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Lean, Six Sigma and its influence on potential and realized absorptive capacity

Absorptive
capacity

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Abstract

Purpose – The purpose of this paper is to explore how Lean and Six Sigma's distinctive practices relate to potential absorptive capacity (PACAP) and realized absorptive capacity (RACAP). The paper seeks to understand which of the practices in Lean Six Sigma are needed to manage absorptive capacity systematically.

Design/methodology/approach – Partial least square based structural equation modeling (PLS-SEM) was used to test the theoretical model drawing on a sample of 125 manufacturing organizations in Malaysia. In addition to examining direct effects, the study also examines indirect effects using bootstrapping method to identify possible mediation effects proposed in the model.

Findings – The results explain that Lean's social practices (LSP), Six Sigma's roles structure (RS) and structured improvement procedure (SIP) positively influence potential absorptive capacity (PACAP). Meanwhile LSP, RS and focus on metrics (FOM) positively influence realized absorptive capacity (RACAP). SIP was found to influence RACAP through PACAP. The analysis reveals the combination of Lean Six Sigma practices that are required in managing PACAP and RACAP differentially.

Research limitations/implications – The study is only confined to manufacturing industries in Peninsular Malaysia. Data collected were cross-sectional in nature. The application of Lean Six Sigma and how it influences absorptive capacity may get sturdier across time, and this may change the effect toward sustainability of firm's competitive advantage. A longitudinal study may be useful in that context. The study also makes specific recommendations for future research.

Practical implications – The results of this study can be used by Lean Six Sigma practitioners to prioritize the implementation of Lean Six Sigma practices to develop absorptive capacity of the organization through PACAP and RACAP, which needs to be managed differentially as they exert differential outcomes. This would enable organizations to tactfully navigate and balance between PACAP and RACAP in accordance to business strategies and market conditions.

Originality/value – Absorptive capacity in Lean and Six Sigma context has largely been studied as a unidimensional construct or used as a grounding theoretical support. Therefore, understanding the multidimensionality through PACAP and RACAP provide insights on how to enhance and maneuver absorptive capacity through Lean Six Sigma systematically. The findings may pave the way for future research in enhancing the current knowledge threshold in Lean Six Sigma.

Keywords Six Sigma, Lean, Absorptive capacity, Potential absorptive capacity, Realized absorptive capacity

Paper type Research paper



1. Introduction

Knowledge is indisputably submitted as a strategic resource in developing and sustaining competitive advantage of firms (Grant, 1996; Kogut and Zander, 1996). Quality management or improvement philosophies are highly driven by knowledge management and organizational learning characteristics (Linderman *et al.*, 2010; McFadden *et al.*, 2014). The increasing rapidity of change in the business cycle and the need to adapt to such a changing environment has prompted firms to ingest notions that stem from quality management. Although quality management is at a phase of maturity with conceptual foundations and definitions (Sousa and Voss, 2002), new initiatives continue to emerge (Gutiérrez *et al.*, 2012).

The fusion between Lean and Six Sigma (Lean Six Sigma) is the latest generation of improvement methodology which has a profound reach globally ever since the new millennium (Bakar *et al.*, 2015; Snee, 2010). It is regarded as a management philosophy more than just a quality improvement method (Pepper and Spedding, 2010; McAdam and Lafferty, 2004; Arnheiter and Maleyeff, 2005). Lean is the extension of Toyota Production System (TPS), whose emphasis is to eliminate waste or non-value-adding activities within processes. Six Sigma on the other hand was created by Motorola but made popular by General Electric (GE) whose focus is on reducing variation in processes through a structured approach (Pepper and Spedding, 2010). Together, Lean Six Sigma is known as “a methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital” (George, 2002, p. 6).

The effectiveness of Lean Six Sigma is of such a magnitude that it is claimed to even combat economic recessionary period by functioning as a survival tool (Chaurasia *et al.*, 2016). Byrne *et al.* (2007) state that the philosophy has the vigor to reach beyond operational excellence and tap into the realm of innovation to sustain competitive advantage. Given the importance of knowledge as a vital resource in sustaining competitive advantage, viewing Lean Six Sigma through the lens of knowledge management and organizational learning can lead to insights about how to administer and orchestrate knowledge systematically (Choo *et al.*, 2007; Lapré *et al.*, 2000).

Pérez-Aróstegui *et al.* (2009) asserted that given the turbulence of the business world and to survive in dynamic environments, firms must foster the abilities of absorptive capacity, which is the ability to identify, assimilate and exploit new knowledge to achieve their commercial objectives (Cohen and Levinthal, 1990). Their study outlined how quality management practices function as forerunners of absorptive capacity. Corresponding to this vein, a few number of scholars have explored the link between Lean and/or Six Sigma and absorptive capacity. Shah *et al.* (2008) research explained the implementation of either Lean or Six Sigma initially helps the subsequent implementation of another related practice under the context of absorptive capacity. McFadden *et al.* (2015) used absorptive capacity to ground the proposition of positive relationship between Lean and Six Sigma in explaining how it enhances patient safety outcomes in the healthcare industry. McAdam and Hazlett (2010) carried out a critical literature review by conceptualizing or treating Six Sigma as a new knowledge to be effectively absorbed within an organization. Yusr *et al.* (2012) assessed the relationship between Six Sigma, absorptive capacity and innovation performance in which they found absorptive capacity to be playing a mediating role. Lis and Sudolska's (2015) case study delineated how Lean management's best practices and routines in a Poland based automotive company associated with the firm's absorptive capacity consequently contributed to its success. Gutiérrez *et al.* (2012) studied how Six Sigma's teamwork and process management have a positive influence on absorptive capacity subsequently influencing learning orientation of firms.

The current turbulent and dynamic business environment have made absorptive capacity as one of the most important dynamic capability in generating sustainable competitive advantage (Fosfuri and Tribó, 2008; Zahra and George, 2002). Equally, Manfreda *et al.* (2014) assented business process improvement methods should be used to enhance the absorptive capacity of firms. However, amidst these studies, scarcely were there any that studied the abilities of absorptive capacity as reconceptualised by Zahra and George (2002). They defined it as being a multidimensional “set of organizational routines through which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organization capability” (Zahra and George, 2002, p. 186). Absorptive capacity, as they proposed involves two components, potential absorptive capacity (PACAP), which makes a firm receptive to acquiring and assimilating knowledge, and realized absorptive capacity (RACAP), which reflects the capacity to leverage the absorbed knowledge. PACAP and RACAP are distinct capabilities which needs to be managed differently as they exert differential outcomes toward sustaining competitive advantage (Albort-Morant *et al.*, 2018). The distinction between the two components is important as scholars submit it explains why some firms fail due to changes in the business environment (Bower and Christensen, 1995). Correspondingly, Gutiérrez *et al.* (2012) called for future studies to look into the effects of Six Sigma practices on PACAP and RACAP. In this study, we will attend to this appeal by exploring how the distinctive practices of Lean and Six Sigma relate to or effect the components of absorptive capacity, PACAP and RACAP. The findings will assist Lean Six Sigma firms, practitioners and managers to realize and administer relevant strategies by tactfully maneuvering the distinctive practices of Lean and Six Sigma in managing and enhancing absorptive capacity of their firms corresponding to the dynamism of the business environment. This will position firms to plan and/or manage the implementation strategies by weighing the distinctive practices of Lean and Six Sigma with the firms’ resources and capabilities to appropriate its absorptive capacity. This represents an extension of the current knowledge of Lean, Six Sigma and absorptive capacity.

This paper is organized as follows: Section 2 gives a literature review on the distinctive practices of Lean, Six Sigma, absorptive capacity preceding the hypotheses development of the study. Section 3 explains the research methods used in this study. Analysis of the results of the study are presented in Section 4, following which Section 5 caters the discussion of the study. Section 6 follows with the managerial and theoretical implication before conclusion, and recommendations for future studies are presented in section 7.

2. Literature review

2.1 Idiosyncrasies of Lean Six Sigma

Past studies had conceptualized Lean and Six Sigma in many different ways (Zhang and Chen, 2016; Zhang *et al.*, 2011; Zu *et al.*, 2008; Zu and Fredendall, 2009; He *et al.*, 2015; Ngo, 2010; Gutiérrez *et al.*, 2012; Schroeder *et al.*, 2008; McFadden *et al.*, 2015; Hadid *et al.*, 2016; Shah *et al.*, 2008; Bortolotti *et al.*, 2015; Larteb *et al.*, 2015; Spasojevic Brkic and Tomic, 2016; Habidin *et al.*, 2016; Fadly Habidin and Mohd Yusof, 2013). Salah *et al.* (2010) reasoned that there is no consensus on how the integration should be done nor are there any universally accepted integration using which Lean Six Sigma can be holistically conceptualized. In a broader perspective, Lean and Six Sigma ideally fall into the quality management domain (Muraliraj *et al.*, 2018). The common practices or typical characteristics of any quality management philosophy, in general, would include top management support, leadership, supplier relationship, workforce management, process management, customer orientation and the likes (Pérez-Aróstegui *et al.*, 2009; Zu *et al.*, 2008). These are almost unequivocal across most quality management philosophies. However, there are always certain or special

characteristics of a particular quality management concept that tends to stand out which differentiates one concept amongst the others. Therefore, it is essential to identify the individualizing characteristic or peculiarity of a constitution, otherwise known as “idiosyncrasies” (Merriam-Webster, 2004). The distinctive properties of Lean and Six Sigma need to be necessarily understood besides the common and usual properties of quality management concepts. In this paper, we will focus on delineating the idiosyncrasies of Lean and Six Sigma.

Lean, as mentioned originated from TPS. Liker and Rother (2011) submitted that one of the predominant reason for Lean’s failure in many organization is attributed to high focus on its tools and techniques, also known as hard practices, meanwhile disregarding human-related practices (soft practices). Liker and Meier (2005) described the TPS is not only about its technical practices in the form of its tools and techniques but a considerable portion contains a strong and well understood social pact with employees and stakeholders of the organization. Scholars thereafter have accounted Lean as a philosophy that revolves around a sociotechnical perspective (Hadid *et al.*, 2016; Shah and Ward, 2003, 2007; Spear and Bowen, 1999; Womack and Jones, 1996). As such, Lean is commonly referred to as a bundle of hard and soft practices (Larteb *et al.*, 2015). In this study we will outline two distinctive or idiosyncratic practices of Lean which are the hard practices hence referred as “Lean Technical Practice” (LTP) and soft practices as “Lean Social Practice” (LSP).

2.1.1 Lean technical practice. On its technical side, Lean involves a collection of tools and techniques which assist in the process of improving work methods by eliminating waste, which is known as *Muda* in Japanese (Kariuki and Mburu, 2013; Kumar and Abuthakeer, 2012; Shah and Ward, 2007). As Pettersen (2009) quoted, Lean is a collection of waste reduction tools. The efforts of forming and enabling the manifold of tools and techniques of Lean or TPS are largely attributed to a number of key personnel and managers of Toyota namely the Toyoda cousins, Kiichiro and Eiji, Taiichi Ohno and Shigeo Shingo (Holweg, 2007; Shah and Ward, 2007). This involved a collection of tools and techniques used to ensure a smooth flow of processes without the intrusion of waste. According to Ohno (1988) there are two underlying pillars in support of Lean’s tools and techniques: “Jidoka”, which means “autonomation” (Baudin, 2007; Kim and Gershwin, 2005; Sugimori *et al.*, 1977), and Just-In-Time (JIT) refers to a “pull” system which advocates a process with continuous flow (Austenfled, 2006, Hutchins, 1999; Sugimori *et al.*, 1977). As expressed by Shah and Ward (2003), the tools are indeed synergistic as each one of them chains to another set of tools or techniques that paves toward the objective of waste alleviation resulting in a process that is value-added.

