

Investigating the relationship between Lean Six Sigma and Innovation

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Abstract

Innovation and Lean Six Sigma (LSS) have been proven to be very useful tools that can be used to achieve a more efficient utilization of resources, produce high quality products, and create competitive advantages that can help organizations to achieve high levels of business performance in today's competitive market. Where LSS tends to redesign and standardize the processes in an organization to control defects and eliminate waste, innovation; that needs a more flexible and open environment, encourages people to generate new ideas and think far beyond the rules and conditions of a particular standard. So, they can be considered as complements and organizations should target incorporating both of them. This paper will look into previous research that has investigated the relationship between LSS and innovation highlighting key aspects and observations of this relationship.

Keywords

Quality management, Lean Six Sigma, Innovation

1. Introduction

Innovation is defined as the process of introducing a concept that is either totally new or different from prior research works or customer's prior experiences to bring value to both customer and business. Based on the degree of novelty, innovation can be either radical, that is introducing a completely new and different approach from what has been followed earlier, or incremental if it is an improvement effort in the current processes. It is to be highlighted that incremental innovations contribute to 90-94% of all innovations, where only 6-10% of innovations are of radical type (Tidd & Bessant, 2013). It is the governance for long-term success and it is an element that has become a necessity for all organizations (Cuc & Tripa, 2007). It helps organizations to have competitive advantages that are either technology related, in the sense of affecting the processes and the way they are integrated with each other, or market related in the sense of dealing with current and future customer's needs (Parast, 2011). Such advantages are vital for an organization to survive especially in markets that are characterized to be unstable and high competitive as they will differentiate the organization from its competitors and will guarantee a unique position for it in the market (Popa, Soto-Acosta, & Martinez-Conesa, 2017). On the other hand, developed by Motorola in 1980s, Six Sigma (SS) is a statistical and strategic tool for reducing system's variations, errors, causes of defects, and costs of poor quality aiming to increase productivity in terms of process's capabilities improvements, customer satisfaction in terms of cost and perceived quality, and as a result the profitability (Dumitrescu & Dumitrache, 2011). It can be applied to processes that are usually described to have repetitive events, whether existing or new processes (Johnstone, Pairaudeau, & Pettersson, 2011). It is a project driven management approach that targets achieving not more than 3.4 defects per million opportunities by using statistical and data gathering approach to enhance the reliability of the system (Yusr, Othman, & Mokhtar, 2012). It is implemented across the organization and requires support from the leadership and participation from rest of the staff to ensure its success (Cuc & Tripa, 2007). SS tools are unique and different in the sense that they provide an organizational infrastructure that promotes ideas' generation and process improvements initiatives. It also enables organizations to have a more flexible structure that can easily adapt to new business's conditions and helps in balancing the efforts between efficiency and innovation (Parast, 2011). Lean, known as Toyota Production System, was developed in the 1990s for the purpose of enhancing Toyota's capability to quickly adapt and accommodate to different market's demands and minimize inventory, and its applications have been expanded from automotive to construction and healthcare sectors (Browning & Sanders, 2012). Lean deals more with reduction of

waste and unnecessary steps targeting a faster process flow, higher productivity, and more efficiency by giving more attention to value added activities (Cuc & Tripa, 2007). Lean principles are based on ensuring the delivery of customer's needs in time, having a better understanding of the process; its activities and their flow, being efficient in regard to inventory management and utilization of resources, and optimizing performance (Polk, 2011). LSS that is combining the two concepts together, has been proven to be a successful tool that targets effectiveness and efficiency and helps an organization to continuously and effectively improve its processes and achieve its market's and financial performance targets. It helps an organization to achieve a continuous improvement of its current processes and introduce new ones that add value to its financial and market's performance. It is claimed that LSS is a more desirable approach compared to other quality management tools, given its ability to hit breakthrough improvements in a short time period that is usually one to three years, and its capability to deal with fast growing and complex economies. LSS; being considered as a process improvement tool and a management style, can be used for enhancing innovation in the recruitment process by introducing concepts like just in time recruitment and eliminating waste and non-value added activities of the process. That can help organizations to maintain a competitive advantage and be an attractive place to work in (Pradeep, 2015). It was also found that LSS has helped organizations from the manufacturing industry in increasing their ability for adapting innovation, along with improving quality of products, addressing customer's concerns, and eliminating waste (Assarlind, Gremyr, & Bäckman, 2013). Organizations should continuously invest in process innovation to sustain their competitive advantages and maintain their market's position. LSS is considered a process innovation initiative that enables organization control, and improve the products' quality and therefore customer's satisfaction (Delgado, Ferreira, & Branco, 2010). Some of the tools that combine and incorporate both of lean and SS principles are control charts, poka-yoke, and visual management. General Electric, Motorola, and Honeywell are examples of companies who have received significant financial outcomes that varied from cost saving to hitting high profit margins by applying LSS to their processes (Dumitrescu & Dumitrache, 2011).

