Exploring the Concept of Technology Management through Dynamic Capability Perspective

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Abstract

It is argue that the study of TM is related to the DCs view in which TM can be explained through DCs lens. The reason why discussion of TM from DCs lens is critical because DCs is designed to explains the source of sustainable competitive advantage in which TM is lacking of. Moreover, under rapidly technological change managing technology will be much difficult in which DCs is providing the guides on how managing the technology can be done under the rapid changes. At the same time, it is well informed that there are many perspectives and school of thought between the two because of their nature of multi-disciplinary and multi-dimensional. Thus, there are similarities and also dissimilarities between them. However, this paper will only focus on the similarities of the two as this can helps to explains how TM can be seen as one form of DCs. It is argue that the similarities between TM and DCs can be discussed under concepts, processes, and lifecycles. It is stressed that the discussion of TM through DCs lens is at exploratory stage. Therefore, the contribution of the paper is to promote the study of TM from DCs perspectives that may open for relevant topics for TM to address current situations.

Keywords: Technology management, dynamic capability, technological capability, rapid technological change, technology lifecycle, capability lifecycle

Introduction

Why relating technology management (TM) to dynamic capability (DCs) is crucial? The study of TM through DCs lens is benefiting the firms in term of explaining the sustainability of competitive advantage (Teece, 2007) as TM is not addressing the sustainability issue adequately in both theories and practices (Brent, & Pretorius, 2007). This is evidenced by the tools and methods use in TM (e.g. Cetindamar, Can, & Pala, 2006) that is mainly not for sustainability. In addition, commercialization and marketing activities have receiving less attention in TM literature (Cetindamar, Can, & Pala, 2006). The commercialization and marketing of resource successfully will help to make a living, thus, DCs is crucial as it is designed to achieve evolutionary fitness which is to make a living for the firms (Helfat, et al., 2007).There are many journals related to TM in which resource-based view (RBV) and DCs papers are published. Even if they are not necessarily connected but at lease the RBV and DCs papers that are published in TM related journals are sharing the issues that are the interests of TM. In addition, Pilkington and Teichert (2006) have listed TM areas such as dynamic organization, alliances and learning, learning organizations, knowledge management, and innovation process in which DCs have similar interests.

For example, the study of technology acquisition through convergence by Hacklin, Marxt and Inganas (2005) that is presented in the 14th International Conference on Management of Technology in Vienna organized by the International Association for Management of Technology (IAMOT) are looking at the role of DCs in which one of the proposed management approaches is the technology RBV.Other examples such as managing inter-industry differences through DCs by Bhutto (2005) published in International Journal of Innovation and Technology Management, and the technological competencies from RBV perspective published in Journal of Engineering and Technology Management (Tyler, 2001). However, the most significant TM study that is related to DCs is discussed by Cetindamar, Phaal, and Probert (2009) in which they demonstrated how TM activities are implemented through DCs lens.The main objective of the paper is to provide understanding on how TM can be studied under DCs lens through the discussion of the similarity in term of concepts, frameworks, and lifecycles of both fields. Thus, the paper will contribute in term of promoting the use of DCs in addressing TM related issues.The study is organized in five sections. In order to understand how DCs and TM are related and relevant to be studied together, the discussion will begins with brief literature review of DCs in section 2.0, followed with the brief literature review of TM in section 3.0. The similarity between the two will be discussed in section 4.0, followed by section 5.0 that will discuss about the potential research areas between the two, while section 6.0 will summarize the discussion.

2.0 Dynamic Capability View

DCs view can be traced back to the works of Penrose in 1959 and rooted to the RBV as both DCs and RBV are sharing the same assumptions and are resource-oriented. However, the field starts to gain attention in early 90s. The most significant works regarding DCs was written by Teece, Pisano, and Shuen in 1997 where the details of the concept was written a decade later in 2007 by Teece. Between those periods, there a growing interest among scholars regarding DCs that is evidenced by the increasing numbers of academic articles published in various international journals and from year 2000 onward the trends are significantly growing.

2.1 The Dynamic Capability Concept

According to Teece, Pisano and Shuen (1997), even though DCs is rooted to RBV, DCs is different from RBV because under RBV perspective, firms gain competitive advantage by possessing bundle of resources or capabilities (used or organized in a special ways) that is heterogeneous among firms. Therefore, with the specific resources they possessing, firms can create wealth through the selection of rational alternative among the potential set of investments. In this aspect, the focus of RBV is exploiting the firms' specific resources or assets to create wealth. In contrast, DCs is designed to create wealth for the firms operating under the environments of rapid technological change with the objective of sustaining competitive advantage. DCs is to build new competitive advantage that meets the changing market needs in a timely manner that emphasizing on two aspects which was not the major focus in the past researches. First, the 'dynamic' aspect of DCs which is refers to the firms' capacity to renew competences such as innovation. Second, the 'capabilities' aspect of DCs which is refers to the firms' ability to create change through the process of integration, building, and reconfiguration of the competences to match the changing environments.

It is not really matter how to maintain the currently enjoyed competitive advantage but what matter most is the way to build competitive advantage under rapidly changing environments (Lopez, 2005). Therefore, in order to face the rapid changing environments, the firms must capable of building the DCs (Kylaheiko, & Sandstrom, 2007) as DCs is an integrative approach to understand the new sources of competitive advantage under dynamic environments (Wu, 2009) where DCs is building the skills and routines that is needed to become competitive (Cepeda, & Vera, 2007).Strategic capabilities are built from resources but possessing of resources does not guarantee capability building of the firms. This is because the resources and capabilities systems of the firms are dynamic in nature and their relationships are always changing. With the valuable, rare, inimitable, and non-substitutable (VRIN) characteristics of the firms' assets, the internal processes and efforts are crucial in building DCs than the external efforts.The firms' resources consist of tangible and intangible assets where the intangible assets are more difficult to manage (Grobler, 2007). This maybe explains why firms normally interested to create flexibility with tangible assets even though it is harder to do instead of intangible assets (Kylaheiko, & Sandstrom, 2007).

Even though some resources can be imitated but the way of exploiting and exploring the resources is hardly imitable (Blyler, & Coff, 2003). This suggests the continuous or semi-continuous realignment of resources, routines, and structures of the firms are crucial in rapid changing environments to achieve strategic fit and to become the source of sustainable competitive advantage.What is fundamental to DCs is the management ability to manage the co-specialized assets based on (technological) opportunities and (market) needs identification (Teece, 2007). Different firms have different DCs because of different environments and strategic importance of change (Zollo, & Winter, 2002). However, even though DCs is idiosyncratic there are commonalities of features of DCs across firms because the way firms' deal effectively with challenges is more or less the same which is known as 'best practice' in the industry (Eisenhardt, & Martin, 2000).DCs performance is measured in term of technical and evolutionary fitness of the resources. Technical fitness is to measure how well capabilities perform it function while evolutionary fitness is to measure how well capabilities can make a living for the firm. However, in order to achieve competitive advantage, firms have to achieve evolutionary fitness in which the technical fitness is one of the sub-sets (Helfat, et al., 2007).