2.1.2 Lean social practice. As argued by Bicheno (2004), Lean is more than a set of tools. Many tend to disregard the social side of Lean, which accounts for the management system in the Lean philosophy (Mann, 2014). As Liker (2004) explained, the DNA of Toyota involves two aspects. Continuous improvement philosophy which is gained through the use of technical practices and respect for people which encompasses the human or social side of Lean. This includes encourage creativity, autonomous work and learning, few layers in the organizational hierarchy to enable quick response, a high level of horizontal integration to increase knowledge transfer, a decentralized decision-making so operating issues can be dealt with effectively and quickly and a high level of vertical and horizontal communication to ensure coordinated action and a judicious human resource management (Ehrlich, 2006; Suárez-Barraza and Ramis-Pujol, 2010).

Based on the survey test results of 226 manufacturing plant in the USA, Zu *et al.* (2008) identified three practices that are distinctively associated to Six Sigma amid traditional quality management practices, which are systematic role structure (RS), structured

improvement procedure (SIP) and a stringent focus on metrics (FOM) (He *et al.*, 2015; Sony and Naik, 2012). As quoted in Zu *et al.* (2010; p.87), studies done about critical success factors for the implementation of Six Sigma underpin the existence of these three practices (Nonthaleerak and Hendry, 2008; Szeto and Tsang, 2005).

2.1.3 Role structure. Firms embracing Six Sigma will have a parallel-meso structure which symbolizes the improvement specialist inherent in the organization, commonly referred to as the belt system (Schroeder *et al.*, 2008; Pyzdek, 2003; Pande *et al.*, 2000). These specialists are framed to the likes of martial arts proficiency level such as Yellow, Green, Black and Master Black Belts generally, with each specially trained and designated with their own roles and responsibilities (Pande and Holpp, 2002; Pyzdek, 2003). In this hierarchical structure, the leaders, known as Champions initiate, support, and review key improvement projects. Black and Green Belts serve as project leaders wherein the former also mentors and supports the latter in problem-solving efforts whereas Yellow Belts serve as team members of the improvement project teams (Sinha and Van de Ven, 2005; Pande *et al.*, 2000; Pyzdek, 2003; Kwak and Anbari, 2006).

2.1.4 Structured improvement procedure. Six Sigma includes a structured process of solving problems through projects. Every Six Sigma project need to undergo a structured methodology known as DMAIC which stands for Define (the problem and goal requirements), Measure (the current process capability), Analyze (to scale down vital-few factors), Improve (the process to eliminate defect root causes) and Control (the process to sustain improvements) (Harry and Schroeder, 2000; Schroeder *et al.*, 2008; Montgomery and Woodall, 2008; Pyzdek, 2003). As for new product or process design, a DMADV (Define, Measure, Analyze, Design and Verify) approach will be used (Pande *et al.*, 2000; Pyzdek, 2003). These phases in the structured improvement method are prescribed with tools and techniques and specifies relevant objectives that need to be achieved before the projects systematically moves on to the subsequent phases and toward completion (Antony and Banuelas, 2002; Kwak and Anbari, 2006).

2.1.5 Focus on metrics. Six Sigma imposes a stringent focus toward metrics, sets challenging or specific targets and goals (Pande and Holpp, 2002; Pyzdek, 2003; Schroeder *et al.*, 2008; Linderman *et al.*, 2006, 2003). Process improvement teams will use critical metrics to evaluate the process in study and monitor its changes over time which increases the visibility of quality related problems and allows the teams to quickly respond if needed (Pande and Holpp, 2002; Snee and Hoerl, 2003). Through this capability, teams may benchmark different processes to identify more improvement opportunities (Dasgupta, 2003).

2.2 Absorptive capacity

Absorptive capacity is the ability of firms to recognize the value of new, external information, assimilate it and apply to business and commercial needs in exploitation (Cohen and Levinthal, 1990). Absorptive capacity does not only reside in firms but also organizational units (Cohen and Levinthal, 1990, p. 131-132; Jansen *et al.*, 2005). Zahra and George (2002) offered a reconceptualization by claiming that the concept is multidimensional. Absorptive capacity is viewed here as a form of dynamic capability that is embedded in organizational routines and processes and in which it comprises of four dimensions (Zahra and George, 2002):

- (1) *Acquisition capacity:* It is a firm's and organizational unit's ability to identify and acquire valuable new external knowledge.
- (2) *Assimilation capacity:* It is a firm's and organizational unit's ability that enable it to understand the new information captured (Kim, 1997). Knowledge assimilation

refers to the ability to grasp the new external knowledge and make sense of it (Albort-Morant *et al.*, 2018).

- (3) *Transformation capacity*: It is a firm's and organizational unit's ability to combine the newly acquired and assimilated knowledge to its existing or prior related knowledge. This is done by adding, deleting or interpreting the knowledge in different ways.
- (4) *Exploitation capacity*: It is a firm's and organizational unit's ability to apply, use or leverage the transformed knowledge to refine or extend its competencies. Exploitation refers to application of the new knowledge for commercial gains (Delmas *et al.*, 2011).

As explained earlier these dimensions compose two distinct components, PACAP and RACAP. PACAP constitutes the dimensions of acquiring and assimilating new knowledge whereas RACAP is composed of the latter two dimensions, transforming and exploiting new knowledge. In analyzing the role and importance of every dimension, Zahra and George (2002) outlined the first two dimensions or PACAP mirrors learning capability. Van Wijk *et al.* (2001) advocated the breadth and depth of knowledge exposure will positively influence a firm's propensity to explore more new and related knowledge. Correspondingly, scholars have found PACAP to reflect and influence exploratory capabilities or characteristics such as exploratory learning (Gebauer *et al.*, 2012) and exploratory innovation (Jansen *et al.*, 2005; Limaj and Bernroider, 2017). RACAP on the other hand reflects firm's capacity to leverage or commercialize the knowledge stock of the firm. RACAP involves a process known as "bisociation," which helps firms to develop new perceptual schema and changes existing process (Zahra and George, 2002) which resembles exploitation capabilities or characteristics such as exploitative learning (Gebauer *et al.*, 2012) and exploitative innovation (Jansen *et al.*, 2005; Limaj and Bernroider, 2017). Both components of absorptive capacity are distinct but play a complementary role and have a tendency to coexist to improve organizational performance (Zahra and George, 2002). Jansen *et al.* (2005) found both PACAP and RACAP may need to be managed differentially as they follow different developmental paths therefore, differ in their ability to create value toward organizational outcomes. This explains although PACAP and RACAP are complementary and coexisting, they could possibly be influenced differentially and consequently exert differential organizational outcomes.

2.3 Hypotheses development

Lean and Six Sigma are quality management methodologies centered on the philosophy of continuous improvement which Helfat *et al.* (2007) attributed to the notion of dynamic capability, a patterned activity to modify operational routines to address rapidly changing environment. Absorptive capacity is regarded as a dynamic capability which "influences the nature and sustainability of a firm's competitive advantage" (Zahra and George, 2002, p. 185). Although studies relating Lean, Six Sigma or Lean Six Sigma to absorptive capacity are moderately evident, the link toward the components, PACAP and RACAP as postulated by Zahra and George (2002) are indeed scarce to non-existent. However, the relation of Lean and Six Sigma practices toward knowledge related concepts are fairly aplenty. Given the interlinkage between knowledge management and organizational learning with PACAP and RACAP (Cohen and Levinthal, 1990; Zahra and George, 2002), we glean information and insights from various domains and field of studies to explain how each idiosyncrasies of Lean and Six Sigma relate to PACAP and RACAP.

2.3.1 Lean technical practice and components of absorptive capacity. Tyagi *et al.* (2015) studied the influence of Lean's tools and techniques through Nonaka's (1994) Socialization-Externalization-Combination-Internalization (SECI) modes and found that the tools provide a basis for team members to accumulate knowledge and learn from external stakeholders such as customers and vendors which is further transformed into the operational routines in part of problem-solving process. For example, to accomplish a JIT (Just in Time) flow, the organization must also learn the capacities of the suppliers and the demand of the customers to make it work without waste and benefiting every stakeholder. This involves learning from external sources and experimenting the ideas to make it work. As explained by Tyagi *et al.* (2015) some of the tools and techniques of Lean such as the Plan-Do-Check-Act cycle involves clearly exploring customers' objectives and the methods required to achieve the objectives in the planning stage. LTP provides a platform for practitioners to use them as a guideline to do work besides stimulating employees learning ability. This enables practitioners to scour for the relevant knowledge that befits their issues. These elucidation resembles the ability of LTP to influence project team's ability to acquire and assimilate new knowledge (PACAP). Therefore, it is hypothesized:

H1a. LTP positively influences PACAP.

Tyagi *et al.* (2015) went on to explain, the tools and techniques used in Lean will assist in the forming of explicit knowledge such as when project team members utilize process maps or Value Stream Map (VSM) to understand their "AS-IS" or current situation of a process besides identifying constraints along the way. Once constraints are identified, the process will be rationalized for improvement (Nave, 2002). This is where tacit knowledge in the form of experience and know-how interplays with new knowledge from contractors, suppliers, internal stakeholders and firm policy makers before being exploited to refine the process. The knowledge will then be internalized and improvised to better suit respective processes as part of best practice applications. This resonates the ability of the tools to not only facilitate acquisition and assimilation of knowledge but transforming and exploiting them for operational use. Lean's toolboxes are shop-floor or practically oriented (Golińska, 2014; Pettersen, 2009). As subscribed by scholars they are integrated or implemented as routines that are systematic and procedural, besides being practiced as part of the improvement regime. (Alsyounf *et al.*, 2011; Ballard *et al.*, 2007; Mann, 2010; Tyagi *et al.*, 2015). Zahra and George (2002, p. 190) propounded that elements and practices associated with RACAP rely on routines that provide structural, systemic and procedural mechanisms by which firms transform and exploit knowledge (Jones, 2006). Therefore, it is hypothesized that:

H1b. LTP positively influences RACAP.

2.3.2 Lean social practice and components of absorptive capacity. Johnstone *et al.* (2011) elucidate the human side of Lean which creates commitment, engagement, autonomy, and flexibility. LSP provides a framework for systematic thinking which emphasizes communications and management in an internally driven value-adding scale (Gong and Janssen, 2015). Lean advocates on strongly held beliefs, shared values and common goals (Liker and Morgan, 2006). Its DNA of "Respect for People" mirrors its emphasis on employee empowerment, trust, honesty and motivation (Oppenheim *et al.*, 2011). Leana III and Van Buren (1999) characterized such attributes to organizational social capital wherein members of the organization have a collective goal orientation and shared trust which translates to collective action. LSP promotes socialization which involves interaction that gains tacit knowledge (Pakdil and Leonard, 2015; Zhang and Chen, 2016). Louise (1980) explained that

socialization helps to communicate values and ways of working collectively to new members which shape the comprehension on job-related matters. [Anderson and Thomas \(1996\)](#) study explain work group socialization aid the process of knowledge acquisition and assimilation of newcomer, a trait that resembles PACAP. The LSP also advocates much on cross-functional networks for best practice sharing such as “Kyohokai” ([Dyer and Hatch, 2004](#)) and “Hansei” ([Liker and Morgan, 2006](#)) in Toyota. The purpose is for information exchange, mutual development and training between member companies and socialization ([Dyer and Hatch, 2004](#)). All of which notably assist in the process of acquiring and assimilating new knowledge (PACAP). The conditions and attributes of LSP enables a learning environment ([Oppenheim et al., 2011](#)) which consequently facilitates knowledge acquisition and assimilation. Thus it is posited that:

H2a. LSP positively influences PACAP.