2. Motivation

Organizations should target incorporating both of LSS and innovation approaches into their processes due to the benefits that can be obtained by each of those two powerful tools. Despite the few differences in the core principles of LSS and innovation, an example of which is the fact that lean's conditions are more of routine and focused on eliminating non-value-added activities whereas the conditions of innovation are novel and deals with dynamic processes (Browning & Sanders, 2012), LSS and innovation have many common objectives and fundamentals. For example, both of LSS and innovation target meeting customer's requirements, where the ultimate goal of both is to produce high quality products that are as per latest trends and needs, and achieve cost's efficiency targets. In other words, both of LSS and innovation focus on how to effectively and innovatively utilize resources in order to gain maximum output value. Lean tool can be used as a tool for directing innovation efforts to be oriented around waste elimination projects, that is to consider lean principles in the selection criteria of innovation projects. In addition, innovation approaches that are based on idea generation lack the data driven and statistical approach of LSS tools, and so they complement each other (Kaufmann & Ramos, 2013). Furthermore, LSS can be expressed and described in terms of the innovation types mentioned earlier. For example, the DMAIC mythology, that is define, measure, analyze, improve, and control, is one of SS tools that is used to improve current products and processes aiming to maintain organization's competitive advantages and adapt to market's changes, and can be looked at as an incremental innovation effort (Chennupati, Laux, Newton, & McFall, 2012). SS can be also used to introduce totally new products and processes, an approach used for that is referred to as Design For SS (DFSS), where tools like identify, define, develop, optimize, and verify (IDDOV); define, measure, analyze, design, and verify (DMADV) can be used to meet new customer's requirements for which radical innovation will be needed (Wang, Yeh, & Chu, 2016). Lean is based on continuous improvement efforts using Kaizen events which are incremental innovation oriented (Dumitrescu & Dumitrache, 2011).

Therefore, combining them will result in a very powerful tool that can help companies in improving their business performance. In an article about whether lean can coexist with innovation, Pixar; the Hollywood animation company, was mentioned as an example for companies who have managed to achieve a successful implementation of lean and innovation. It was found that, lean can easily fit in any innovation process, and its role starts at the stage of capturing customer's requirements, and later when efforts are being made to improve product's delivery (Article: Knowledge at Wharton, 2009). Innovation creates a culture that is needed for a more effective implementation of LSS methodologies. For example, improving an existing process using a LSS approach like DMAIC, can be more fruitful if it is being considered as incremental innovation where efforts will be made to differentiate the process and make it unique (Collins, 2011).

3. Methodology

As the objective of this research was to look into and investigate the relationship between LSS and innovation, that were found to have many similar objectives and can create a powerful tool if combined together, a literature review approach was followed aiming to provide a comprehensive overview of this relationship and reach to a conclusion that future research can build upon. The patterns of the publications will be discussed followed by a review of each publication.

3.1 Patterns of Publications

The collected material covered the period from 2007 till 2017 as illustrate in Figure 1:

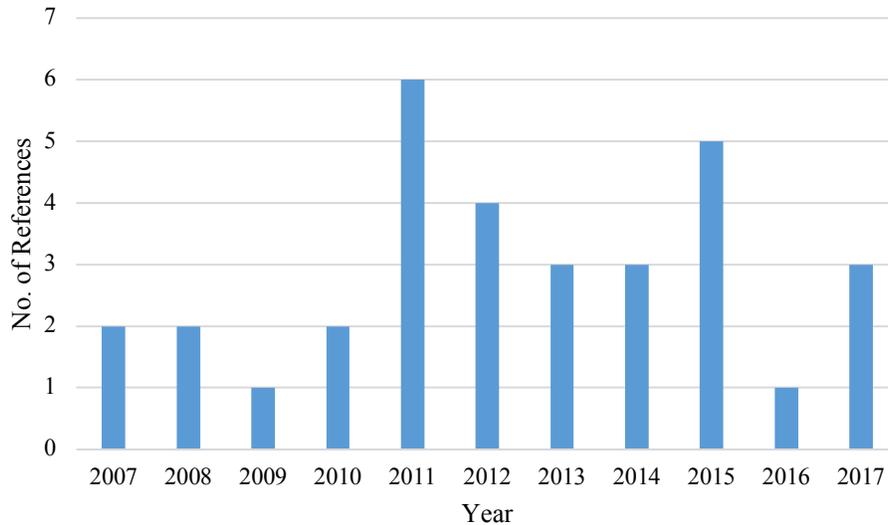


Figure 1. Distribution of references by year of publication

The collected material has included contribution from difference sources as illustrated in Figure 2:

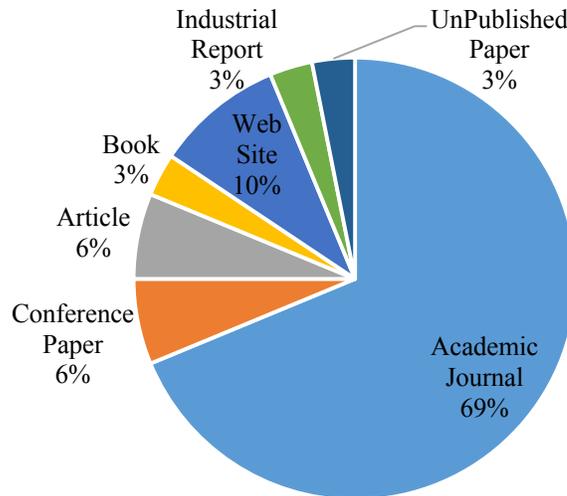


Figure 2. Distribution of the references by type

3.2 Review of Publications

Previous research works carried out in regard to studying the impacts that LSS has on innovation and the relationship between them are reviewed below highlighting their objectives, results, limitations, and other research gaps. Research works about critical success factors and implementation frameworks of LSS that incorporate innovation aspect were considered as well.

Yusr, Othman, and Mokhtar (2012) tried to find out the relationship between SS and innovation performance in order to come up with a conceptual framework for this relationship. The mediating role of absorptive capacity, that is one of the main pillars of innovation performance as it is the capability to acquire, assimilate, transform, and exploit knowledge which is an essential input to innovation, was tested as well. Their study was targeting the manufacturing companies in Malaysia where innovation found to be at a very low level compared to other industries. Data was collected through an online survey and was analyzed using the partial least square, that is used when knowledge about the variables' distribution is limited. Based on the results, SS found to have a positive relationship with innovation performance, as it is translated into process improvement initiatives which enhance innovation. To successfully apply SS, there are critical success factors that have to be considered which at the same time will build up a base for knowledge management capacities, being referred to as absorptive capacity, that are needed for the implementation. By that, a positive conclusion regarding the mediating role of absorptive capacity in the relationship between SS and innovation performance can be made. Future research may focus on carrying out a more explicit study about absorptive capacity and looking into its elements, factors affecting it, and any possible improvement opportunities. Furthermore, other antecedents of innovation performance than absorptive capacity can be considered and their impact on the relationship between SS and innovation performance can be investigated. Tools other than partial least square can be used to analyze the collected data to achieve more accurate results that will better shape the relationship between the different factors to be studied (Yusr, Othman, & Mokhtar, 2012).

Another paper by Johnstone, Pairaudeau, & Pettersson (2011) looked into how to achieve creativity and innovation in pharmaceutical industry while meeting LSS principles. One of the main challenges that is being faced by companies in this industry is how to meet customer's expectations in terms of providing innovative products but at low costs and high quality. So, there is a tradeoff between innovation and process improvement or efficiency tools like LSS and the paper tries to resolve this matter. It has been evidenced that LSS tools have positive impact on the industry, and that is reflected in efficiency enhancement that was achieved in terms of cycle time improvements, which is one of the most important measures in such type of industries where high competition is in place and fast delivery is a must. According to the authors, LSS has to be looked at as a cultural change, and as culture is at the very deep level of organization, management's commitment and flexibility to accommodate with such changes are important. The paper also highlights the importance of changing the perspective of standardization, on which LSS is based, being a way that has to be strictly followed to more of a base for innovative improvement's opportunities. Organizations' capacities have to be directed towards innovation's effort and not to be wasted on non-value added activities, and integrating LSS concepts with innovation agenda will help companies in achieving breakthrough innovations. The paper concludes stating that the impact of LSS on innovation is not direct and it is observed through the culture and the atmosphere that result from implementing LSS tools which will help as a result in fostering innovation. Lean thinking helps organizations to be more efficient in regard to determining the problems to be solved and then utilizing its resources accordingly. It also treats problems as opportunities for acquiring new knowledge and increases the overall level of passion and involvement of its employees. These are some examples about how lean can help in enhancing innovation in an organization which can be drawn from the model presented in the paper for relating the different requirements for innovation and LSS with each other. It would be interesting to carry out a deep investigation about the intangible impacts of LSS and how such impacts are related to innovation (Johnstone, Pairaudeau, & Pettersson, 2011).

