and internal factors affect company positions in the markets and its profitability, it is often the case that internal factors are extremely important [3]. Based on the resource-based view (RBV), whatever a company needs to succeed in terms of its resources should exist within the firm. Therefore, the main challenge of a company is how to use its limited resources and angle its process towards gaining competitive advantage [5].

2.2 Technology as a source of competitive advantage

Technology is one of the main drivers of competition. It can change the structure of an industry, create new business opportunities or eliminate businesses. Despite the importance of technology, it should be emphasized that technology is not important for its own sake. Technology is important if it helps firms to reduce costs, create differentiation, and improve the quality of their products. Technology is embodied in every value activity and everything a firm does, involves some sort of technology [6]. Therefore, technology can have a powerful effect on both cost and differentiation. If a firm can discover better technology for performing a process better than other competitors, it can gain a competitive advantage [7].

Abernathy and Utterback (1987) studied the concept of technology in manufacturing and suggested that there are two paths for technology in any organisation, namely product technology and process technology [8]. The development of technology starts with the development of products (product technology), and when it succeeds in making differentiation or increasing quality, the development in the process (process technology) begins to reduce the cost with economies of scale. This is illustrated in Figure 1.

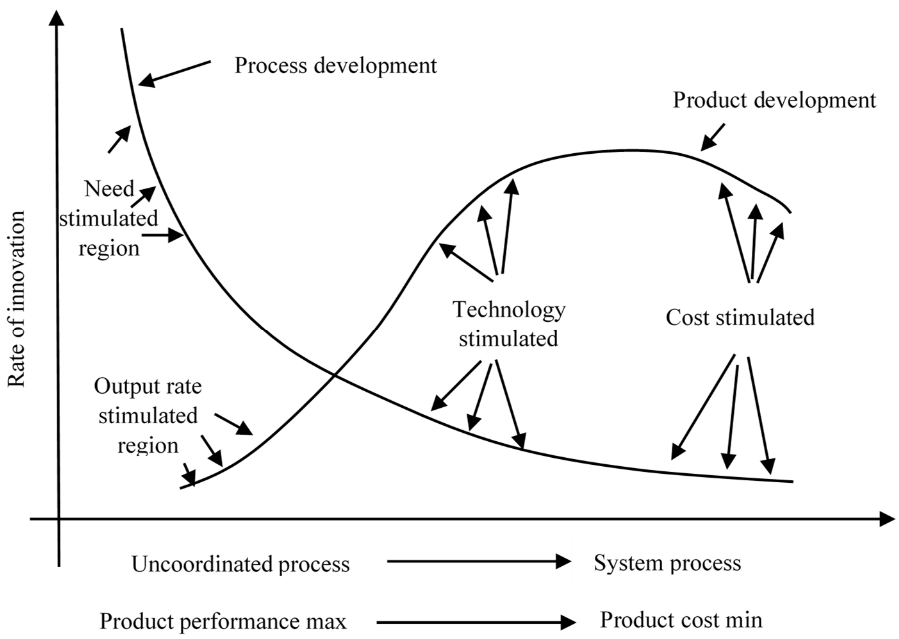

Figure 1 Two paths of technology development: process and product [9]

Tuominen, Knuuttila, and Takala (2003) studied the development of technology regarding the product life cycle and proposed three types of technology: Basic, Core, Spear-head technology [10]. The relationship between these three types of technology and the product life cycle is demonstrated in Figure 2.