[Nonaka and Takeuchi \(1995\)](#), as cited by [Carlile and Rebutisch \(2003\)](#), explained the challenge in creating new knowledge is not merely to make tacit knowledge explicit, but also the need to redefine, negotiate and transform the knowledge to be used for the creation of collective solution ([Carlile, 2002](#)). [Zahra and George \(2002\)](#) asserted social integration mechanism will lower the barrier of information sharing and increase the efficiency of assimilation and transformation capabilities that eventually lead to exploitation of knowledge. Transformation of knowledge occurs through two realms: across specialization and within specialization of a specific work ([Carlile and Rebutisch, 2003](#)). The multifunctional employees, teams and cross-functional workforce in Lean ([Forza, 1996](#)) caters a platform for knowledge transformation which allows for the “across” and “within” specialization of a specific work, ensuing the socialization process. The pool of knowledge acquired from external parties would enable them to utilize the relevant knowledge by transforming and exploiting (RACAP) them when necessary as part of their improvement regime and strategic decision-making. Members of the cross-functional team undergoes a series of interaction involving tacit and explicit knowledge which represent the way existing knowledge is transformed into new knowledge ([Linderman et al., 2004](#)). Besides, cross-functional teams are also regarded as a knowledge transformation mechanism ([Hirunyawipada et al., 2010](#); [López et al., 2016](#)). [López et al. \(2016\)](#) explain cross-functional teams tend to redefine and realign their perceptions or mental models in the form of collective reflection during the knowledge transfer process in continuous improvement initiatives to verify the usefulness of the new knowledge for application. [Zahra and George \(2002\)](#) explicated RACAP includes knowledge transformation capabilities which helps firms to develop new perceptual schema or changes to the existing process. This implies that LSP enable the capability to transform and exploit new knowledge. This leads us to hypothesize that:

H2b. LSP positively influences RACAP.

2.3.3 Six sigma role structure and components of absorptive capacity. [Gutiérrez et al. \(2012\)](#) claimed the RS should be administered to promote beneficial learning by demonstrating and facilitating the efforts on how to absorb knowledge and putting them into use. [Yusr et al. \(2012\)](#) complements that the RS allows the process of evaluating, assimilating, integrating and using knowledge. Although there are traces of the components of absorptive capacity in these statements and within literatures, nevertheless the working details that explain how are they influenced by RS is rather vague. Six Sigma’s RS or specialized position allows the expansion and capitalization of existing knowledge in the organization where the leaders are

seen as a focal point and source of knowledge stock (De Mast, 2006). The RS facilitates hierarchical coordination mechanism for work across multiple organizational levels to ensure better work design and coordination capabilities (Arumugam *et al.*, 2013; Sinha and Van de Ven, 2005; Zu *et al.*, 2008; Van Den Bosch *et al.*, 1999). This cross-functional leadership allows the transmission of knowledge without borders within an organization besides they are encouraged to continuously expand their proficiencies through seminars, conferences and industrial meetings to gain new insights and enhance their capabilities. According to Arumugam *et al.* (2016), this cross-functional nature enhances the total pool of knowledge and skills through learning among different project teams.

One of the key ingredients for Six Sigma implementation is training and education, which complements the formation of the belt system or RS (Antony and Banuelas, 2002) and the training infrastructure is rather powerful in this improvement regime (Antony *et al.*, 2005). Within the hierarchical belt system, the role of Master Black Belt is to train and mentor Black Belts. Sometimes project leaders such as Black Belts and Green Belts, may be designated to carry out training to educate others in the team who may not be familiar with Six Sigma (Hoerl *et al.*, 2001). Black Belts also coach and mentor Green Belts meanwhile, Green Belts will take on the role of teaching local functional teams on Six Sigma knowledge (Pyzdek, 2003). In the early stages of Six Sigma implementation and setting up of the RS, firms usually hire consultants or experienced Master Black Belts to acquire the Six Sigma knowledge and use of the methods (Chen and Holsapple, 2009; Moosa and Sajid, 2010). Chen and Holsapple's, (2009) case study showed a firm displayed knowledge acquisition characteristic when local consultants and Master Black Belt were hired in the initial stages of the Six Sigma deployment to acquire the skills, talent and tacit knowledge of the initiative that was non-existent in the organization. Additionally, knowledge assimilation was also found to be evident through Black Belt, Green Belt and management training sessions when candidates from various function and destinations were brought together for the learning session. It was found that these specialized roles have a tendency to learn and assimilate knowledge from project reports and gain experience through successful and unsuccessful project outputs.

Choo *et al.* (2007) quoted that the specialized position and the role of leaders in Six Sigma creates recognition and foster the collective desire to learn. These explain the establishment of RS in Six Sigma generates and intensifies learning ventures, resonating in the ability of the RS to function as a driver of learning capability, thus it is hypothesized:

H3a. RS positively influences PACAP.

Pyzdek (2003) explained the significance of improvement specialists, especially Black Belts as change agents, who go out and seek for improvement projects and report to many different people in the organization. Schroeder *et al.* (2008) explained that these project leaders play a boundary spanning role, as actors who are strongly linked to the internal and external environment of organizational functions and subunits. Six Sigma also involves multifunctional teams for improvement activities (Schroeder *et al.*, 2008) and the Black Belts lead the cross-functional project teams within the organization (Pyzdek, 2003). The members of project teams are regarded as "gatekeepers" of information about specific work functions, subject matter experts and knowledge that maybe crucial for improvement initiatives. Illuminating the role of change agents in influencing the features of RACAP, Jones (2006) quoted Harada (2003, p. 1738) who enlightened that to translate and expend information into organization specific knowledge, "boundary spanning individuals" must also be connected to internal knowledge transformers. This means knowledge acquired by gatekeepers and boundary spanners must be passed on to those who can transform and exploit that knowledge (Jones, 2006).

The Black Belts who notably have experience in handling projects that are cross-functional in nature carries and caters extensive knowledge with them through their boundary spanning role. The RS displays how the project leaders' knowledge can be further enriched with the knowledge of project team members' in addition to the gatekeepers of a specific organization unit. During the course of a project, the transformed and integrated knowledge of the Black Belt and project team members from earlier stages of Define, Measure and Analyze will be verified in application during the Improve phase by the process owner through a pilot plan. The improved solution subsequently will be handed over to the process owners for comprehensive roll-out and monitoring (Pyzdek, 2003). This explains how boundary spanners and gatekeepers in the context of Six Sigma's RS are being mobilized in not only acquiring and assimilating new knowledge (PACAP) but transforming and exploiting project related knowledge.

Change agents are particularly important in guiding others to recognize the benefits of adopting new ways of working (Jones, 2006). Project leaders such as Green and Black Belts involved in a Six Sigma project will work collaboratively with project team members and process owners by providing opportunities for all to participate in decision-making which eases the transformation and exploitation of new knowledge (RACAP). Besides, as per Jones (2006, p. 359), "structure and culture influence the organizational ability to transform and exploit new knowledge (RACAP)". De Mast (2006) submits Six Sigma offers an organizational structure and a culture that stimulates investigative and experimental attitude in all levels of an organization. This explains the capability of Six Sigma's RS to transform and exploit new knowledge (RACAP):

H3b. RS positively influences RACAP.

2.3.4 Six sigma structured improvement procedure and components of absorptive capacity. The DMAIC methodological approach is known as a rational and systematic way of capturing and generating knowledge (Choo *et al.*, 2007). Adler *et al.* (1999) views this as a meta-routine, or a routine for problem-solving process. The structured method is a cognition-influencing mechanism that leads to learning behaviors and knowledge creation (Choo *et al.*, 2007). The use of DMAIC methodology aids in the process of learning in project teams (Anand *et al.*, 2010; Arumugam *et al.*, 2014; Choo *et al.*, 2007; Linderman *et al.*, 2010; Javier Lloréns-Montes and Molina, 2006). However, the relation between DMAIC and the components of absorptive capacity, PACAP and RACAP are rarely discoursed. One way to understand this link is through recognizing the nature of activities that occurs at every phase and trace the most common and highlighting attributes of PACAP (knowledge acquisition and assimilation) and RACAP (knowledge transformation and exploitation). Table I provides the objectives of each phase and the key activities undertaken which was summarized from various sources as depicted in Appendix 1.

Arumugam *et al.* (2013) enlightened that the Define and Measure phases are parallel to operational learning wherein team members acquire and assimilate the knowledge of the project under investigation. At this stage, project team members reason with the problems they are facing and arrive to a broad and collective understanding of the issue, which is conceptualized as "know-what" knowledge. Teams will draw different knowledge from various sources to characterize the process by dealing with facts and concepts about the state of a problem or opportunity (Arumugam *et al.*, 2013) which may span across various divisions, business units, subsidiaries and even customers and suppliers. The activities that occurs during knowing-what process are seeking information from customers and suppliers, conversation with members of similar projects, seeking of information or knowledge from internal and external sources of the organization or experts and the likes (Arumugam *et al.*,

Phases	Core objectives of the phase	Summary of key activities
Define	Define the problem in the process under investigation and the goals of the improvement activity	Understand the particular problem which needs to be addressed Identify customer and their requirements (VOC) Develop project charter
Measure	Measure the current process performance or baseline performance	Gather data to validate the problem Establish validity, adequacy and reliability of measurement system and key metrics of the business process Develop data collection plan
Analyze	Analyze the process or problem to identify the root causes behind the problem	Narrow the search of causes by using multiple tools and techniques. Explore and identify common causes in terms of i.e., man, method, machine, materials, measurement and mother nature. Use of data analysis, hypothesis testing to identify and verify causes
Improve	Improve the process by eliminating underlying root causes	Generate and gather inventive solutions to address underlying causes of the problem Evaluate potential solutions versus critical criteria i.e., cost and benefits Finalized solutions undergo small-scale pilots to test viability before being rolled out actively
Control	Control the process after improvement to sustain the results	Develop control plan to monitor key or critical process measures Identify response or contingencies in case of deviation or problem recurrence Handover responsibilities to process owners

Table I.
Summary of core objectives and key activities of DMAIC phases

2013, p. 392). As Pyzdek (2003) described, the early stages of DMAIC cycle involves learning about the problem and what is important to the customer. As depicted in Define and Measure phase, project team members will acquire information pertaining to the problem that is being investigated and identify the customers and their specific requirements. This knowledge acquired will then be assimilated to make sense on the severity of the problem with respect to customer's requirement. The activities and the conceptualization of know-what knowledge (Arumugam *et al.*, 2013) are much inclined to the dimensions of knowledge acquisition and assimilation which forms PACAP:

H4a. SIP positively influences PACAP.

The subsequent phases of Analyze, Improve and Control illustrates the “know-how” knowledge wherein the team engage in collective learning behavior by knowing and implementing far-reaching adaptations involving modification of processes for improved outcome, otherwise known as process optimization (Arumugam *et al.*, 2013). In other words, at these phases team members rationalize and transform the conceptual ideas gained from various stakeholders and team members into practical use by testing out through pilot runs and executing new ideas to materialize the improvements. The activities that unfolds during these phases are critical observation of the problem, use of various tools and techniques to understand the relationship among variables, synthesize ideas, reflection and action cycle (Arumugam *et al.*, 2013, p. 393). These activities imply to the effort to transform and exploit the knowledge that is learned to yield organizational outcomes. Knowing-how involves

identifying ways of using members' knowledge to come up with viable and inventive solutions for the underlying issues which includes modifying, converting, altering and capitalizing the information learned from the preceding phases. These activities depict inclination to knowledge transformation and exploitation in the subsequent phases of Analyze, Improve and Control. Hence, it is proposed that:

H4b. SIP positively influences RACAP.

Figure 1 depicts the inclination of DMAIC activities associated to the attributes of PACAP and RACAP.