2.2 The Dynamic Capability Framework

There are numerous DCs frameworks in literature and most of them are context dependents. However, the one that is receiving the most attention is contributed by David J. Teece as other frameworks are generally proposed according to the work of Teece (2007), and Teece, Pisano and Shuen (1997). The DCs framework proposed by Teece (2007) is designed in three capacities namely sensing, seizing, and managing threats or transformation. Figure 1 shows the framework proposed by Teece (2007) and is briefly explained as follows:

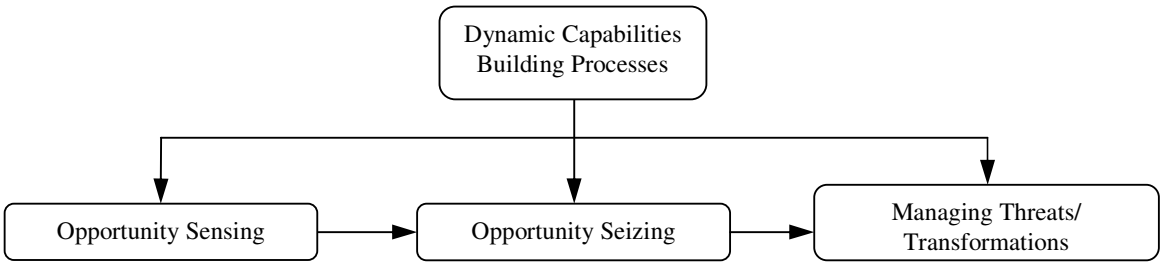


Figure 1
The dynamic capability framework by David J. Teece

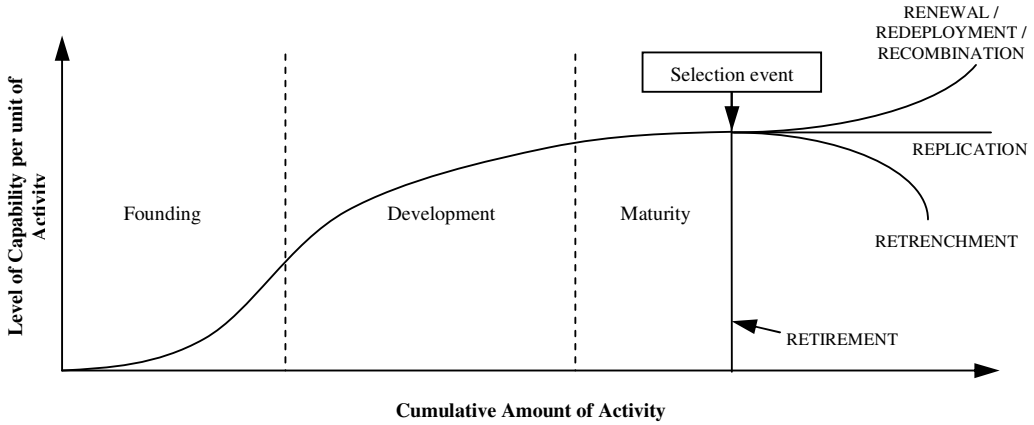
The opportunity sensing capacity: involves scanning, searching, learning, exploring, and calibrating the technologies and markets opportunities and threats. The sensing is needed especially when the market trajectory is hard to be predicted. The new opportunities or threats can be sensed through the investment in researches and other activities as the information gathered from these activities may create new knowledge that may well be open for new opportunities. There are many ways in sensing the opportunities and threats such as through research and development (R&D) activities, and competitors', customers', and/or suppliers' actions that may spot or cause the change to happen.

The opportunity seizing capacity: takes place after the technologies or markets opportunities have been sensed and identified. Seizing involves decision making in what to invest especially when the domain designs is still not very clear. The firms should seize the opportunities that is solving the customers' problems and when thing getting clear, firms must ready with the right timing to give full commitment to the related resources by grasping the technologies that is most likely to be accepted by the marketplaces. The seizing of particular opportunities can be secured through the commitment and loyalty building of the customers.

The managing threats or transformation capacity (resource reconfiguration): involves recombination and reconfiguration of the firms' technological assets and organizational structure based on the technologies and market opportunities that have been identified and selected. The process of creating alignment of the firms' assets and structures with the changing environments are to create fitness for the sustainability of profit growth. The redeployment and reconfiguration also involves redesigning the business model, and realigning the activities and routines of the firms.In any situations, not all of these capacities will be necessarily and equally needed. As DCs has many forms, is multi-dimensional and to be used in various contexts, some capacities will be more critical than the others (see Ellonen, Wikstrom, & Jantunen, 2009). Thus, depending on the context, the three capacities is not necessarily must exists together and use in the logical sequences.

2.3 The Capability Lifecycle

The concept of DCs exists to explain how firms can sustain competitive advantage under volatile environments. As the markets grow, the market preferences will also changing making the firms' current competitive advantage no longer sufficient to meet the new changes. Hence under volatile environments, it is seemed that the firms' competitive advantage is becoming much shorter and difficult to sustained (Biedenbach & Soderholm, 2008).The nature of competitive advantage which is very short-lived under volatile environments implies that the firms' capabilities have specific lifecycles as the 'firms achieve new resource configurations as markets emerge, collide, split, evolve, and die' (Eisenhardt & Martin, 2000: 1107). Thus, the concept of capability lifecycle (CLC) is introduced by Helfat and Peteraf (2003) to shows the evolution of the general patterns and paths of firms' capabilities over time that is consisting of three stages from founding to development to maturity.



The way CLC evolves can be seen through 'a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursue of improved effectiveness' (Zollo & Winter, 2002: 340).The selection event can occurs at any point of the three stages and can take any of these forms; renewal, redeployment, recombination, replication, retrenchment, and/or retirement in which the first three are to increase the level of capabilities, replication is to sustain the capability, and retrenchment and retirement are to reduce and phasing out the capabilities. The authors further explain the selection of branches is impacted either by the threat of obsoleteness (market-driven), or opportunities for growth (technology-driven). Figure 2 shows the CLC introduced by Helfat and Peteraf (2003) with the selection event occurred at the end of the maturity stage.