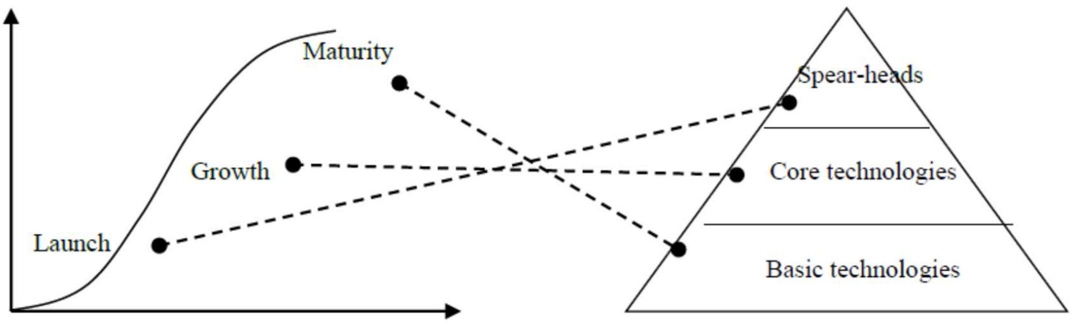

Figure 2 Different technology through product life cycle [10]

Product development starts with spear-head technology. This kind of technology helps a company to differentiate itself in the future and gain a competitive advantage. In the particular ceramic tile manufacturing firm used for this case study, spear-head technology included automated kiln (baking processes) and conveyor-based automatic movement (including sensors). The core technology is the kind of technology that got approved in product development and brought a competitive advantage to the firm in the current situation. Indeed, core technology is the previous spear-head technology which has also developed the process in such a way it is suitable for the economy of scale and yet is cost-effective. In this case, the core technology would be the press-moulding process and its moisture-sensitive controlling mechanism. Finally, basic technology is related to mature technology which might have less cost/benefit trade-off in improving, and sometimes the firm outsources basic technology to focus on core and spear-head technology development. In this manufacturing firm, basic technology includes raw-material control/selection mechanism, painting processes, and packaging operation.

Considering the Tuominen et al., (2003) work, we can draw a more comprehensive picture of the different technologies through the process and product technology development [10], as depicted in Figure 3.

3 Literature gap

A focus on technology and decision about technology investment is a fundamental problem that is faced by the management field. By making the right choices in the technology to invest in and following correct technology strategies, firms can gain and sustain competitive advantage which guarantees their success in the market. Takala, Leskinen, Sivusuo, Hirvelä, and Kekäle (2006) proposed a sand cone model to prioritize different strategy focus, including knowledge and technology, in the Finnish air force [11]. This model was also applied to determine the strategy and knowledge focus of the Finnish ice hockey team [12]. Later on, the sand cone model was also applied to knowledge management strategy in a Malaysian university library [13]. Coccia (2017) developed a framework of technology choices during its evolution in an organization and sought to answer the question of when to apply radical development in technology and when it is suitable to use incremental innovation in technology [14].

There are some researches which follow Barney and Wernerfelt, considers the firms' limited resources, and tries to prioritize the technology and knowledge need of the firm based on the main strategies of the companies in such a way that resource allocation for all the different activities is balanced [15,16]. The main idea behind these research works is to find that type of technology (basic, core, spearhead) which causes the highest amount of uncertainties in the firm and to invest in it to reduce risk and sustain a competitive advantage. In the study by Takala, Zucchetti, Daneshpour, Kunttu, Välisalo, Pirttimäki and Kiiski (2016), the concept of different types of technology (spear-head, basic, and core) is used within the sand cone model, with the authors using the maximum coefficient of variance to decide which types of technology causes the highest amount of uncertainty among different departments [17]. This work built upon the previous works and tried to apply both the RBV and sand cone models in establishing technology requirements. The research was based on this particular assumption that the main source of risk and uncertainty was due to the difference in the attitude of decision-makers in dealing with the subject [18]. Moreover, this research sought to expand the notion of technology in both the product and process development phase. Finally, the proposed mothed is applied in a multinational conventional company for the first time while the previous works focus on technology-based start-ups and local industries.