2.3.5 Six sigma focus on metrics and components of absorptive capacity. Six Sigma places a stringent FOM and measures to achieve specific and challenging goals in its improvement projects (Linderman *et al.*, 2003). Six Sigma's strategy of setting high goals is in parallel to stretch goal strategy (Choo, 2011). Challenging goals coupled with strict FOM channel a sense of challenge to project team members that serve as motivational mechanism which regulates human action by mobilizing effort, direct attention and focus on learning to solve the problem associated with the stretch target (Choo, 2011; Locke and Latham, 1990). Describing the domain of Six Sigma's FOM, Zu *et al.* (2008) clarified business-level performance measures and goals derived from customer expectations, are integrated with process-level performance measures. This establishes a high level mutual understanding of customers' expectations between Six Sigma firms and its customers which are eventually extended to suppliers, spanning across the supply chain, in the effort of achieving those expectations (Pyzdek, 2003).

As stated by Yli-Renko *et al.* (2001), establishing high level mutual expectations enhance knowledge acquisition meanwhile shared expectation and goals enable firms to invest more effort into knowledge assimilation. A high level mutual expectation between Six Sigma firms and its customers encourage knowledge acquisition of customers' desires, needs or demands by the firm. This information is assimilated into customer-oriented metrics such as Voice of Customers (VOC) and Critical to Quality (CTQ) (Schroeder *et al.*, 2008). Alcaide-Muñoz and Gutierrez-Gutierrez (2017) asserted Six Sigma metrics help firms to identify potential customers along with their requirements and needs, leading to exploration of reliable information. These goals and expectations are translated through Six Sigma projects within the organization, sometimes together with suppliers (Pyzdek, 2003), and assimilated into performance and quality metrics such as Rolled Throughput Yield (RTY), Defects Per Million Opportunity (DPMO), 10x performance measures and the likes in the effort to accomplish the goals of the customers. Alcaide-Muñoz and Gutierrez-Gutierrez (2017) posited the continued use of Six Sigma metrics cultivate exchange of information about processes and procedures in addition to development of explicit knowledge and learning between workers. Therefore, it is postulated:

H5a. FOM positively influences PACAP.

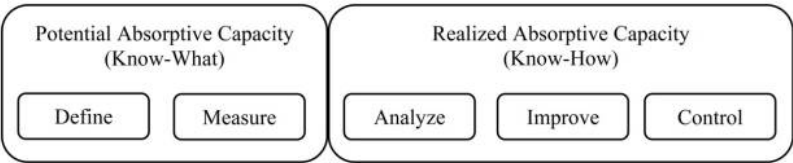


Figure 1.
Inclination of DMAIC
Activities to PACAP
and RACAP

FOM facilitates the creation and use of a common language (Kumar *et al.*, 2008). Carlile and Reberich (2003) conferred the establishment of a common language eases the representation and transformation of knowledge. In an organization, there are several specialization and division of labor wherein different occupational communities have different work experience and functions. As a result, different perspective and multiple meanings emerge from various sources of the organizational functions and network (Bechky, 2003; Perrow, 1970). Clark (1996) stated that to develop shared understanding between groups that have different work contexts, group members had to co-create some common ground. Bechky (2003) substantiated creating a common ground between organization's communities can transform the understandings of one another, generating a richer understanding of problems they face.

Six Sigma metrics creates a common language that functions as a common ground by synergizing the acquired and assimilated information which brings a synonymous understanding to all communities of the organization through the use of specific metrics. Information that is coded in the metrics could then be extracted, recoded and interpreted according to occupational context to be used for solution seeking or problem-solving activities by respective or relevant organization subunits, functions or networks. For instance, customers' expectations or demand may bring differing implication and meaning to different functions or subunits within the organization. Six Sigma metrics such as the CTQ acts as a common metrics that is understood synonymously which explains the critical to quality desires of customers. From CTQ the relevant information for every subunits or functions can be extracted, transformed, interpreted or recoded with respect to their occupational context and subsequently used for problem-solving or seeking of solutions. Zahra and George (2002) explains transformation capability refers to recognizing and combining different sets of information to arrive at a new schema to be exploited for operational benefits. Bechky (2003) added such transformation engenders broadly shared understanding that allows the knowledge to be used across the organization. It is therefore sufficing to say:

H5b. FOM positively influences RACAP.

2.3.6 Potential absorptive capacity and realized absorptive capacity. Zahra and George (2002) revealed that PACAP and RACAP are distinctive but play complementary roles as they have a tendency to coexist. The distinction of PACAP and RACAP allows the comprehension of why some firms fail while some thrive in constantly changing environment such as technological lockout of industrial shocks (Bower and Christensen, 1995). Firms may acquire and assimilate knowledge (PACAP) however they may not necessarily have the ability to transform and exploit (RACAP) them for profit generation (Zahra and George, 2002). Vice versa, firms may have the proficiency in transforming and exploiting knowledge (RACAP) but may be inept in acquiring and assimilating them (PACAP) resulting in the inability to respond to environmental changes (Jansen *et al.*, 2005). Besides, without absorbing the knowledge first, firms could not exploit the knowledge, as RACAP involves transforming and exploiting the assimilated knowledge (Zahra and George, 2002). Although there are numerous accounts for organizational success through Lean Six Sigma implementation, it is noteworthy to indicate there are also failures (Albliwi *et al.*, 2014). Understanding how the capabilities of absorptive capacity relates under the context of Lean Six Sigma may aid in disentangling the failures. For instance, suppose PACAP do not positively influences RACAP, this may lead to substantial managerial implication to re-strategize the use of Lean Six Sigma and its purposeful application. As Albort-Morant *et al.* (2018) puts forth, obtaining external knowledge (PACAP) does not

necessarily guarantee the operation of the knowledge (RACAP). Besides, [Zahra and George \(2002\)](#) mentioned that PACAP and RACAP require different managerial roles to harvest and nurture them. Additionally, [Jansen *et al.* \(2005\)](#) observed different organizational mechanism associate differently to PACAP and RACAP. Lean Six Sigma application within an organization may trigger the development of PACAP and RACAP differentially resulting in a fluid and non-linear path to enhance competencies ([Zahra and George, 2002](#); [Cepeda-Carrion *et al.*, 2012](#)). As such, this research intends to clarify whether PACAP positively predicts RACAP under the context of Lean Six Sigma. Hence, it is hypothesized that:

H6. PACAP positively influences RACAP.

[Zahra and George \(2002\)](#) mentioned that PACAP and RACAP are indeed separate but complimentary. Consistently, [Cepeda-Carrion *et al.* \(2012\)](#) found that PACAP could function as an antecedent of RACAP. Given the sequential manner of these components and the fact that they are fluid and may follow a non-linear path in developing organizational competencies, it motivates the study to contemplate whether PACAP acts as a mediator between the distinct practices of Lean Six Sigma and RACAP ([Cepeda-Carrion *et al.*, 2012](#); [Flor *et al.*, 2017](#)). This leads us to scrutinize:

H7a. PACAP mediates the relationship between LTP and RACAP.

H7b. PACAP mediates the relationship between LSP and RACAP.

H7c. PACAP mediates the relationship between RS and RACAP.

H7d. PACAP mediates the relationship between SIP and RACAP.

H7e. PACAP mediates the relationship between FOM and RACAP.

Figure 2 below portrays the research framework of this study in line to the hypotheses articulated above.

3. Research methodology

The data for this study were collected through a questionnaire survey method. The organization as a whole is the unit of analysis. The target population of the survey was manufacturing firms in Peninsular Malaysia as registered under the Federation of Malaysian Manufacturers (FMM) 2016 directory (47th edition). Given the prevalence of International Organization for Standardization's (ISO) link toward Lean and Six Sigma ([Chiarini, 2011](#); [Karthi *et al.*, 2011](#)) and [Kumar *et al.*, 's \(2009\)](#) claim that ISO may be the foundation toward embracing Lean and Six Sigma, the list containing 2844 firms were narrowed to 1,311 firms that are classified under ISO 9001 and 14001 certifications, the commonly adopted ISO certifications in Malaysia ([Idris *et al.*, 2012](#); [Ratnasingam *et al.*, 2013](#)). Emails and series of cold calls were made to these 1311 firms enquiring their status on Lean Six Sigma application of which 842 firms reverted in total. However, 298 firms claimed to be only using either Lean or Six Sigma. Based on it, 544 firms were identified to be practicing both Lean and Six Sigma at the time of the research. Target or preferred respondents were Green Belts, Black Belts, Master Black Belts and Champions or Sponsors of Lean Six Sigma projects as the study requires respondents in leadership and managerial

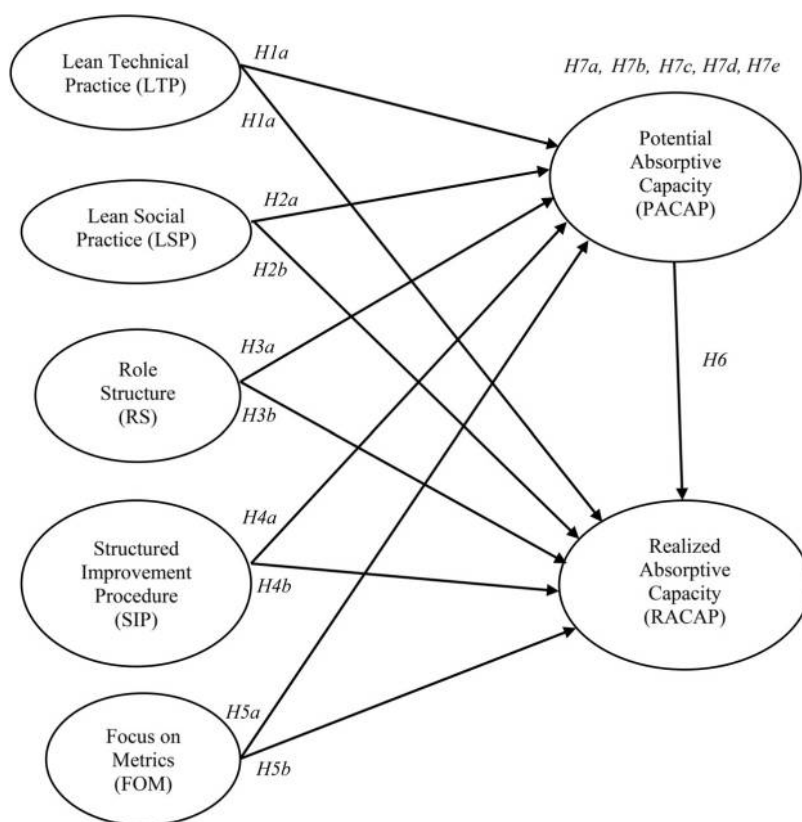


Figure 2.
Research framework

role. The measurement instrument used to operationalize the constructs in the theoretical framework was validated multi-item measures which were adapted from literatures as specified in [Appendix 2 \(Sekaran and Bougie, 2010\)](#).

A “five-point” Likert-type scale ranging from 1 to 5 was used to measure each item. The questionnaire was pretested by an expert panel consisting of three university lecturers in the field of Quality Management, Economics and Business and three industrial practitioners or experts in the field of process improvement to review its content validity. Subsequently, a pilot survey was carried out on 25 randomly selected companies to test the reliability of the study instrument before data collection. The assessment found reliability scores of Cronbach alpha (CA) ranging from 0.553 to 0.940 ([Appendix 3](#)). The generally accepted CA score is 0.70 and beyond (Hair *et al.*, 1998). However, [Hinton *et al.* \(2004, p. 363\)](#) described a CA value between 0.50 and 0.75 indicates a moderately reliable construct. Nevertheless, [Hair *et al.* \(2016, p. 101\)](#) enlightened the CA is “sensitive to the number of items in the scale and generally tends to underestimate the internal consistency reliability” and “PLS-SEM prioritizes the indicators according to their individual reliability”. Given the limitation and requirement respectively, they suggested the use of Composite Reliability (CR) as a measure of internal consistency reliability which is deemed to be technically more appropriate as it takes into account the different outer loadings of the indicator variables ([Hair *et al.*, 2016](#)). According to [Hair *et al.* \(2016\)](#) CR values between 0.60 and 0.70 are acceptable in exploratory

research meanwhile values between 0.70 and 0.90 are regarded as satisfactory. CA which usually results in low reliability value is a conservative measure of reliability whereas CR represents upper bound of the reliability (Hair *et al.*, 2016). Gpower program was used to decide on the optimum sample size (Hair *et al.*, 2016). Given the maximum predictors on a single construct being six, and with a considerable effect size of 80 per cent for social science research as recommended by Cohen (1992), the minimum sample size required for the study's framework is 98. Using a census approach, the 519 questionnaires (excluding the pilot surveys) were distributed through mail survey of which 147 were reverted. Of these, 17 were unusable due to substantial missing information resulting in a total of 125 usable questionnaires which is equivalent to 24.1 per cent response rate. The response rate is of substantial amount surpassing the 98 minimum sample size requirement.