Figure 2
Capability lifecycle (example of selection event at the end of maturity stage)

The renewal of capabilities: to improve the current capabilities by providing new alternative of capabilities to respond to the crisis such as the increasing cost of input. The renewed capabilities are for the same market and product.
The recombination of capabilities: to combine difference capabilities such as manufacturing capabilities with R&D capabilities. This can be the alternative of renewal of capabilities for current product and market.
The redeployment of capabilities: to apply the capabilities to different market but similar products or services where the same capabilities are identical across the markets. Redeployment can be done either by transferring the capabilities from old market to new one or by sharing capabilities between old and new markets.
The replication of capabilities: capabilities are replicated for the same market but to different places or geographical areas if the benefits of transferring the capabilities exceeding the cost. For example, when certain product is prohibited (threats) by the government under new policies, the capabilities can be transferred to new geographical areas or countries (opportunities) that are not prohibiting the product or to expand the current business to other areas when the opportunities exists.
The retrenchment of capabilities: not all DCs is for growth as some is for shrinkage (Helfat, et al., 2007), hence retrenchment of capabilities is undertaken when demand for the product is falling that is affecting the production productivity. Therefore, retrenchment is to degrade the capabilities level but still allows firm to make some profit out of it. This reconfiguration type is to respond to the external threats that forcing the firm to limit the production capacities but in less severe situation.
The retirement of capabilities: in severe situation, the retirement of capabilities is to respond to the external threats such as government prohibition of selling certain product that forcing the firm to ends the life of capabilities where the firm has to shut down the production facilities of the related capabilities. The retirement also may needed when the cost of holding the capabilities becomes burden to the firm and the firm willing to let go the capabilities even at some expenses (Helfat, et al., 2007). For example, acquisition reconfiguration capability including divesting resources of both the acquirer and acquired firms that have becomes irrelevant (Helfat, et al., 2007e).As discussed earlier the reconfiguration of resources is not just for growth, it is also to maintain or downsize the firm, hence all the six types of capabilities reconfiguration processes can be related each other such as one type can be the beginning of another type and where more than one type may involve in one situation. For example, the capabilities that are retired at one geographical area are replicated to other geographical areas or redeployed to different market of same product.

3.0 Technology Management View

TM is multi-disciplinary field that is bridging between the sciences and engineering disciplines to the business disciplines (Khalil, 2000). Even though TM is closely related to innovation, they are actually two different disciplines (e.g. technological innovation is different from marketing innovation) that are explained by scholars such as Cetindamar, Phaal and Probert (2009). It is argue that technology affects wealth and rent creations of the firms and nations. Therefore, managing technologies especially for technology-intensive industries such as semiconductor and pharmaceutical is crucial in determining the success of the firms.

3.1 The Technology Management Concept

TM has becoming an established academic discipline since two decades ago and located within management field instead of economics or public policy (Pilkington, & Teichert, 2006) and is focusing on the firm (Pilkington, 2008), in which the analysis is at firm-level (Phaal, Farrukh, & Probert, 2004) instead of industry-level. However, TM is also studied at national-level (Khalil, 2000). TM is multi-functional and multi-disciplinary field (Phaal, Farrukh, & Probert, 2004) and very diversity. Moreover, Cetindamar, Phaal and Probert (2009) have proposed TM activities from DCs perspectives (more examples of diversity of frameworks and applications can be seen in Liao (2005)).

There are many definitions of TM in literature, but the one that is well accepted in literature and TM publications and commonly referred is created by Task Force on Management of Technology (1987). For example, the definition was used in TM textbooks by Khalil (2000), and White and Bruton (2007). Hence, this paper is referring TM as:

> *a process, which includes planning, directing, control and coordination of the development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization (Task Force on Management of Technology, 1987).*

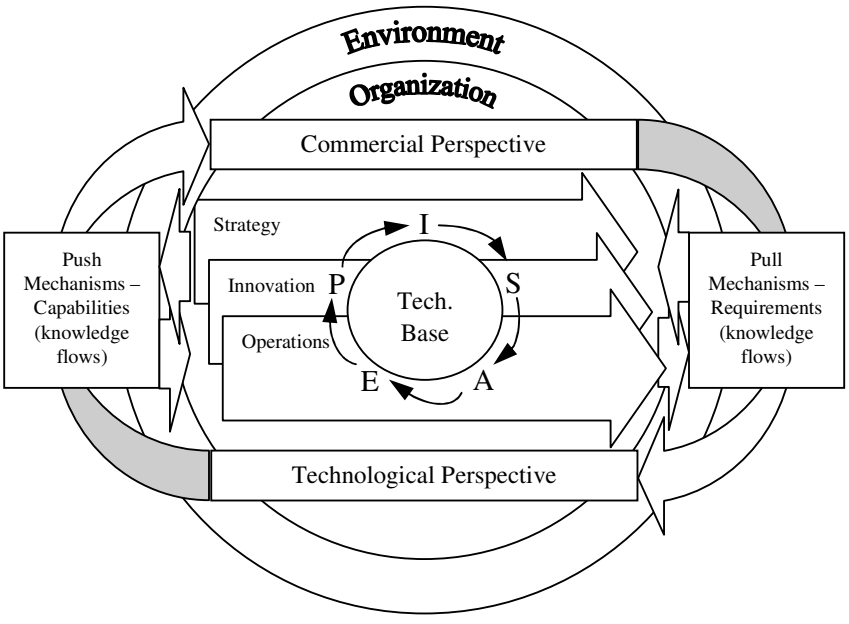
TM is to achieve competitive advantage in which White and Bruton (2007: 393) have defining competitive advantage as 'the condition that enables a firm to operate more efficiently and/or effectively than the companies it competes with', in which the competitive advantage of technology and innovation-focused firms is related to the technological complexity and skills and knowledge of the firms at managing the technology (White, & Bruton, 2007).When firms pursue for new product or new process developments, the capabilities use to develop the products/processes are basically developed through and around the technologies (Khalil, 2000). As the capabilities are transferred through technologies to the new products/processes, it is basically the technological capabilities are develop behind them.