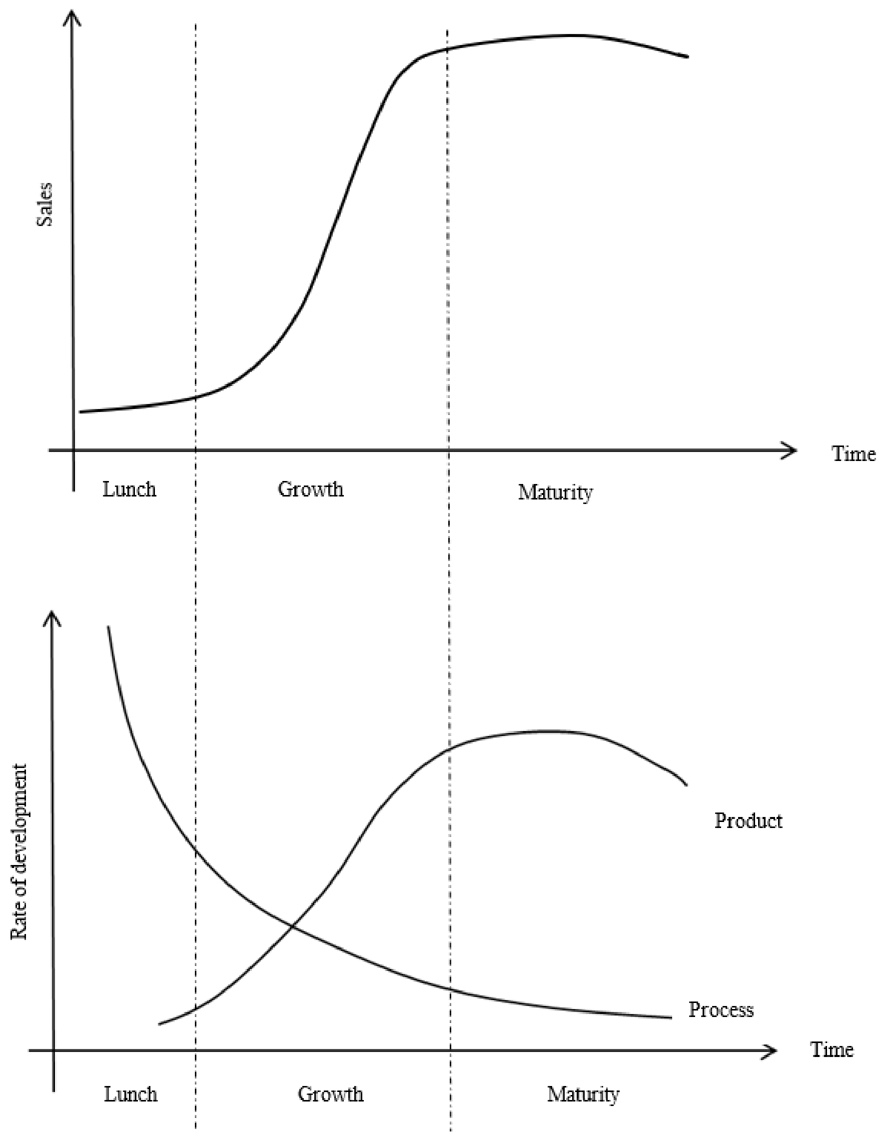

Figure 3 Different technology all over product and process development

4 Method

This research applies the sense and respond questionnaire, a method introduced by Ranta and Takala [2]. The sample of this questionnaire is presented in Table 1. Having filled this questionnaire, respondents evaluate their expectations and experiences regarding each attribute. Also, they are able to compare themselves with competitors and determine the development of each criterion within a specific time frame.

Table 1 Format of sense and respond questionnaire.

Performance attribute	Scale: 1=low, 10=high		Compared with competitors			Direction of development		
	Expectation (1-1)	Experience (1-10)	worse	same	better	worse	same	better
Performance 1								
Performance 2								

In order to integrate sense and respond questionnaire to Miles and Snow topology (which is one of the most popular business strategy classifications), each attribute above is assigned to the component of the RAL model [19] based on the RAL model, prioritizing among quality, cost, time and flexibility is directly related to responsiveness, agility, and leanness [2]. This relationship is demonstrated in Figure 4.