4. Analysis results

4.1 Descriptive analysis

Table II exhibits the background of the respondents. Sub-sector wise, Transport Equipment and other Manufacturers and Electrical and Electronics are the major contributors with 35.2 per cent and 29.6 per cent respectively, followed by Non-Metallic Mineral Products, Basic Metal and Fabricated Metal Products (17.6 per cent). Slightly over half (56 per cent) of the 125 companies employed more than 1,000 workers. Amongst these firms, 40 per cent are Malaysian-owned, 5.6 per cent are government-linked organizations and 54.4 per cent are MNCs. Majority of the firms are private organizations accounting for 91.2 per cent of the total firms and most (74.4 per cent) have been in business for more than 15 years. Half (49.6 per cent) of the firms have been using Lean and Six Sigma for more than eight years and 38.4 per cent had been using it between six and eight years. This qualifies to illustrate that majority of the responding firms are experienced practitioners of Lean Six Sigma.

Almost half (49.6 per cent) of the Lean Six Sigma practicing firms utilizes DMAIC and PDCA methodology in their process improvement endeavour. Lean commonly uses the PDCA cycle whereas Six Sigma is known for the DMAIC cycle. Therefore, it is notable that those firms apply both methodology interchangeably in the application of Lean Six Sigma. Around 47.2 per cent of the firms claim to benefit more than \$200,000 in average annual savings generated from Lean Six Sigma projects. About 17.6 per cent claim to be yielding between \$50,000 and \$100,000 and 15.2 per cent of the firms are benefiting under \$50,000 from Lean Six Sigma projects. Of the 125 firms, 34.4 per cent of the respondents were Black Belts, followed by Green Belts who account for 32.8 per cent. There were 24 Champions or sponsors and 17 Master Black Belts comprising the remaining distribution of the respondents. Therefore, the respondents of this survey demonstrated an adequate knowledge and experience in the implementation of Lean Six Sigma. An independent *t*-test (for non-demographic variables) and Chi-Square test (for demographic variables) was conducted to verify response bias between early and late respondents which showed no significant concern. Given the study involves self-reporting on questionnaire, there is a possibility of common method variance (CMV) issue for which a Harman's single factor test was effected (Podsakoff *et al.*, 2003). The analysis shows the restricted extraction of a single factor only explains 21.5 per cent of the variance, suggesting CMV is not a concern in the data.

4.2 Measurement model analysis results

The SmartPLS was used to assess the psychometric properties of the measurement and structural model (Ringle *et al.*, 2015). According to Hair *et al.* (2016) once the research model is formed, the outer model or measurement model must be tested. Evaluation of the outer

Characteristics	Categories	Overall		Absorptive capacity
		Frequency	(%)	
Industry Sub-Sectors	Petroleum, Chemical, Rubber and Plastic	7	5.6	
	Electrical and Electronics	37	29.6	
	Food, Beverages and Tobacco	15	12.0	
	Non-Metallic Mineral Products, Basic Metal and Fabricated Metal Products	22	17.6	
	Transport Equipment and other Manufacturers	44	35.2	
Number of Employees	Less than 100	10	8.00	
	100-250	15	12.00	
	251-500	14	11.20	
	501-1000	16	12.80	
	More than 1000	70	56.00	
Firm Ownership	MNC	68	54.40	
	Malaysian-Owned	50	40.00	
	Government Linked Company	7	5.60	
Firm Type	Public Listed (Berhad)	11	8.80	
	Private Limited (Sdn. Bhd.)	114	91.20	
Duration in Business	Less than 5 years	3	2.40	
	6-10 years	20	16.00	
	11-15 years	9	7.20	
	More than 15 years	93	74.40	
Duration of Lean Six Sigma Implementation	2-3 years	7	5.60	
	4-5 years	8	6.40	
Methodology used	6-8 years	48	38.40	
	More than 8 years	62	49.60	
	DMAIC	35	28.00	
	PDCA	19	15.20	
Average Annual Savings from Lean Six Sigma Projects	DMAIC and DFSS	9	7.20	
	DMAIC and PDCA	62	49.60	
	Less than \$ 50,000	19	15.20	
	\$50,000-100,000	22	17.60	
	\$100,000-150,000	12	9.60	
	\$150,000-200,000	13	10.40	
Lean Six Sigma Qualification	More than \$200,000	59	47.20	
	Black Belt	43	34.40	
	Master Black Belt	17	13.60	
	Green Belt	41	32.80	
	Champion/Sponsor	24	19.20	

Table II.
Respondents'
demographic profile

model involves average variance extracted (AVE) and composite reliability (CR) and discriminant validity (Table III).

AVE must be greater than 0.5 to reflect at least 50 per cent of items explain the construct and CR must be greater than 0.7 (Hair *et al.*, 2016). The results show internal consistent reliability and convergent validity criteria are fulfilled for all variables.

Discriminant validity was evaluated following Fornell and Larcker (1981) criterion of comparing the correlations between constructs and the square root of the AVE for that construct. All the values on the diagonals were greater than the corresponding row and column values indicating the measures were discriminant (Table IV).

However, studies lately have emerged highlighting shortfalls of conventional discriminant validity measures such as cross loadings and Fornell-Larcker criterion (Voorhees *et al.*, 2016). Therefore, a contemporary approach in testing discriminant validity

IJLSS

Constructs	Item	Loadings	AVE	CR	Cronbach
Lean Technical Practice (LTP)	LTP3	0.658	0.501	0.749	0.514
	LTP4	0.673			
	LTP5	0.785			
Lean Social Practice (LSP)	LSP2	0.625	0.515	0.905	0.882
	LSP3	0.694			
	LSP4	0.728			
	LSP5	0.712			
	LSP6	0.702			
	LSP7	0.745			
	LSP8	0.731			
	LSP9	0.752			
	LSP10	0.760			
Role Structure (RS)	RS1	0.687	0.516	0.810	0.688
	RS2	0.764			
	RS3	0.715			
	RS4	0.705			
Structured Improvement Procedure (SIP)	SIP1	0.856	0.685	0.866	0.770
	SIP2	0.758			
	SIP3	0.864			
Focus on Metrics (FOM)	FOM2	0.618	0.509	0.861	0.808
	FOM3	0.795			
	FOM4	0.746			
	FOM5	0.688			
	FOM6	0.744			
	FOM7	0.677			
	FOM8	0.677			
Potential Absorptive Capacity (PACAP)	PACAP2	0.714	0.514	0.840	0.764
	PACAP4	0.660			
	PACAP7	0.709			
	PACAP8	0.770			
	PACAP9	0.727			
Realized Absorptive Capacity (RACAP)	RACAP1	0.604	0.517	0.809	0.687
	RACAP7	0.782			
	RACAP9	0.767			
	RACAP10	0.708			

Notes: LTP1, LTP2, LSP1, RS5, FOM1, FOM8, PACAP1, PACAP3, PACAP5, PACAP6, RACAP2, RACAP3, RACAP4, RACAP5, RACAP6, RACAP8, RACAP11, RACAP12 was deleted due to low loading which improved AVE and CR

Table III.
Measurement model

Constructs	FOM	LSP	LTP	PACAP	RACAP	RS	SIP
FOM	0.714						
LSP	0.546	0.718					
LTP	0.374	0.434	0.708				
PACAP	0.184	0.370	0.288	0.717			
RACAP	0.455	0.484	0.320	0.438	0.719		
RS	0.382	0.392	0.312	0.348	0.451	0.718	
SIP	0.392	0.386	0.333	0.552	0.414	0.430	0.827

Table IV.
Discriminant validity

Notes: Diagonals represent the square root of AVE while the other entries represent the squared correlations

using Heterotrait-Monotrait ratio of correlations (HTMT) as proposed by [Henseler et al. \(2015\)](#) was conducted. Discriminant validity is said to be of an issue when the values surpass 0.85 (HTMT_{0.85}) or 0.90 (HTMT_{0.90}). HTMT_{0.85} is a stringent criterion than the HTMT_{0.90} value. Given the results reported in [Table V](#), all the values amongst the constructs are lower than the stricter value of HTMT_{0.85}. Therefore, it indicates that discriminant validity of this measurement model is ascertained and proves of no concern.

4.3 Structural model analysis results

The structural model was tested by performing a bootstrapping procedure with a resample of 5,000 as suggested by [Hair et al. \(2016\)](#). The result is as presented in [Figure 3](#) and [Table VI](#).

The results indicate LTP does not significantly influence PACAP ($\beta = 0.074$, NS) and RACAP ($\beta = 0.019$, NS) resulting in *H1a* and *H1b* not supported. On the contrary, the social side of Lean, LSP seem to be positively influential toward PACAP ($\beta = 0.216$, $p < 0.01$) and RACAP ($\beta = 0.177$, $p < 0.05$). Hence, *H2a* and *H2b* are supported. Six Sigma's RS also seem to positively influence PACAP ($\beta = 0.109$, $p < 0.1$) and RACAP ($\beta = 0.192$, $p < 0.1$), which supports *H3a* and *H3b*. The SIP, however, only seem to strongly predict PACAP ($\beta = 0.471$, $p < 0.01$) and not RACAP ($\beta = 0.038$, NS). FOM on the other hand seems to have a strong positive effect on RACAP ($\beta = 0.219$, $p < 0.01$) but it is negatively related to PACAP ($\beta = -0.188$, NS). Correspondingly, *H4a* and *H5b* are supported meanwhile *H4b* and *H5a* are not supported. From the analysis, it is also evident that RACAP is positively influenced by PACAP ($\beta = 0.239$, $p < 0.05$). Hence, *H6* is supported ([Table VI](#)).

To test the indirect effect, [Preacher and Hayes' \(2008\)](#) method of bootstrapping was used. The result of the analysis should reveal a significant *t-values* for the indirect effect of every relationship and the 95 per cent Bootstrapping Confidence Interval (CI) between the upper and lower limit should not straddle a zero in between. Based on the above results, between hypotheses *H7a* to *H7e*, it can be confirmed that only *H7d* is supported given an indirect effect (of $\beta = 0.471 \times 0.239 = 0.113$), *t-values* of 2.099, and the 95 per cent Bootstrapped CI: [LL = 0.007, UL = 0.218] does not straddle a 0 in between (refer [Appendix 4](#)). Based on the result it can be concluded that the mediation effect of PACAP on the relationship between SIP and RACAP is statistically significant.