By referring to the definition of resource by Wernerfelt (1984), it is obvious that technology is part of resources and as argue by White and Bruton (2007: 16), 'technology is the knowledge, products, processes, tools, and systems used in the creation of goods or in the provision of services'. This is similar to Phaal, Farrukh and Probert (2004) in which they treat technology as one type of knowledge resources that can be divided into tacit and codified technological knowledge. In addition, Khalil (2000: 54) claims 'the efficient utilization of technological resources is a critical aspect of the management of techno-economic enterprises'. The important of technological resources to the firm objectives further explained by Phaal, Farrukh and Probert (2004: 5) in which the

> *establishing and maintaining the linkages between technological resources and company objectives is of vital importance and represents a continuing challenge for many firms.*

3.2 The Technology Management Framework

There are various TM processes/activities, for example Cetindamar, Can and Pala (2006) have identified eleven activities consisting of technology utilization, knowledge management, technology acquisition, R&D management, technology integration, technology protection, license/patent purchasing, technology transfer, technology planning and forecasting, technology strategy, technology assessment, and technology commercialization and marketing. However, the TM processes that are of interest of the paper are in the TM framework discussed in Phaal, Farrukh, and Probert (2004). The framework have been chosen because of it relatedness to DCs. The framework is accordance to the three-level stages that is being use by the University of Cambridge Manufacturing Leaders Program that is; it is base on RBV, use at the firm-level of analysis, and to include business environment where the firm operates. In addition, the authors treated the technology as resource and two of the authors (Phaal and Probert) have explicitly relating the TM activities/processes to DCs in an article leads by Centidamar in 2009 (which will be explained later in section 4.2).



The objective of this framework is to give understanding on how strategy, innovation and operational processes can be supported with the technological and commercial knowledge within the internal and external context of the firm. This framework is the high-level framework that provides understanding of the key aspects of TM. There are two major processes in the TM framework. As seen in figure 3, the first process is TM processes that consisting of identification, selection, acquisition, exploitation, and protection (marked with letter I, S, A, E, and P) processes and operating around the technology base. These processes are briefly explained as follows:

Figure 3
Technology management framework at firm-level

The identification process: to identify, search, and collect data about the technology and the market changes (Cetindamar, Phaal, & Probert, 2009) in which the technology that may be crucial for the firm in the future but is not part of the firm existing technology base will be identified. The identification of technology can be done through conferences, suppliers' feedback, latest publications regarding the related technology, etc (Phaal, Farrukh, & Probert, 2004).

The selection process: involves decision making process of the issue, objective and priority and to align the technology with the strategy (Cetindamar, Phaal, & Probert, 2009). The technologies selection that is significant for the future products development of the firms can be done through pilot studies, technologies portfolio, etc (Phaal, Farrukh, & Probert, 2004).

The acquisition process: to acquire the selected technologies and to decides either to buy or develop them (Cetindamar, Phaal, & Probert, 2009). Thus, the technologies that have been selected will be acquired via internal development such as R&D, or external sourcing such as licensing (Phaal, Farrukh, & Probert, 2004).

The exploitation process: the acquired technologies will further be exploited by incorporating the technologies into products (Phaal, Farrukh, & Probert, 2004). The exploitation activity is basically to commercialize the acquired technologies that involve the implementation, absorption and operation of the technologies (Cetindamar, Phaal, & Probert, 2009).

The protection process: the firms' valuable technologies need to be protected in term of copyright, trademarks, patents, etc in order to assure the technologies will be benefiting only to the firm (Phaal, Farrukh, & Probert, 2004). For example, protection is needed to the firms' knowledge, and intellectual properties including the staffs (Cetindamar, Phaal, & Probert, 2009).Another process in TM framework is the firms' core business processes in term of strategy, innovation, and operational. The TM processes discussed earlier is distributed and existed within the core business processes. These processes are important for the management as it is the focus of business for the sustainability of the firms.

The push and pull mechanisms between technological and commercial perspectives are crucial within the firms' business environments as these mechanisms connect the core business processes. As the TM processes are not functioning in isolation instead distributed within business processes, understanding the relationships between TM processes, business processes, and pull/push mechanisms between the commercial and technological perspectives in the businesses environments is crucial for the effective TM.The TM processes are not necessarily in order form from identification to protection since the use will be depending on the context in which it has to be flexible and the relationships is more complicated in practice (as in jigsaw puzzle, see figure 5). For example, pre-selection of technologies may occur before identification process in order to create relevant boundary of technologies that will involve in the identification process.

3.3 The Technology Lifecycle

The technology lifecycle (TLC) in TM has been widely discussed in extant literature under the topic of technology and/or innovation. As the discussion of TLC is well established, there are many references regarding TLC that can be referred as they a more or less the same. For this paper, the explanations of TLC will mainly be based on Khalil (2000) and White and Bruton (2007).

'Most of the studies show an S-shaped pattern of use of the new innovation over time' (Nelson, & Winter, 1982: 268). Thus, as seen in figure 4, technology performance development cycle is following the s-curve shape (Khalil, 2000). The curve is located between two axis where the technology performance parameter against time. According to Khalil (2000), technology performance can be understood in term of any attribute for example measured as a number of transistors per chip. The technology performance in this sense is more towards improving the efficiency of the technology in which resembles the technical fitness of DCs performance (see Helfat, et al., 2007).

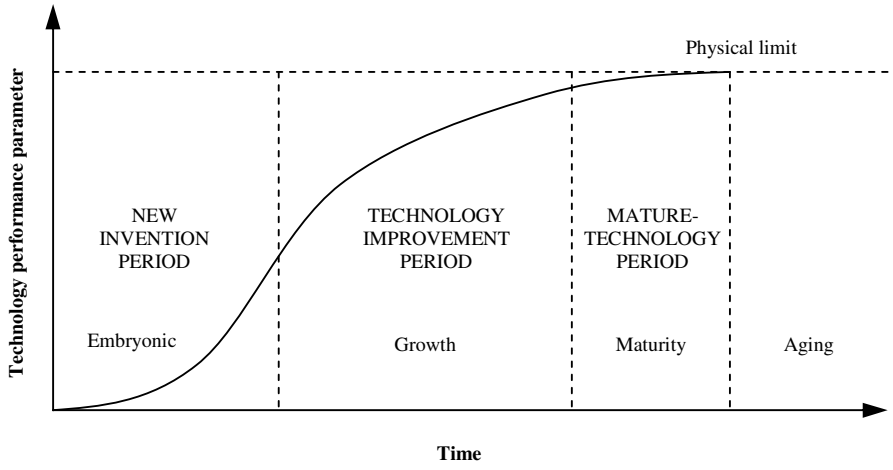


Figure 4
Technology lifecycle

The s-curve of TLC is important to examine when the technological change is happening (White, & Bruton, 2007). Thus, studying TLC will enable managers to better manage the technological capabilities and therefore will increase the performance (i.e. technical fitness). This is critical especially under rapidly technological change in which even small mistake in decision will be costly to the firms (Teece, 2007). The stages in TLC are briefly explained as follows:

The embryonic stage: in this period the application of invention takes places through innovation (White, & Bruton, 2007) in which technological capabilities are built through the exploration activities that has the potential to initiate new market preferences (technology driven) or to fulfill emerging market preferences (market driven). The new product or process that opens a new market can be radical in nature and introduced through radical technology.