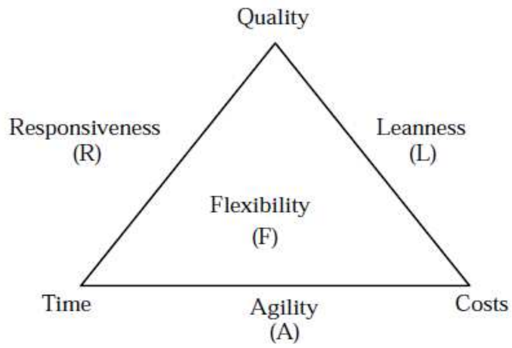

Figure. 4. RAL model [20]

Table 2 presents attributes which are used in this study. It also presents their assignment to the RAL model components.

Table2. Detail attributes of the sense and respond questionnaire

	ATTRIBUTES	
	Knowledge & Technology Management	
1	Training and development of the company's personnel	← Flexibility
2	Innovativeness and performance of research and development	← Cost
3	Communication between different departments and hierarchy levels	← Time
4	Adaptation to knowledge and technology	← Flexibility
5	Knowledge and technology diffusion	← Cost
6	Design and planning of the processes and products	← Time
	Processes & Workflows	
7	Short and prompt lead-times in the order-fulfilment process	← Flexibility
8	Reduction of unprofitable time in processes	← Cost
9	On-time deliveries to customer	← Quality
10	Control and optimization of all types of inventories	← Quality
11	The adaptiveness of changes in demands and in order backlog	← Flexibility
	Organizational systems	
12	Leadership and management systems of the company	← Cost
13	Quality control of products, processes and operations	← Quality
14	Well defined responsibilities and tasks for each operation	← Flexibility
15	Utilizing different types of organizing systems	← Flexibility
16	Code of conduct and security of data and information	← Cost
	Information systems	
17	Information systems support the business processes	← Time
18	Visibility of information in information systems	← Time
19	Availability of information in information systems	← Time
20	Quality & reliability of the information in information systems	← Quality
21	Usability and functionality of information systems	← Quality

Additionally, respondents are requested to evaluate each of the attributes above in terms of the percentage share of technology. They should also determine the share of basic, core, spear-head technology in detail so that all the attributes combine into a sum totalling 100%. The idea behind this corresponds to Porter's point of view, which is that everything a firm does shall incorporate some sort of technology [7].

Once the questionnaire is filled, the next step is to find which technology type causes the biggest amount of disagreement among respondents for each attribute. To find the source of disagreement and uncertainties, variability coefficient regarding each technology is calculated as follow:

$$Coef.Var_{Basic} = \frac{Standard\ Deviation_{Basic}}{Average_{Basic}} \quad (1)$$

$$Coef.Var_{Core} = \frac{Standard\ Deviation_{Core}}{Average_{Core}} \quad (2)$$

$$Coef.Var_{Spear\ Head} = \frac{Standard\ Deviation_{Spear\ Head}}{Average_{Spear\ Head}} \quad (3)$$

In order to evaluate the risk level associated with each type of technology regarding RAL model components, formula 4 is used:

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$$c_1: Quality, c_2: Time, c_3: Cost, c_4: Flexibility$$

$$\begin{cases} Total\ TK\ \underset{c_1,c_2,c_3,c_4}{risk}\ (RMS) = \sqrt{\sum_{c_1,c_2,c_3,c_4}\left[\left(\sum_{b_1,c_1,sh} Coef.Var_i\right)^2\right]^2} \\ Partial \begin{cases} TK\ \underset{c_1,c_2,c_3,c_4}{risk}\ Basic\ (RMS) = \sqrt{\sum_{c_1,c_2,c_3,c_4}\left[\sum_b \left(\frac{std_i}{mean_i}\right)^2\right]^2} \\ TK\ \underset{c_1,c_2,c_3,c_4}{risk}\ Core\ (RMS) = \sqrt{\sum_{c_1,c_2,c_3,c_4}\left[\sum_{core} \left(\frac{std_i}{mean_i}\right)^2\right]^2} \\ TK\ \underset{c_1,c_2,c_3,c_4}{risk}\ Sh\ (RMS) = \sqrt{\sum_{c_1,c_2,c_3,c_4}\left[\sum_{sh} \left(\frac{std_i}{mean_i}\right)^2\right]^2} \end{cases} \end{cases} \quad (4)$$