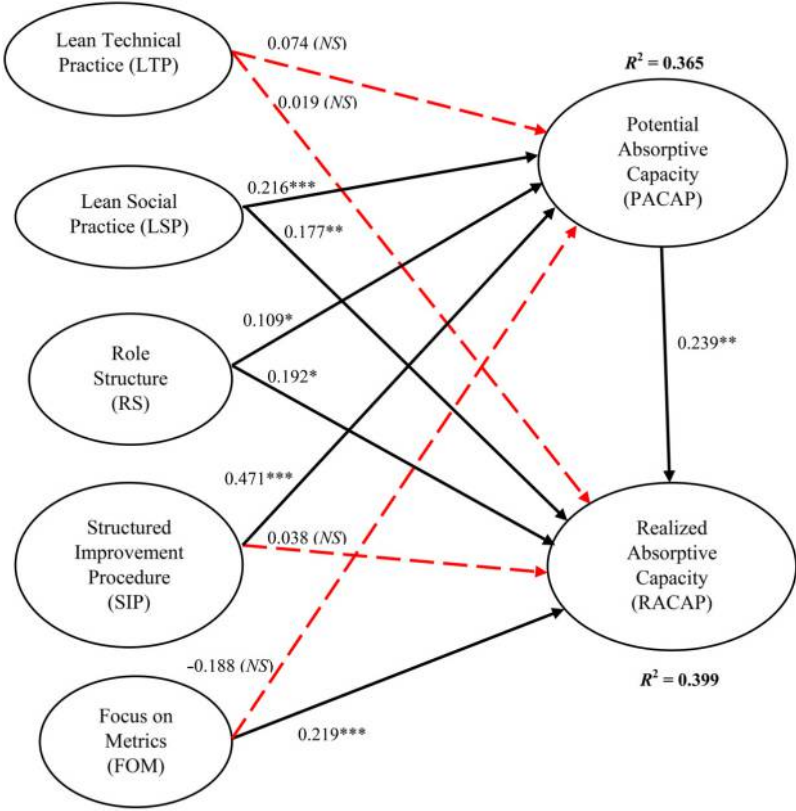
With reference to [Appendix 5](#), the R^2 value shows that Lean Six Sigma's idiosyncrasies explained 36.5 per cent variance on PACAP and 39.9 per cent variance on RACAP. [Sullivan and Feinn \(2012, p. 279\)](#) explained

[...] while a P value can inform the reader whether an effect exists, the P value will not reveal the size of the effect. In reporting and interpreting studies, both the substantive significance (effect size) and statistical significance (P value) are essential results to be reported.

Constructs	FOM	LSP	LTP	PACAP	RACAP	RS	SIP
FOM							
LSP	0.640						
LTP	0.593	0.678					
PACAP	0.229	0.447	0.423				
RACAP	0.591	0.604	0.527	0.581			
RS	0.499	0.501	0.521	0.470	0.640		
SIP	0.480	0.473	0.551	0.704	0.547	0.592	

Table V.
Discriminant validity
(HTMT ratio)

Figure 3.
Results of structural
model



Notes: $p < 0.1^*$, $p < 0.05^{**}$, $p < 0.01^{***}$, NS not Significant

The effect size (f^2) is a test which evaluates the changes in R^2 values of all endogenous constructs when a specified exogenous construct is omitted from the model. This will enable the researcher to realize whether the omitted construct has a substantive impact on the endogenous constructs (Hair *et al.*, 2016). Cohen (1988) state that effect sizes of the relationships are small if the $f^2 = 0.02$, medium if $f^2 = 0.15$, and large when $f^2 = 0.35$. There are five relationships with small effect sizes (H2a, H2b, H3b, H5b and H6) and one with medium effect size (H4a) meanwhile the rest can be considered as absent of any effect size. The analysis also reveals that the structural model is free from multicollinearity issues as variance inflation factor (VIF) readings are below the 3.33 threshold (Diamantopoulos and Siguaw, 2000). The Q^2 value explains the predictive relevance of the research model (Hair *et al.*, 2016; Fornell and Cha, 1994). The Q^2 value is acquired through the blindfolding procedure for a specified omission distance (D) (Hair *et al.*, 2016). The distance chosen for this study is 7. Given all the Q^2 values are greater than zero, ranging from 0.152 to 0.167, it can be concluded that the research model has sufficient predictive relevance.

Absorptive
capacity

Hypothesis	Causal path	Path coefficient (β)	t -statistics	Result
H1a	LTP \rightarrow PACAP	0.074	0.782 (NS)	Not Supported
H1b	LTP \rightarrow RACAP	0.019	0.222 (NS)	Not Supported
H2a	LSP \rightarrow PACAP	0.216	2.417***	Supported
H2b	LSP \rightarrow RACAP	0.177	1.742**	Supported
H3a	RS \rightarrow PACAP	0.109	1.309*	Supported
H3b	RS \rightarrow RACAP	0.192	1.591*	Supported
H4a	SIP \rightarrow PACAP	0.471	4.842***	Supported
H4b	SIP \rightarrow RACAP	0.038	0.323 (NS)	Not Supported
H5a	FOM \rightarrow PACAP	-0.188	1.907(NS)	Not Supported
H5b	FOM \rightarrow RACAP	0.219	2.499***	Supported
H6	PACAP \rightarrow RACAP	0.239	1.924**	Supported
H7a	LTP \rightarrow PACAP \rightarrow RACAP	0.018	0.602	Not Supported
H7b	LSP \rightarrow PACAP \rightarrow RACAP	0.052	1.329	Not Supported
H7c	RS \rightarrow PACAP \rightarrow RACAP	0.026	0.836	Not Supported
H7d	SIP \rightarrow PACAP \rightarrow RACAP	0.113	2.099*	Supported
H7e	FOM \rightarrow PACAP \rightarrow RACAP	-0.045	-1.362	Not Supported

Table VI.
Hypothesis testing
result and path
coefficient

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; NS (Not Significant); A two-tailed test is used for mediation assessment: * $p < 0.05$; ** $p < 0.01$

5. Discussion

LTP was found to have insignificant relationship on both components of absorptive capacity (PACAP: $\beta = 0.074$, $t = 0.782$; RACAP: $\beta = 0.019$, $t = 0.222$). This contradicts previous studies' findings such as Stanica and Peydro's (2016) which found Lean tools have a positive effect on the knowledge transfer process in the organizations, which reflect the traits of absorptive capacity. However, the results obtained may be in line with Anand *et al.* (2009), who explained that operational Lean tools is a minimum but not sufficient condition for the development of Lean culture and infrastructure. Another possible explanation to this may be as per Assen (2016) who stated that Lean's tools did not have a direct effect toward the outcome but were impactful toward Lean's infrastructural practices (social practices) which in turn was significantly related to the outcomes. However, it is also noteworthy to point out that Lean's tools and techniques had also been conceptualized in bundles of practices in some research. Shah and Ward (2003) is renowned to have bundled the tools of Lean into four; Just in Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM) and Human Resource Management (HRM) which consist of 22 tools and techniques. Cua *et al.* (2001) found high performing plants commonly use bundles of tools or practice that are TQM, JIT and TPM oriented. However, Hadid *et al.* (2016) in identifying the interaction of technical and social practices of Lean, classified 23 practices of Lean tools into four factors, being; process, physical structure, customer value and error prevention. In this study, measurement of Lean tools was adopted from Gowen III *et al.* (2012) involves five commonly utilized tools in Lean organizations regardless of industry. These low number of items were chosen to facilitate the convenience of respondents who may detract in answering genuinely given a long list of tools which require them to identify each tool in their organizational context. The classification of commonly used tools and techniques of Lean in the manufacturing industry into bundles of practice may have an alternate outcome toward the components of absorptive capacity which we recommend as an avenue for future research.

LSP is found to be positively significant in influencing PACAP ($\beta = 0.216$, $t = 2.417$, $p < 0.01$) and RACAP ($\beta = 0.177$, $t = 1.742$, $p < 0.05$). The social network of Lean requires the

participation of all relevant stakeholders in decision-making while engaged in improvement activities. Consistent with the study by [Anderson and Thomas \(1996\)](#) which explained work group socialization aid the process of knowledge acquisition and assimilation of newcomer, [Cohen and Levinthal \(1990\)](#) enlightened that participation increases the range of prospective “receptors” in the organization’s environment, which filters and facilitates new external knowledge acquisition and assimilation ([Aldrich and Herker, 1977](#)). These enables the characteristics of PACAP. Besides socialization capabilities enable the creation of broad and tacitly understood rules for appropriate actions ([Camerer and Vepsäläinen, 1988](#); [Volberda, 1999](#)). The social network of Lean involves an interaction between customer–supplier relationship which consequently spurs strong social norms and beliefs ([Adler and Kwon, 2002](#); [Zailani et al., 2015](#)). This is consistent with [López et al. \(2016\)](#) as they explain cross-functional teams tend to redefine and realign their perceptions or mental models in the form of collective reflection during the knowledge transfer process in continuous improvement initiatives to verify the usefulness of the new knowledge for application. This would enhance commitment and compliance for the exploitation process, wherein the tacit understandings could be spawned and transformed into knowledge that could resolve critical issues which benefits the business network as a whole. As such it elicits RACAP in a Lean organization. [Fynes and Ainamo’s \(1998\)](#) work supplements these facts as they articulate how Lean’s cross-organisational architecture creates a learning environment for the exploitation benefit amongst its supply chains.

The RS of Six Sigma or commonly known as the belt system was also found to be positively related to PACAP ($\beta = 0.109$, $t = 1.309$, $p < 0.1$) and RACAP ($\beta = 0.192$, $t = 1.591$, $p < 0.1$). This finding extends the line of contribution by closing the gaps from [Gutiérrez et al. \(2012\)](#), who could not determine whether the lateral communication mechanisms, facilitated by the belt system, influences PACAP or RACAP. This study led to the discovery of the gap, wherein the results showed RS positively influences both phases of absorptive capacity. The RS acts as a hierarchical coordination mechanism for quality improvement work across multiple organizational levels which nurtures the knowledge transfer process in the form of information acquisition and assimilation amongst internal and external stakeholders ([Sinha and Van de Ven, 2005](#); [Gutiérrez Gutiérrez et al., 2016](#)). The cross-functional leadership, training and mentorship through the RS is known to accommodate learning capabilities wherein the leaders act as knowledge stock of Six Sigma expertise that enable the knowledge acquisition and assimilation capability to permeate through project and training endeavors ([Chen and Holsapple, 2009](#); [Moosa and Sajid, 2010](#)). According to [Hoerl et al. \(2001\)](#), Six Sigma project leaders, who plays specialized roles as improvement specialists, are trained in the practice of collecting, combining and synthesizing knowledge through which they can exploit that knowledge for the purpose of project resolutions. Apart from organizational structure and a culture that stimulates investigative and experimental attitude the RS brings to the organization ([De Mast, 2006](#)), the interaction between boundary spanning role of the project leaders (Black Belts) and project team members who act as information gatekeepers engenders transformation capability in recognizing and combining different sets of information to arrive at a new schema to be exploited for operational benefits which resembles RACAP ([Zahra and George, 2002](#)).

The findings of this research revealed that SIP positively influences PACAP ($\beta = 0.471$, $t = 4.842$, $p < 0.01$). Parallel to theoretical view where PACAP is commingled with learning abilities ([Zahra and George, 2002](#); [Kim, 1995](#)), this finding is in line with previous study by [Choo et al. \(2007\)](#) wherein they found Six Sigma’s structured method contributes significantly to learning behaviors. [Adler et al. \(1999\)](#) enlightened that learning behaviors

can be achieved through systemized meta-routines, which can maintain efficiency and flexibility in problem-solving processes. However, it was found that SIP was not directly related to RACAP ($\beta = 0.038$, $t = 0.323$, not significant), which comes in contrast to [Choo et al. \(2007\)](#) who mentioned that structured method as variance reducing or exploitative mechanism. [Gebauer et al. \(2012\)](#) explicated PACAP is related to exploratory learning whereas RACAP is associated with exploitative learning. The mediation test reveals SIP influences RACAP through PACAP ($\beta = 0.113$, $t = 2.099$). In the Define, Measure and Analyze phase, team members are engaged in learning and acquiring more information of the project. Upon gathering those information, execution plans will follow through to put the solutions in place. This also proves that the DMAIC structure fosters the components of absorptive capacity, PACAP and RACAP in a systematic and sequential manner. This finding is in line with [Hwang et al. \(2017\)](#) wherein they found evidence of Six Sigma's structured method impacting exploration and exploitation traits as a means of creative process prior to influencing performance.