The growth stage: within time the use and the processes behind the technology are improving (White, & Bruton, 2007). By mastering the knowledge and doing the activities more efficient and in an effective way, the technological capabilities are building the competitive advantage.

The maturity stage: the technology reaches the highest levels of efficiency and effectiveness and becoming highly routinized. Improvement of the product or process is more incremental in nature in which the technology is steadily maintained (Khalil, 2000). This phase marks the profitability period of the firm with the technology (White, & Bruton, 2007). However, the technology will reach its physical limit in which the technology will become vulnerable for substitution or will become obsolete (Khalil, 2000).

The aging stage: technological capabilities reach the maturity at the physical limit (Khalil, 2000). In this stage, the utility of the technology is declining. Thus, the technology needs to be modified in order to avoid the products or processes becoming obsolete (White, & Bruton, 2007).

4.0 Dynamic Capability and Technology Management Relationships

TM and DCs is different such as one is focusing on managing the technology as a source of competitive advantage and another one is focusing on the renewal of resource base (including technological resources) to sustain competitive advantage, but they are related in few aspects which means TM can be studied and understood as one form of DCs in term of technological capabilities. This is not to say that TM is part of DCs or the other way around but to shows that the study of TM can be expanded from the perspective of DCs. In order to explain how TM can be studied and understood as DCs, this section will focus on the concepts, processes, and lifecycles of both disciplines.

4.1 The Concepts

TM can be seen through the lens of DCs in term of concepts for the reasons that are explained below:

First, both DCs and TM is at firm-level of analysis. By connecting TM with general management will 'allows for the dynamic development of enterprises' (Tschirky, 1991: 713) because DCs is focusing on management role and change (dynamism).Second, Pilkington and Teichert (2006) have listed RBV as one of the TM interests. Just like DCs, TM is also grounded to RBV (Phaal, Farrukh, & Probert, 2004) as TM sees resource as critical for the firm success. In addition, Cetindamar, Can and Pala (2006: 92) argue 'strategic TM examines technology as a critical resource in securing competitive advantage'. DCs is to renew resource base in which one of them is technological capability. TM can be understood as sub-set of DCs as DCs is addressing all resources, TM is addressing only the technological resource.

Thus, managing of technological capability is also one form of DCs in the context of managing technology and technological change.Third, Liao (2005: 389) suggesting that change is a source of TM development. He explains, 'the changes due to social and technical reasons may either enable or inhibit TM methodologies and application development'. In addition, when considering changes, firms must use TM methodologies that can address changes because the existing TM methodologies may impede changes. As Liao (2005: 389) argues:

> *This means that inertia, stemming from the use of routine problem-solving procedures, stagnant knowledge sources, and following past experience or knowledge may impede changes in terms of learning and innovation for individuals and organizations.*

Moreover, in the face of technology convergence,

> *… it is therefore a question of how dynamically existing technology resources can be bundled into new solutions, quickly enough for responding to disruptive technology strategies implied by the industrial changes (Hacklin, Marxt, & Inganas, 2005: 6).*

Fourth, TM is multi-disciplinary (Liao, 2005; Khalil, 2000) and multi-functional (Phaal, Farrukh, & Probert, 2004), whereas DCs is multi-dimensional (Teece, 2007). Both of them have many types/forms depending on the context under study. Thus, they share many similarities in term of research areas. Alongside with the TM interests listed by Pilkington and Teichert (2006), in general, TM and DCs share interest in areas such as entrepreneurships, innovation, knowledge management, R&D, new product development (NPD), acquisition, integration, and commercialization and marketing. In addition, TM and DCs see capabilities building as the processes of searching, building and maintaining resources through internal developments such as R&D, and NPD, and external sourcing such as alliances, and merger and acquisition (M&A).Fifth, technologies that is used in business is the assets of the business (Khalil, 2000) in which both TM and DCs concepts are to be used in the business ecosystems (Teece, 2007) or business environment (Phaal, Farrukh, & Probert, 2004) where firm is operating. This environment consists of competitors, suppliers, customers, liabilities, policy makers, etc.

4.2 The Processes

As discussed earlier, TM framework consists of TM processes and core business processes. However, the TM processes/activities will be discussed here to shows the relationships with DCs. Cetindamar, Phaal, and Probert (2009: 238) argue:

> *This (referred to DCs) is highly relevant for understanding TM that aims to explain how combinations of resources and processes can be developed, deployed and protected for each TM activity.*

The TM processes or activities (as use in Cetindamar, Phaal and Probert (2009)) is basically the processes to build the technological capabilities where under the concept of DCs promoted by Teece (2007) the technological capabilities is one of the crucial element as the changing environments is characterized by the technological uncertainty together with the changing market preferences.First, as explained in section 3.2, the TM processes that consist of identification, selection, acquisition, exploitation, and protection will be the focus of discussion. The TM processes together with learning process (the sixth process discussed by Cetindamar, Phaal and Probert (2009)) is to demonstrate how TM can be seen and understood as DCs. *The learning process* that occurs in every single TM activity (I, S, A, E, and P in section 3.2) is to create the technological capabilities and the firms' competencies building. Figure 5 shows all the six TM processes and the supporting processes proposed by Cetindamar and colleagues. They argue the processes are not in a fix sequential basis but more like a jigsaw puzzle which means the sequence of processes can change base on the situations faced and not all the activities will equally involves in every situations. This is similar to DCs capacities in which not all the three capacities (sensing, seizing, and reconfiguration) will involve in one situation.

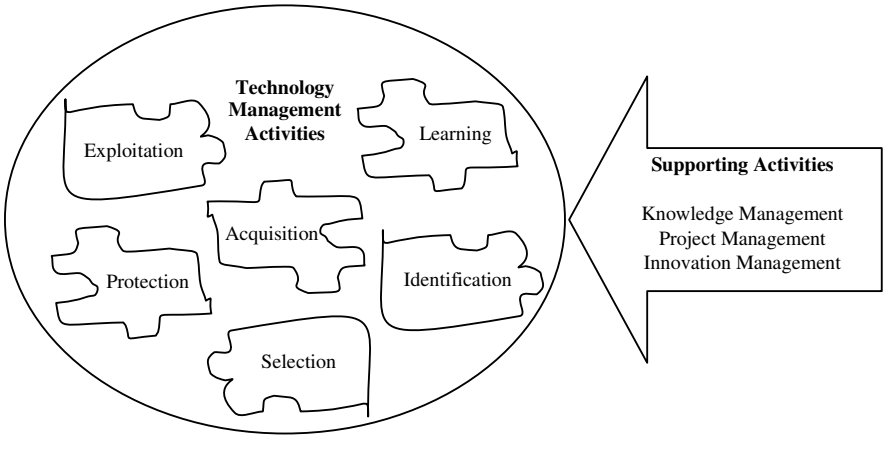


Figure 5

Technology management activities and the supporting activities

Second, it appears that DCs sensing is similar to the TM process of identification, DCs seizing is similar to TM processes of selection, and acquisition, while DCs managing threats/reconfiguration is similar to TM processes of exploitation, and protection which means both TM and DCs processes are identical. Thus, TM processes can resemble DCs capacities for building technological capabilities under TM context (for the detail on how TM processes can be used as DCs, please refer to Cetindamar, Phaal and Probert (2009)).