In the formula above, the $Coef.Var_i$ for different types of technology is calculated by formula 1-3. In order to evaluate how the strategy related to knowledge and technology is sustainable, the following formulas are used:

$$Total\ Risk(Geom) = [(1 - SCA)TKrisk]^{\frac{1}{2}} \quad (5)$$

$$Total\ SCA\ risk\ level = 1 - Total\ Risk(Geom) \quad (6)$$

In formula 5, SCA stands for the sustainable competitive advantage of a firm without considering the technology and knowledge.

5 Results

The results of the study show that the resource of the ceramic manufacturing firm is correspondingly allocated among different tasks. Resource allocation based on the Balanced Critical Factor Index (BCFI) is presented in the following bar chart.

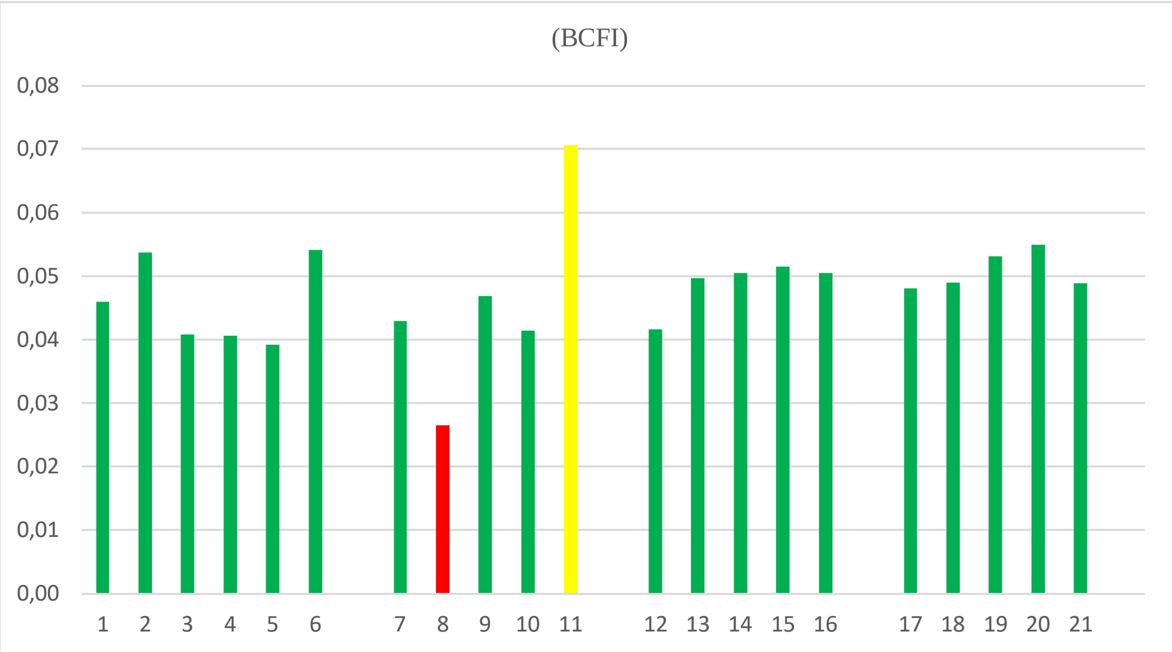

Figure 5 Resource allocation of the company based on the BCFI

As Figure 5 illustrates, only the attribute "Reduction of unprofitable time in processes" is under-resourced and the "Adaptiveness of changes in demands and in order backlog" is an over-resourced attribute. In terms of strategy position, the manufacturing firm is an analyser type, which is based on Miles and Snow typology [21]. The manufacture strategy indices are presented in Table 3 and Figure 6.