FOM seem to be positively effectual toward RACAP ($\beta = 0.219$, $t = 2.499$, $p < 0.01$) but surprisingly, negatively effects PACAP ($\beta = -0.188$, $t = 1.907$, not significant). This contradicts our earlier supposition of FOM establishing a high level mutual expectation between firms and external stakeholders. However, it does provide a common ground or language that facilitates knowledge transformation and exploitation capability (RACAP). Besides, this finding supplements the workings of [Linderman et al. \(2006\)](#). Setting project targets in Six Sigma is based on stretch goal strategy which has high FOM and goals ([Choo, 2011](#); [Schroeder et al., 2008](#)). This trait induces motivation for project team members to take more effort, be more persistent and intensify their focus and attention on relevant activities to accomplish the goals ([Zu et al., 2008](#); [Linderman et al., 2003](#)). It can be deliberated that the type of learning capability infused through FOM may differ as it is much oriented toward exploitative features. It is elucidated that a mechanistic structure with tightly coupled connections foster exploitative learning ([Burns and Stalker, 1961](#); [Weick and Westley, 1999](#)). In this case, FOM may be essential toward RACAP where rigorous efforts are placed in transformation and exploitation of knowledge to identify solutions and ensure the target is met. In the expense of realizing the target, the importance of PACAP is diminished. It is conceivable in this context that FOM relates more positively on RACAP and conversely on PACAP.

The study found PACAP is positively related to RACAP ($\beta = 0.239$, $t = 1.924$, $p < 0.05$) in the context of Lean Six Sigma application. This finding ratifies the theoretical argument by [Zahra and George \(2002\)](#) that PACAP and RACAP are separate but play a complementary role. Scholars have also noted the corresponding roles played by the two components which reflect the functionality of absorptive capacity ([Fosfuri and Tribó, 2008](#); [Cepeda-Carrion et al., 2012](#); [Leal-Rodríguez et al., 2014](#)). This finding corroborates the fact that embracing Lean Six Sigma does not only engender learning capability but transpire or capitalize the resulting knowledge into tangible and beneficial outcomes to the organization. Through PACAP, Lean Six Sigma firms will possess the ability to track changes in their industries effectively and facilitate the deployment of necessary capabilities in a timely manner. This implies reduced sunk investments, as firms could manage its routines and capabilities proficiently. In the process of scouring for resolutions in Lean Six Sigma projects, team members will transform and exploit their knowledge base. The project teams consequently endure a process known as "bisociation" which conveys new perceptual schema that assists in new knowledge conversion hence fostering innovation.

In addition to that, PACAP is consistent with exploratory traits as it requires change, flexibility and creativity ([Albort-Morant et al., 2018](#); [Gebauer et al., 2012](#); [Limaj and](#)

Bernroider, 2017) and RACAP is with exploitative traits given its requirement for control and stability (Albort-Morant *et al.*, 2018; Limaj and Bernroider, 2017; Gebauer *et al.*, 2012). The findings of this study indicates Lean Six Sigma's potency in nurturing ambidextrous capability in firms through the distinctive practices as delineated above, enabling firms to gain and sustain competitive advantage. This supports the supposition by some authors who claim that quality improvement philosophies such as Lean Six Sigma is conducive toward both exploration and exploitation oriented activities and capabilities (Schroeder *et al.*, 2008; Zhang *et al.*, 2011; Jugulum and Samuel, 2010). Competent in maneuvering improvement continuously, Lean Six Sigma provides a cushioning mechanism especially at times of turbulence and tribulations, corresponding in the formation of an organizational context that is dynamic in characteristic. Therefore, appropriating the use of Lean Six Sigma, organization could strike a balance between exploitative and explorative capabilities according to business objectives, hence creating an organic structure that is ambidextrous, deemed as a substantial predictor of sustainable competitive advantage (Schroeder *et al.*, 2008; Tushman and O'Reilly, 1996).

6. Managerial and theoretical implications

Managers and practitioners should be aware on how Lean Six Sigma's idiosyncrasies function toward generating capabilities that are dynamic in the form of PACAP and RACAP. This study rationalizes five distinctive practices of Lean Six Sigma and its effect on the components of absorptive capacity. The findings cater managers and practitioners with options to tactfully and systematically enhance absorptive capacity of their firms and navigate them in accordance to the necessities of organizational strategies amid changing business environment. According to March (1991), exploration is related to the process of seeking new opportunities, knowledge and possibilities that are characterized by increasing variation, flexibility and experimentation. Exploitation on the other hand refers to the refinement, implementation, execution and improving efficiencies of current capabilities or knowledge. Van den Bosch *et al.* (2003) explained March's distinction between exploration and exploitation in the development of organizational knowledge are related to the attributes of knowledge absorption.

Additionally, given that PACAP involves exploration features whereas RACAP involves exploitation characteristics (Albort-Morant *et al.*, 2018; Datta, 2012), this will enable firms to concurrently balance the exploration of new opportunities and exploitation of existing ones (O'Reilly and Tushman, 2008) through the use of Lean Six Sigma. To enhance PACAP and tap into exploratory traits through Lean Six Sigma initiatives, practitioners and managers should ensure adherence to the DMAIC methodology (SIP). The organization should consider setting up a functional hierarchical system (RS) that signifies the improvement specialist it possesses. Additionally, managers should also create a socialization network (LSP) that is psychologically safe for a conducive learning environment. Meanwhile to influence RACAP and exploitation characteristics, apart from RS and SIP, managers should opt for challenging and rigorous project goals (FOM) in place of fuzzy targets as it was found to engender exploitative learning. Balancing the development and regulation of PACAP and RACAP is akin to stabilizing explorative and exploitative traits of firms' competencies, paving the way toward ambidexterity.

Although scholars had discoursed on the potential of continuous improvement philosophies such as Lean Six Sigma in fostering ambidextrous organization (Schroeder *et al.*, 2008; Choo *et al.*, 2007; Jugulum and Samuel, 2010), empirical justification which supports the statement are scarce. This study provides tangible justifications as to how Lean Six Sigma could foster ambidextrous capability through the traits of absorptive

capacity. This study submits that dynamic capabilities are indeed rooted in operational routines or processes which determines the functional ability of an organization and modifying them to suit the changes in the business environment may prove vital for survival. The findings also substantiate that components of absorptive capacity needs to be managed differently wherein the findings empirically showed which of Lean Six Sigma's distinctive practices are related to PACAP and RACAP accordingly.

7. Conclusion

The objective of this research is to examine how Lean Six Sigma's distinctive practices relate to the components of absorptive capacity. The study found that five distinct Lean Six Sigma practices differentially contribute to absorptive capacity through PACAP and RACAP. The findings of the study allow the comprehension of the critical practices of Lean and Six Sigma as per literature and how they stimulate dynamic capabilities of firms. LSP, RS and SIP were found to positively effect PACAP which promotes flexibility and creativity allowing for exploration oriented activities through learning what is unfolding in the market and exploring new relevant knowledge and information. LSP, RS and FOM were found to positively effect RACAP which favor control and stability encouraging exploitation and commercialization of the absorbed knowledge or information to yield organizational benefits. PACAP was also found to mediate SIP and RACAP. LTP was found to be non-significant on both PACAP and RACAP, possibly owing to inadequacy of items in operationalizing the construct. This consequentially denotes the potency for ambidextrous capability through organizational knowledge development. The ambidexterity this philosophy brings had been largely anecdotal in past literatures wherein this study provides empirical support through the concept of potential and realized absorptive capacity. These capabilities enable firms to sustain their competitive advantage which is very much a need for current turbulent and dynamic business environment. Firms need to view Lean Six Sigma as a comprehensive management philosophy that drives business strategies dynamically.

Although extensive articulation and effort is devoted in this research, it is not one without limitation as with many studies. Firstly, the study is cross-sectional in nature. Data collection was carried out approximately at the same time. The development of absorptive capacity doesn't happen swiftly as time is of essence. A recommendation to this would be to engage in a longitudinal study to see the changes on components of absorptive capacity parallel to the practices of Lean Six Sigma at two different timelines, preferably in the beginning stages of the application and in the long run. Secondly, interpreting the results should be dealt with caution as the findings are applicable in the context of manufacturing industry in Peninsular Malaysia. Given the small sample size garnered in the study, control variables were not included. Stretching the study to find the differences in services industry through a multi-group analysis or controlling for the type of industry is an avenue for future research. This could also be done across sub-sectors. Thirdly, LTP was found to be an insignificant factor in predicting both PACAP and RACAP. We believe the items chosen may not be entirely representative of this construct although the items used in operationalizing the construct was adapted from past literature which outlines the commonly used tools in the industrial world. The classification of tools and techniques of Lean in the manufacturing and services industry into bundles of practice, such as by [Shah and Ward \(2003\)](#) and [Hadid *et al.* \(2016\)](#), may have an alternate outcome toward the components of absorptive capacity. Besides, the distinctive practices of Lean and Six Sigma are interrelated in enhancing organizational competencies. In this study, we sought to learn how they are individually related to PACAP and RACAP. We have not considered their interrelationship toward influencing PACAP and RACAP which may explain transitivity

effect of these practices which can be an interesting branch to look into as well. Further, future studies could also learn how do these distinctive practices of Lean and Six Sigma interact toward exploration and exploitation conspicuously. Substitution of PACAP and RACAP constructs with exploration and exploitation consistent with Hwang (2015) and toward ambidextrous capability are some interesting propositions along this line of study.

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Further reading

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Appendix 1

Absorptive
capacity

Phases	Objective of phase	Key actions/ activities	Authors
Define	Define the goals of the improvement activity	Identify customer and the vital goals to be achieved. This is cascaded into strategic level, operational level and project level goals	Pyzdek (2003)
	Define the problem	Identify the problem or opportunity, scope of the project, customer requirement, business case, roles of members and stakeholders and pre-plan of whole project	Pande and Holpp (2002)
	Define opportunities	Identify and/or validate the business improvement opportunity, define critical customer requirements, document or map processes, establish project charter	Montgomery and Woodall (2008)
	Define goals and project scope	Establish project description (defining problems and goals), selection of relevant project, identify potential benefits, create project charter and communication plan	Breyfogle III (2003)
	Define problem selection and benefit analysis	Identify and map relevant processes, identify stakeholders, determine and prioritize customer needs and requirements, make a business case for the project	De Mast and Lokkerbol (2012)
	Define customer requirements and project boundaries	Define the requirements and expectations of the customer, the project boundaries, map the business flow	Kwak and Anbari (2006) (Adapted from McClusky (2000)
	Define the scope and goals of the improvement project in terms of customer requirements	Identify project's CTQs, develop team charter, define process map	Antony <i>et al.</i> (2005)
Measure	Measure the existing system	Establish valid and reliable metrics to help monitor progress toward the goals defined at the previous step	Pyzdek (2003)
	Gather data to validate and to quantify the problem or opportunity	Identify the output measures, establish initial sigma level of the process and develop data collection plan	Pande and Holpp (2002)
	Measure process performance	Determine what to measure, manage measurement data collection, develop and validate measurement systems, determine sigma performance level	Montgomery and Woodall (2008)
	Development of a reliable and valid measurement system of the business process identified in the Define phase	Plan the project and metrics to be used, establish baseline of process, consider usage of Lean tools, ensure data integrity, map process and assess inherent risk of the process	Breyfogle III (2003)
	Translation of the problem into a measurable form, measurement of the current situation and refine	Select one or more CTQs, determine operational definitions for CTQs and requirements, validate measurement systems of the CTQs, assess the current process capability, define objectives	De Mast and Lokkerbol (2012)