4.3 The Lifecycles

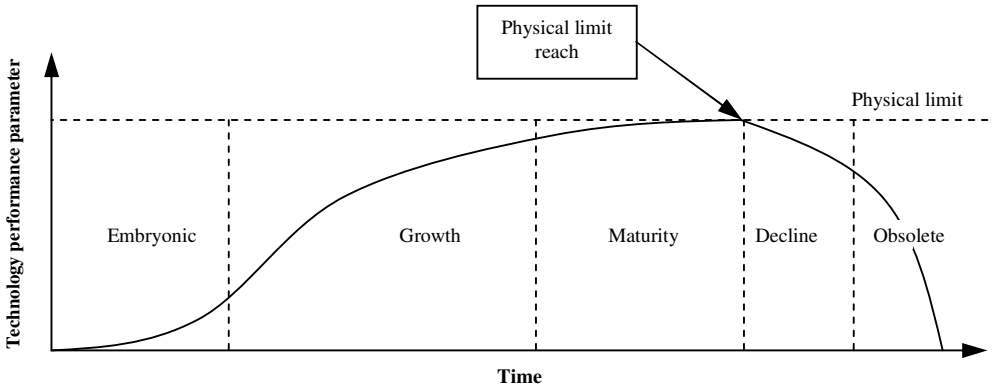
In general, as CLC is for understanding the evolution of DCs (Helfat & Peteraf, 2003), TLC can be treated as sub-set of CLC that focusing on the building of technological capabilities. Hence by examining the evolution of TLC under influence of technological changes from the concept of CLC will be fruitful to understand TM from DCs lens. In addition, Brent and Pretorius (2007: 635) argue:

> *a set of principles, methods and techniques or tools must be established for effectively assessing the potential value of a technology and its contribution to sustainable development during the market uptake phases of its life cycle.*

Moreover, the reasons for understanding TLC from CLC perspective because the types of innovations that are classified as radical and incremental innovations are causing radical and incremental development of technology in which the rates of technological changes is becoming much faster especially for high-tech industries (Khalil, 2000). This issue is covered in DCs as it is to respond to rapidly technological change (Teece, 2007). The relatedness of TM to DCs in term of lifecycle is explained as follows:

First, as shows in figure 4 (section 3.3) TLC is divided into four stages: embryonic, growth, maturity, and aging. The maturity stage will ends when the technologies reach its physical limit and will become obsolete and replaced. When the technologies mature, the technologies will reach the physical limit and the activities becoming routinized and causing rigidity. The current technologies will become commodities, and the new and better technologies will emerge (Khalil, 2000) that will replace the current technologies. In this sense, both CLC and TLC are identical in term of stages in the lifecycle.

Second, both TLC and CLC involve learning process that begins with the new discovery of capabilities with very little knowledge of the capabilities (such as radical or revolutionary innovations). Over time, the knowledge of the new product is developing through the learning process and the technologies capabilities established. The competitive advantage gained and the activities becoming more and more exploitation in nature.Third, both affected by environmental changes where the importance of market dynamism in the process comes when it affects the length of the TLC and the existing competitive advantage (figure 6 and 7). This is what makes the discussion of TLC under DCs becomes relevant.Under stable market, the substitution of current technologies will not happen without reaching the physical limit but under dynamic markets the physical limit of the technologies are no longer becomes the only factor affecting the performance of TLC since the technologies themselves will keep changing together with the changing markets preferences (co-evolve) even though the physical limit is still very far to be achieved.



The market dynamism can be seen as moderately dynamic markets at one end and high-velocity markets at the other end (Eisenhardt & Martin, 2000). Therefore, the 'damage' to the firms' competitive advantage can range from 'minor damage 'to' major damage base on the levels of uncertainty and market dynamism. The level of 'damage' will decide type of reconfiguration at the selection event. It is argue that in any industries, firms will face different types of market dynamism over time. To express this differently, at one time the markets are very stable but another time the markets are very volatile.

As shows in figure 6, the lower the levels of market dynamism, the longer the TLC, the more the competitive advantage is sustainable. The slower the technologies become obsolete or substituted, the easier the technologies to reach the physical limit.

Figure 6
Slow growing markets condition (stable market) cause longer lifecycle. Capability is renewed when reaching physical limit.

In figure 7, the higher the levels of market dynamism, the shorter the TLC, the less the competitive advantage is sustainable. The faster the technologies become obsolete or substituted, the harder the technologies to reach the physical limit.

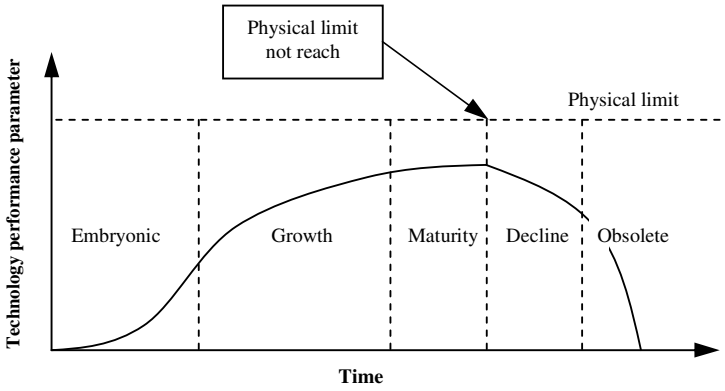
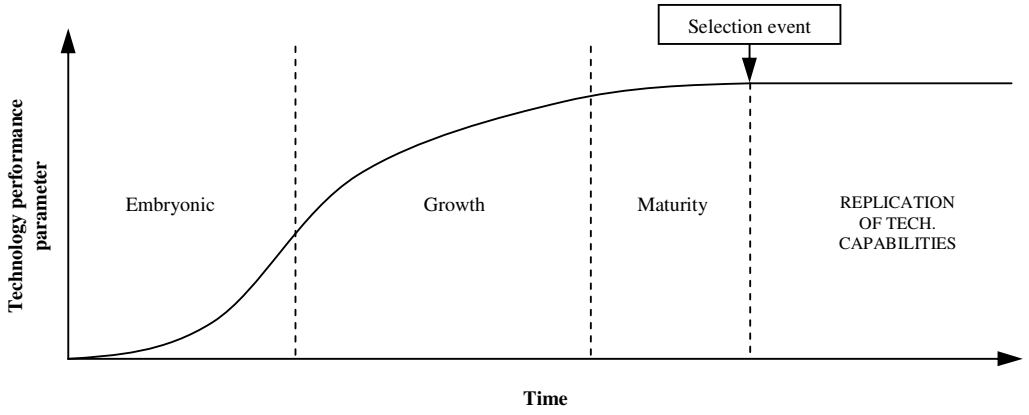


Figure 7
Fast growing markets condition (rapid changing market) cause shorter lifecycle. Capability is renewed before reaching physical limit.