Table 3 The manufacturing firm's business strategy indices

PROSPECTOR	ANALYSER	DEFENDER	REACTOR
0.89	1.00	0.90	0.89

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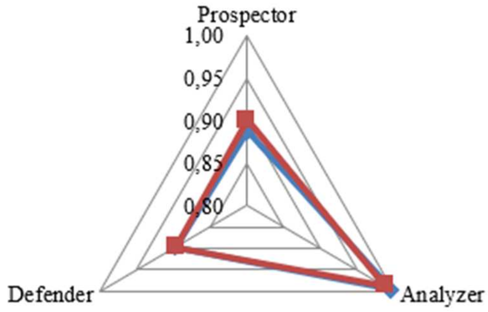

Figure 6 Company business strategy based on Miles and Snow typology

The percentage share of different technology for different attributes are presented in Figure 7.

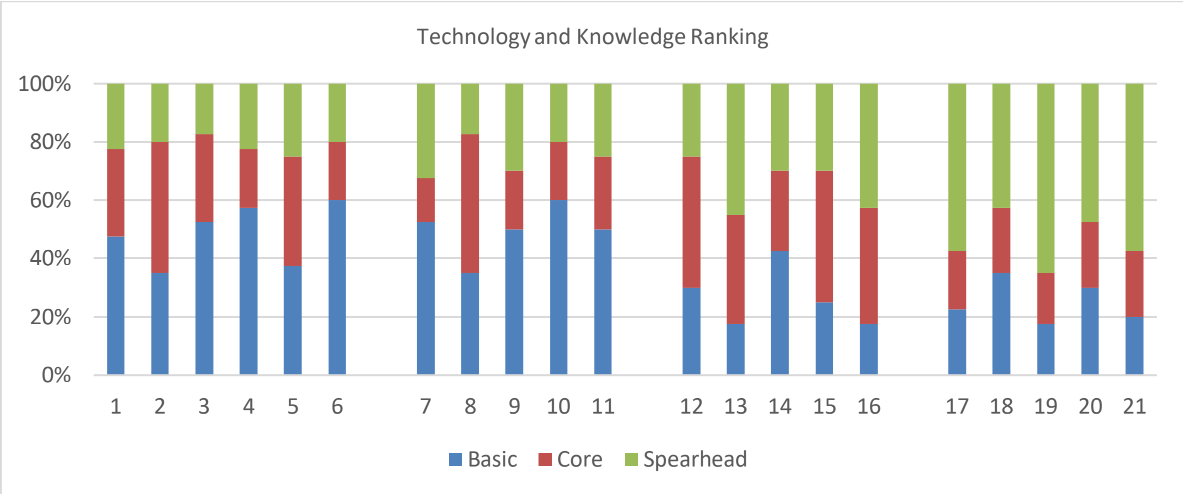

Figure 7 Percentage partition technology share for different attributes

As Figure 7 demonstrates, one technology is not the most dominant one for all the attributes. For example, spear-head technology is the dominant technology for activities related to information systems while basic technology and core technology correspond with dominance in activities related to “knowledge and technology management” and “organizational system”, respectively.

The coefficient of variance and risk related to each type of technology is calculated based on formulas 1 to 6 and the results are presented in Figure 8.

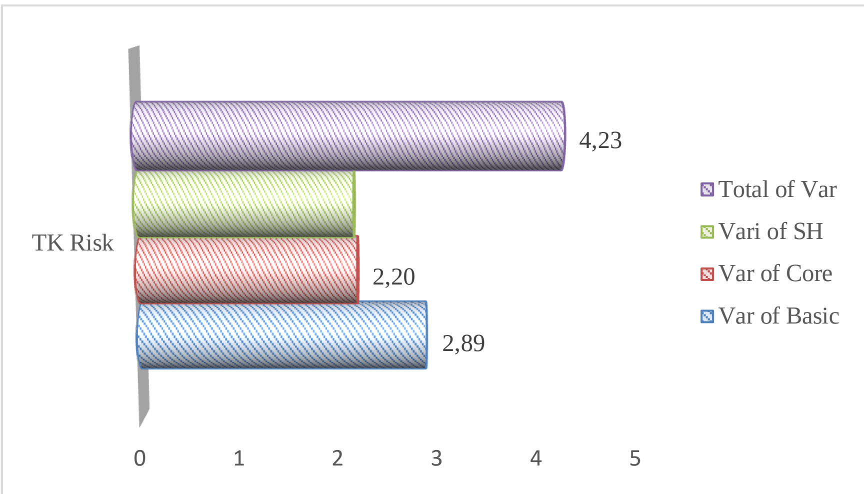

Figure 8 The uncertainties related to different technology and overall variance perspective