(continued)

Table AI.
Objective and key
activities or actions
in DMAIC phases

Phases	Objective of phase	Key actions/ activities	Authors
Analyze	definition of project objectives Measure process capability subject to customer's needs	Measure the process to satisfy customer's needs, develop a data collection plan, collect and compare data to determine issues and shortfalls	Kwak and Anbari, 2006 (Adapted from McClusky (2000)) Antony <i>et al.</i> (2005)
	Establish proper measurement system and define baseline of process performance	Select CTQ characteristics, define performance standards, validate and analyze measurement systems	
	Analyze the system to identify ways to eliminate the gaps in the process	Eliminate the gap between the current performance of the system or process and the desired goal, determine current baseline, use exploratory, descriptive and statistical tools for data analysis	Pyzdek (2003)
	Identify "root causes" behind problem	Analyze root causes from common cause categories, hypothesize possibilities and run statistical analysis to determine significance	Pande and Holpp (2002)
	Analyze opportunity	Analyze data to understand reasons for variation and identify potential root causes, determine process capability, throughput, cycle time, formulate, investigate, and verify root cause hypotheses	Montgomery and Woodall (2008)
	Analysis of data to learn about causal relationships to detect the sources of variability and unsatisfactory performance	Collect desired data for analysis, review reports, identify sources of variability and unsatisfactory performance	Breyfogle III (2003)
Improve	Identification of influence factors and causes that determine the CTQs' behavior	Identify potential influence factors, select the vital few influence factors	De Mast and Lokkerbol (2012)
	Analyze the causes of defects and sources of variation	Analyze the causes of defects and sources of variation, determine the variations in the process, prioritize opportunities for future improvement	Kwak and Anbari (2006)
	Gather and analyze data to identify factors affecting the response variable	Establish process capability, define performance objectives, identify variation sources	Antony <i>et al.</i> (2005)
	Improve the system	Find creative ways of doing things efficiently and effectively, use project management and tools and statistical methods to implement and validate the improvements	Pyzdek (2003)
	Develop ideas to improve process condition	Modify problem statement, goal and project scope, develop creative ideas and solutions, test the solutions, seek approval of solutions from champion and process owner	Pande and Holpp (2002)
	Improve performance	Generate and quantify potential solutions, evaluate and select final solution, verify and gain approval for final solution	Montgomery and Woodall (2008)

Table AI.

(continued)

Phases	Objective of phase	Key actions/ activities	Authors
Control	Optimize the process by identifying key variables' settings	Consider the use of Design of Experiment (DOE), address improvements for key variables from Analyze phase, evaluate improvement viability, document and communicate improvement, summarize benefits	Breyfogle III (2003)
	Design and implementation of adjustments to the process to improve the performance of the CTQs	Quantify relationships between Xs and CTQs, design actions to modify the process or settings of influence factors in such a way that the CTQs are optimized, conduct pilot test of improvement actions	De Mast and Lokkerbol (2012)
	Improve process by eliminating variation	Improve the process to eliminate variations, develop creative alternatives and implement enhanced plan	Kwak and Anbari (2006) (Adapted from McClusky (2000))
	Identify potential solution for implementation	Screen potential causes, discover variable relationships, establish operating tolerances	Antony <i>et al.</i> (2005)
	Control the new system	Institutionalize the improvement by standardizing operating or management method, use statistical tools to monitor stability and progress	Pyzdek (2003)
	Control process by measuring and monitoring results	Identify key process input and output variables of the process, develop control and response plan, ensure proper handover to process owner	Pande and Holpp (2002)
	Control performance	Develop ongoing process management plans, mistake-proof process, monitor and control critical process characteristics, develop out of control action plans	Montgomery and Woodall (2008)
	Ensuring the changes will stick	Ensure changes made documented, assign responsibilities to monitor changes, establish control measures and appropriate communication plan	Breyfogle III (2003)
	Empirical verification of the project's results and adjustment of the process management and control system to ensure improvements are sustainable	Determine the new process capability, implement control plans	De Mast and Lokkerbol (2012)
	Control the improvements to meet customer requirements	Control process variations to meet customer requirements, develop a strategy to monitor and control the improved process, implement the improvements of systems and structures	Kwak and Anbari (2006) (Adapted from McClusky (2000))
	Ensure the sustenance of results in improve phase	Ensure the results are sustained, share the lessons learnt	Antony <i>et al.</i> (2005)

Sources: [Antony *et al.* \(2005\)](#), [Breyfogle III \(2003\)](#), [De Mast and Lokkerbol \(2012\)](#), [Kwak and Anbari \(2006\)](#), [Montgomery and Woodall \(2008\)](#); [Pande and Holpp \(2002\)](#), [Pyzdek \(2003\)](#)

Lean technical practice (LTP) (Gowen et al., 2012)

- (LTP1) 5S workplace organization: (Sort, Set in order [straighten], Shine, Standardize, Sustain).
- (LTP2) Process Mapping (Flowchart, process map and so on)
- (LTP3) Value Stream Mapping (VSM)
- (LTP4) Kaizen or Kaizen Blitzes (continuous improvement events)
- (LTP5) Just-in-Time (JIT) process management or inventory management

Lean social practice (LSP). (Hadid et al., 2016) (LSP1) An appropriate reward system

- (LSP2) Effective communication system
- (LSP3) Employee empowerment for continuous improvement program
- (LSP4) Employee commitment in continuous improvement program
- (LSP5) Employee involvement in continuous improvement program
- (LSP6) Having multifunctional employees for continuous improvement program
- (LSP7) Encourage leadership in quality and continuous improvement program
- (LSP8) Obtaining management support for continuous improvement program
- (LSP9) Appropriate performance measurement system in continuous improvement program
- (LSP10) Training for quality and continuous improvement program

Role structure (RS). (Zu et al., 2008)

- (RS1) We use a black/green belt role structure (or equivalent structure which may be called Six Sigma deployment structure) for continuous improvement.
- (RS2) We use a black/green belt role structure to prepare and deploy individual employees for continuous improvement programs.
- (RS3) The black/green belt role structure helps our firm to recognize the depth of employees' training and experience.
- (RS4) Our firm provides employees with task-related training so that employees who have different roles in the black/green belt role structure can obtain the necessary knowledge and skills to fulfill their job responsibilities.
- (RS5) In our firm, an employee's role in the black/green structure is considered when making compensation and promotion decisions.

Structured improvement procedure (SIP). (Choo et al., 2007)

- (SIP1) The project strictly followed the sequence of DMAIC steps.
- (SIP2) The team felt that following the DMAIC steps was not important (reverse-coded).
- (SIP3) Each step in DMAIC was faithfully completed.

Focus on metrics (FOM). (Zu et al., 2008)

- (FOM1) Our firm sets strategic goals for quality improvement to improve firm financial performance.
- (FOM2) Our firm has a comprehensive goal-setting process for quality.

- (FOM3) Quality goals are clearly communicated to employees in our firm.
- (FOM4) In our firm, quality goals are clear and specific.
- (FOM5) Our firm translates customers' needs and expectation into quality goals.
- (FOM6) In our firm, measures for quality performance are connected with the firm's strategic quality goals.
- (FOM7) The measures for quality performance are connected with critical-to-quality (CTQ) characteristics.
- (FOM8) Our firm systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate process improvements.

Potential absorptive capacity (PACAP). (Leal-Rodríguez et al., 2014)

- (PACAP1) We have frequent interactions with top management and corporate headquarters to acquire new knowledge
- (PACAP2) Employees regularly visit other branches, units or project teams
- (PACAP3) We collect information through informal means (e.g., lunches with colleagues, friends, chats with trade partners)
- (PACAP4) Members do not visit other divisions, units or project teams (reverse-coded).
- (PACAP5) We periodically organize special meetings with clients, customers, suppliers or third parties to acquire new knowledge
- (PACAP6) Employees regularly approach third parties and external professionals such as advisers, managers or consultants
- (PACAP7) We are slow to recognize shifts in our market (e.g., competitors, laws and regulations, demographic changes, etc.) (reverse-coded).
- (PACAP8) New opportunities to serve our clients are quickly understood.
- (PACAP9) We quickly analyze and interpret changing client and market demands.

Realized absorptive capacity (RACAP). (Leal-Rodríguez et al., 2014)

- (RACAP1) We regularly consider the consequences of changing market demands in terms of new ways to provide services/products.
- (RACAP2) Employees record and store newly acquired knowledge for future reference.
- (RACAP3) We quickly recognize the usefulness of new external knowledge for existing knowledge
- (RACAP4) Employees hardly share practical experiences (reverse-coded).
- (RACAP5) We work hard to seize the opportunities for our unit from new external knowledge (reverse-coded).
- (RACAP6) We periodically meet to discuss the consequences of market trends and new product/services development.
- (RACAP7) It is clearly known how activities within our unit should be performed.
- (RACAP8) Clients' complaints fall on deaf ears in our unit (reverse-coded).
- (RACAP9) We have a clear division of roles and responsibilities.
- (RACAP10) We constantly consider how to better exploit knowledge.
- (RACAP11) We have difficulties implementing new products and/or services (reverse-coded).
- (RACAP12) Employees have a common language regarding our products and/or services.

Table AII. Reliability statistics from pilot test	Constructs	Cronbach's alpha	No. of items
	LTP	0.573	5
	LSP	0.940	10
	RS	0.726	5
	SIP	0.776	3
	FOM	0.812	8
	PACAP	0.870	9
	RACAP	0.553	12

Appendix 4

Hypothesis	Relationship	Std. Beta	Std. Error	<i>t</i> -values	Decision	Bootstrapped confidence interval	
						95% LL	95% UL
<i>H7a</i>	LTP → PACAP → RACAP	0.018	0.0294	0.602	Not Supported	−0.040	0.075
<i>H7b</i>	LSP → PACAP → RACAP	0.052	0.0388	1.329	Not Supported	−0.024	0.128
<i>H7c</i>	RS → PACAP → RACAP	0.026	0.0312	0.836	Not Supported	−0.035	0.087
<i>H7d</i>	SIP → PACAP → RACAP	0.113	0.0536	2.099*	Supported	0.007	0.218
<i>H7e</i>	FOM → PACAP → RACAP	−0.045	0.0330	−1.362	Not Supported	−0.110	0.020

Table AIII.
Mediation of PACAP

Notes: A two-tailed test is used for mediation assessment: **p* < 0.05; ***p* < 0.01

Appendix 5

Absorptive
capacity

Hypothesis	Relationship	t-values	Decision	R^2	f^2	VIF	Q^2
<i>H1a</i>	LTP → PACAP	0.782 (NS)	Not Supported	0.365	0.007	1.321	0.167
<i>H2a</i>	LSP → PACAP	2.417***	Supported		0.045	1.644	
<i>H3a</i>	RS → PACAP	1.309*	Supported		0.014	1.369	
<i>H4a</i>	SIP → PACAP	4.842***	Supported		0.253	1.383	
<i>H5a</i>	FOM → PACAP	1.907 (NS)	Not Supported		0.035	1.569	
<i>H1b</i>	LTP → RACAP	0.222 (NS)	Not Supported	0.399	0.000	1.330	0.152
<i>H2b</i>	LSP → RACAP	1.742**	Supported		0.031	1.717	
<i>H3b</i>	RS → RACAP	1.591*	Supported		0.044	1.388	
<i>H4b</i>	SIP → RACAP	0.323 (NS)	Not Supported		0.001	1.733	
<i>H5b</i>	FOM → RACAP	2.499***	Supported		0.049	1.624	
<i>H6</i>	PACAP → RACAP	1.924**	Supported		0.060	1.574	

Table AIV.
Effect size and
predictive relevance
of the research model

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; NS: not significant

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