Fourth, when market changes happen, the decision to sustain competitive advantage is made at the selection event (Helfat, & Peteraf, 2003) just like Khalil (2000) suggesting the modification of technological capabilities when the technologies reach the physical limit. As mentioned previously, under dynamic markets firms might loss the competitive advantage much faster even before the technologies themselves reach the physical limit (refer figure 7), therefore the selection event of CLC is chosen to explain TLC of TM under rapidly technological change.



The reason why decision has to be made at selection event because this is the point where market dynamism can cause 'retirement' to the capabilities especially when market is highly volatile and uncertainty. As DCs is context dependent (Helfat, et al., 2007), the TLC is the specific CLC for technological capabilities under technological change in the context of TM. As the selection event can occurs at any point along the stages of the TLC, the selection of the right combinations of innovation activities and technological capabilities to the market needs becomes crucial. The six resource reconfiguration in CLC (as discussed in section 2.3) can be demonstrated in TLC as seen in figure 8 to 10.

Figure 8
Maintaining technological capabilities through replication

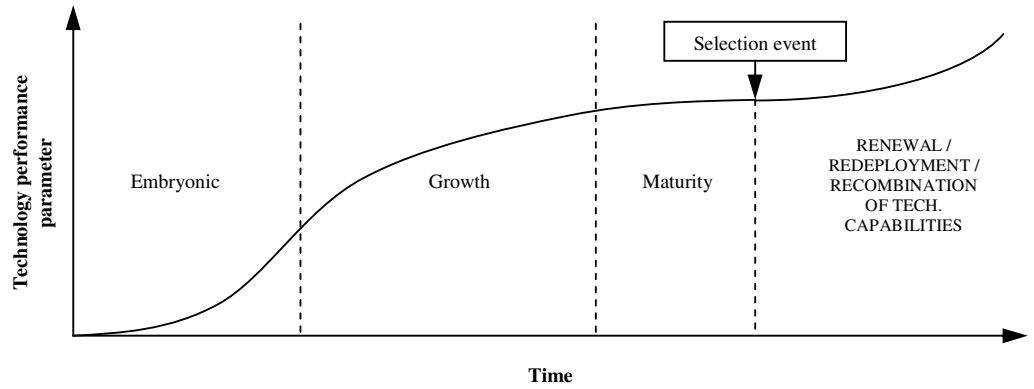


Figure 9
Increasing technological capabilities through renewal/redeployment/recombination

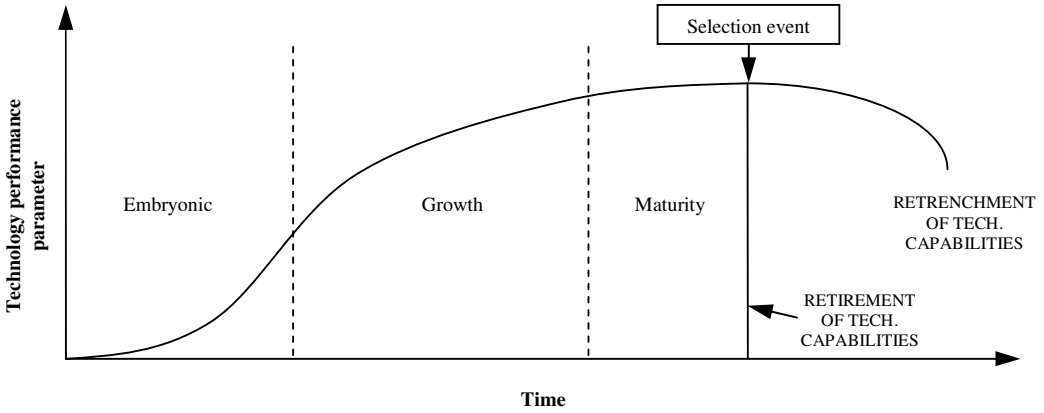


Figure 10
Reducing technological capabilities through retrenchment/retirement

Figure 11 and 12 show how the reconfiguration of technological capabilities that is explained with TLC can helps to explain the source of sustainability competitive advantage when the changing technology is radical in nature (figure 11) and incremental in nature (figure 12). As seen in the figures, sustainable competitive advantage can be achieved through the creation of many short-term competitive advantages (Eisenhardt, & Martin, 2000) (marked as TLC-1, TLC-2, and TLC-3).

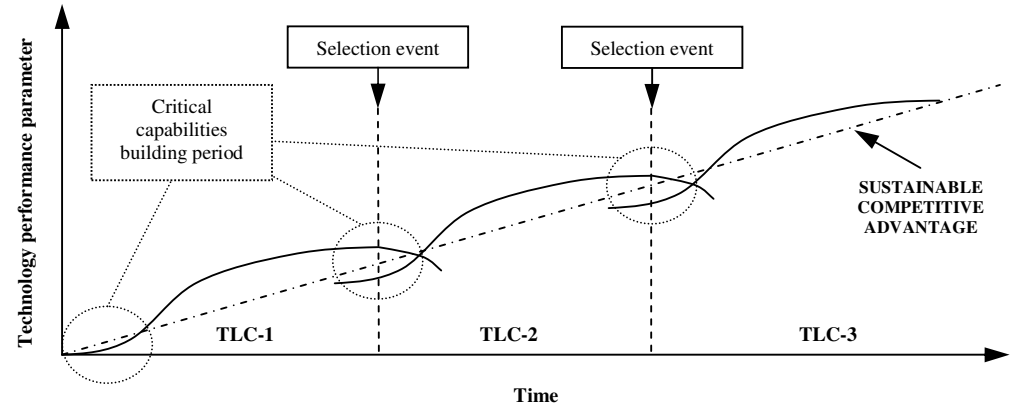


Figure 11
Sustaining competitive advantage through multi-generations of technology lifecycles (for new opportunities, technology-driven or radical innovation)