As depicted in Figure 8, basic technology is the main source of risk and uncertainties in the ceramic manufacturing firm. Considering the development of technology in terms of process and product, dominating basic technology shows that the firm should invest more in process development rather than product development. In strategic move and initiative, the firm should invest more in developing manufacturing processes, including automation, and at the same time, look towards reducing the overall operational cost.

Figure 9 presents the impact of technology and knowledge policy in gaining a sustainable competitive advantage for the manufacturing firm. As is presented in figure 9, and taking into consideration the knowledge and technology perspectives, the firm resource allocation and policy is significantly less sustainable compared to the situation in which technology and knowledge factor are excluded.

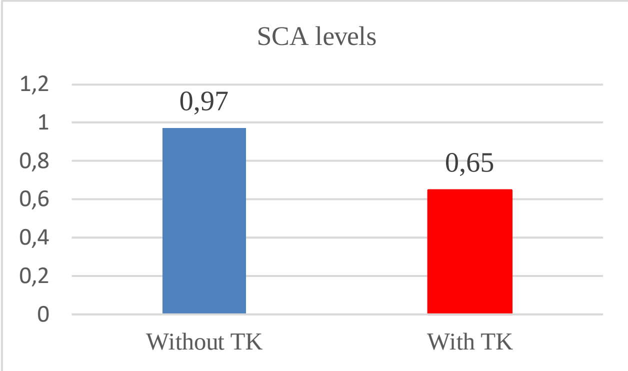

Figure 9 The effect of technology and knowledge factor on the level of SCA

Specifically, the comparison of the total SCA considering knowledge, technology, and sustainability regarding each type of technology is presented in Figure 10. The figure also shows that the decision regarding basic technology is less sustainable as compared to other types of technology.

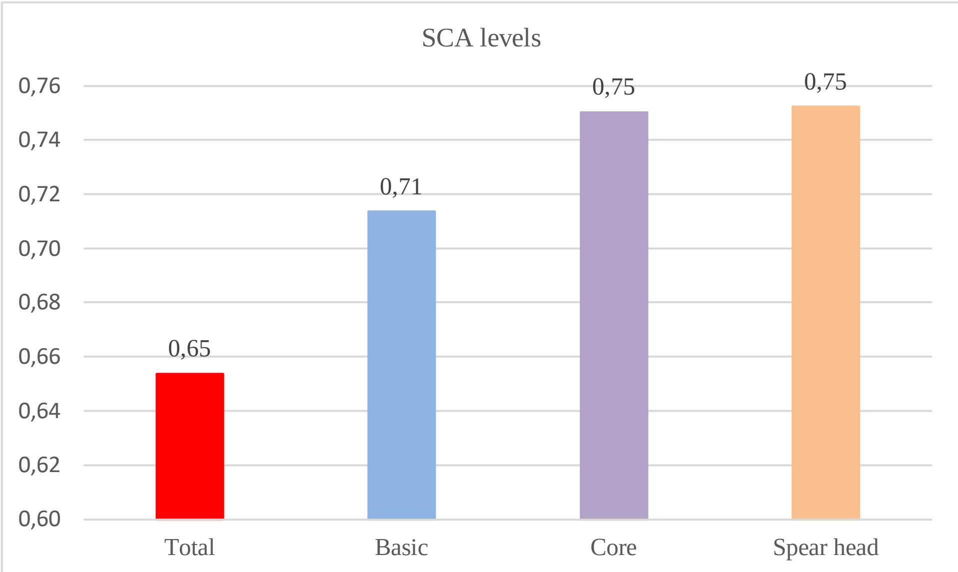

Figure 10 The SCA level with technology and knowledge factor, total and partial

6 Discussion

This research contributes to the field in two main subjects:

1. Developing a tool for technology and knowledge decision-making activities. In this regard, this work is built upon previous works that propose a method to prioritize technology investment and validate it in high-tech start-ups [22]. What is new here is that the proposed model is applied to a multinational large-size firm in a more conventional industry and the obtained results proved that the model is applicable both in general and in a conventional manufacturing industry.
2. The work contributes to current literature related to process and product development phases in the firm. Previous works made a connection only between technology types and product development. However, this work expanded the concept further and related technology types to both product and process development. Based on the current literature, innovation and development in the firms begin with the product. Tasmin and Woods (2007) advocate that product innovation is strongly related to the effective management of a firm's knowledge, process, technology, and its niche market [23]. Once a firm produces a product that can differentiate itself from others, the next stage would be to develop the relevant processes in such a way that producing the new product could also be made economical. The initial phase of product development, which is called the launching phase, is

closely incorporated with spearhead technology. At this stage, the cost of producing a product is extremely high, with the firm generally having an internal plan to apply it in the future and reduce its cost. In the phase of growth, the ability of new products in making differentiations is proven and the process is optimized in such a way that producing the new product on a large scale is economical. This condition where both product and process development are at the optimal level is related to the core technology. The growth stage of product development is followed by a maturing phase in which neither the product nor the process has the capacity to develop further and the company should reduce the cost of producing its products as much as possible, with a focus on newly invented product and through innovated technology in order to sustain its position in the market. The last phase is very much related to the existing basic technology. This research corresponds to the different types of technology which is embedded in the initial process and product development phase. The domination of basic technology in the studied firm in this research suggests that the firm should focus on the development of this current process rather than developing new products to sustain its position and competitiveness in the market. This result corresponds to the situation of the attribute “reduction of unprofitable time in processes” being an under-resourced attribute. This attribute also belongs to the “Cost” component of the RAL model. Therefore, investing this criterion, and related issues such as better control of work-in-progress, will ultimately reduce costs.

7 Conclusion

Business strategy as a comprehensive plan that integrates a firm’s major goals and action plans, positioning it as an essential role in a firm’s success. The role of business strategy is more important in today’s business world because of rapid change and the turbulent environment in the global business landscape. The concept of technology and the decision related to that is very important because the level of automation in industry is increasing rapidly, particularly with the introduction of new technologies and robots [24]. Since the mid-1990’s, sense and respond point of view has replaced traditional “make and buy” attitude in the business world and enabled firms to sense market changes in a timely manner and respond to those changes quicker [25]. Since the introduction of sense and respond philosophy, different research works have been conducted to integrate Miles and Snow typology and to constitute different drivers of competition. The latest effort was to consider technology and knowledge factor in the sense and respond questionnaire and try to propose a method that assists technology and knowledge decision making processes in the organization. This research work was built upon previous works and considers three types of technology in an organization: basic, core, and spearhead, and tries to show which kind of technology is worth investing in, based on firms' overall strategy and resource allocation. The method which is proposed here is based on the sand cone concept and uses the maximum coefficient of variance of each technology type to prioritize different technologies. The data has been gathered from a big multinational company in the industry of ceramic tile manufacturing, and the results of this study show that this method, which was previously tested in high tech start-ups, could also be implemented in other industries as well. From a practical point of view, the paper tries to present and validate a tool that could constitute technology in company business strategy. This tool could fulfil the communication gap between the operational manager who has main knowledge regarding the technology requirement, and the business manager who is the main person responsible for setting firm business strategy. However, the author suggests the implication of proposed tools in other industries and the inclusion of a bigger number of respondents as well. Another direction of future work would be to conduct a case study and implement the proposed tool among the two different samples of a business: top managers and operational managers, in order to see how much their point of view differs.

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