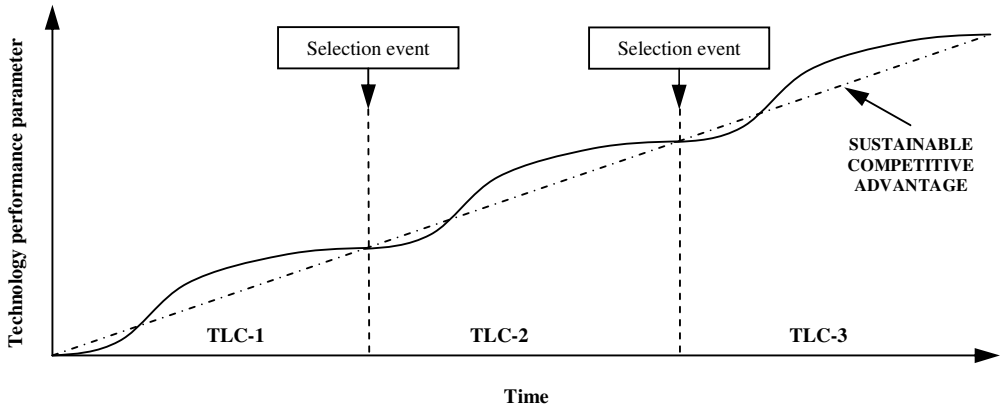


Figure 12
Sustaining competitive advantage through multi-generations of technology lifecycles (for market fulfillment, market-driven or incremental innovation)

5.0 Discussion and Suggestion

As explained in literature, DCs is highly related to entrepreneurships, innovation, knowledge, learning, and change. It is also highly resource-centric and focusing on changes of the resources to create and sustaining competitive advantage. In addition, DCs is not just to respond to the rapidly changing technology as it can also be the source of change because firms and environments is co-evolve. Moreover, DCs is very useful for high-tech industries where managing of (technological) resource is crucial in which change is certain and affecting the resources, and where respond to the change is very critical for the survival of the firms.At the same time, TM is designed to manage technological capability in which technology is very critical and argue to have crucial effects to the firms' competitive advantage. The technological change will affects the competitive advantage of the firms as the technology that is needed to compete has been competed away by the changes. Thus, managing the technology is very critical under volatile environment which means the sustainability of the technological capabilities is very significant issue for TM.

Because of the focus of DCs is on the sustainable competitive advantage, DCs is crucial for the study of TM as the sustainability issue (either in economy, social, or environments) is lacking of research in TM literature even though this issue is critical for the firms to survive under challenging environments. This shows that the connection between TM and DCs is possible and are evidenced by TM and DCs literatures in which scholars from both fields have investigating and relating TM and DCs in their researches. For example, TM processes can be studied as DCs in which processes/skills/routines that is existing in thin market (Teece, 2007) or under regime of high appropriability (Teece, 1986) is the major elements in creating and maintaining competitive advantage. However, the number of researches is still limited in which more areas between the two need further exploration.DCs is designed for decision makers of high ranking management level and addressing the strategic issues (Teece, 2007) while as suggested by literature (e.g. Phaal, Farrukh, & Probert, 2006; Liao, 2005), TM tools and methodologies are focusing on the operational level and less on the strategic level.

Therefore, exploring how TM can be seen through the lens of DCs can enhance TM literature at strategic level (TM is also addressing the operational level as in definition in section 3.1). Thus, what can be learnt from studying DCs is quite significant to improve the way to manage technology under rapidly technological change. Hence, by understanding the management of technological change to develop the technological capabilities under volatile environments through the lens of DCs will open for the future research area.
The paper is not suggesting that TM and DCs can be one as both of them have dissimilarity too. For examples, TM is highly focusing on technological resource where DCs is focusing on various resources including technological resource. Secondly, TM is addressing the technological change whereas DCs is not just addressing the technological change and market change as changes can be initiated by the changes made to the resources themselves.

Thirdly, TM is using various management tools in which majority of them are designed to be used at operational level and addressing profitability issues in which DCs is designed to be by high management level and addressing sustainability issues. However, the dissimilarity is not elaborated further as it is not the major focus of the paper (this can be researched in the future) as the paper is to shows how both fields can be related and investigated so that the study of TM can be enhanced from the perspective of DCs. Thus, there may be other aspects that can hinder the study of TM from DCs lens that is out of the scope of the paper. Hence, by investigating the similarity and dissimilarity between TM and DCs can helps to increase the understanding of the areas where TM and DCs can be studied together and/or where TM and DCs has contradictions that need to be deals with in order to adapt the concept of DCs to TM in more effective ways in which can be the starting point at researching TM through DCs lens.The paper is raising the issue not just to suggest the alternative to address the lacking of sustainability issue in the current TM literature but to create awareness of the relevance of exploring TM through DCs lens in general. In this case, the paper is to explicitly promoting the study of TM from DCs perspectives as there is big potential to explore DCs as the field is still very new. Hence, for TM scholars that are interested in DCs, perhaps the first thing they should do before exploring TM and DCs related issues is to fundamentally understand DCs.

6.0 Conclusion

DCs is designed to explain the source of sustainable competitive advantage especially under rapidly technological change through the renewal of resource base. As TM is lacking the literature in term of sustainability aspect, by looking at DCs perspective may helps to explain how TM can be used to sustain the competitive advantage for technology-intensive firms. DCs is not completely new to TM scholars as the TM interests especially in the US and Europe is focusing on the RBV topics (where DCs is also addressed). In addition, there is numerous DCs literature that have been published in TM related journals and presented in TM conferences. Hence, as DCs and TM share many similar interests in fields such as entrepreneurships, innovation, and knowledge management, exploring TM through DCs perspectives will enhance TM literature at strategic level regarding the sustainability issues. In general, TM and DCs is identical where both are rooted to RBV in which technological capabilities is treated as resource in both literature. TM and DCs framework consists of processes in which the TM processes can be implemented according to the processed in DCs.

In addition, the evolution of technological capability (in TM) and resources (in DCs) can be explained by understanding the lifecycles in which the embryonic, growth, and maturity phases in TLC for TM are identical to the founding, development, and maturity in CLC for DCs in which the selection event in CLC can helps to explain how technological capabilities can be reconfigured according to the changes. It is suggested that TM can be studied and understood as one form of DCs in term of the processes of renewal the technological capabilities that is shown through the discussion of the relationships between TM and DCs in term of the concepts, processes, and lifecycles. The discussion is focusing only on the similarity aspects of both disciplines and ignoring the dissimilarity in order to shows the relationships.The study of TM from DCs lens is not only to address the sustainability issue as both fields are context dependent. In conclusion, this paper is to promote the study of TM from DCs lens in which more potential areas can be explored in the future to address TM related issues.

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