Nicoletti (2015) introduced a method called the 7 D's that are: define, discover, design, develop, digitize, deploy, and diffusion, which aims to digitize the innovation process and redesign it so that it will achieve LSS results. In other words, it translates lean's concepts with respect to different innovation types, and considers automation at the same time. It is challenge for organizations to be able to follow lean's principles while maintaining the innovation's spirit and implementing initiatives in this regard. The define stage is to meant to identify the context in which the innovation is proposed to take place. The discover stage is an exploration stage for improvement and development opportunities. Next is the design stage where the flow of process's activities is defined and modeled into a framework. In the develop stage, the potential idea is being translated into an innovation of value. Attempts to lean the innovation and automate it are the focus of digitize phase. At the deploy stage, an actual implementation of the innovation takes place. Finally, the diffusion stage emphasizes the use and the spread of the innovation throughout the organization. The method has been proven to be successful in many cases, example of which is General Electric who has obtained many benefits out of it. The research can be extended to other sectors than manufacturing and other innovation types

than process innovation. The paper has also reviewed previous works in this regard, an example of which was applying LSS principles for more effective product development in terms of cost, quality, and delivery time. Others have extended the use of lean in product development and have come up with a lean innovation roadmap that consists of implementation streams for different lean product development components. Another group of researchers have extended the previous views and developed a transformation framework for the same. Another research work has focused on using the value system, being a way to prioritize different factors related to innovation projects, to achieve lean innovation. The impact of lean principles in innovation intense organizations was investigated and found to be positive. For organizations of unique and complicated operation's atmosphere, a path was found to achieve a win-win solution by which both of lean and innovation principles can be met and satisfied. Another paper has carried out a deep study of lean's culture, design, and management and compared them with different innovation types in order to have a better understanding of the conditions associated with implementing each of them. An investigation about the capability of customer-focused approaches, one of which is LSS, to generate innovation was carried out. The link between lean's concept, being more into accelerating processes, and opening the room for innovation in many directions was looked into and considered. It was claimed that tools that promote effective and efficient innovation like outsourcing strategies, weather for material or human resources, and short run manufacturing that helps in taking decisions whether to proceed to high volume manufacturing, are in line with lean concepts (Nicoletti, 2015).

Byrne, Lubowe, & Blitz (2007) published a paper highlighting the importance of having an operational strategy that focuses on both efficiency and innovation. They have given some examples about companies who have successfully implemented LSS methodologies in a more broader and strategic approach to achieve innovation and gained the advantages of such implementations on their business's performance mainly and many other organizational performance aspects. One of which was Caterpillar, who has based its strategic vision on SS initiatives, and was able to achieve innovation in many of its products. Another example was the Korean steelmaker "POSCO" who was able to reposition itself as a global premium provider of innovative products with the help of LSS. ScottishPower is another example of a company that used LSS to achieve higher market share by innovating in customer service means. So, LSS approaches can do more than just process improvement, as it is used as a base for innovation (Byrne, Lubowe, & Blitz, 2007).

In his research about the effect of SS projects on innovation and firm performance, Parast (2011) checked whether a relationship between SS projects and firm's radical or incremental innovation exists, the factors influencing this relationship, and if SS projects can be considered an advantage for the innovation. It is claimed that SS tools can do more than just improvements in the financial performance, as they enhance the creativity and innovation levels in the organization. A knowledge-based framework of SS was introduced, by focusing on the tools and the context in which they will be used, by which the overall knowledge's level in the organization can be enhanced. Efforts should be emphasized equally between process management and innovation to be able to meet both. Process management can help in directing innovation efforts towards process improvement initiatives and ensuring that resources are allocated accordingly. The author of this paper has examined the relationship between SS programs and the different types of innovation, whether they target existing or new customer. Based on the results, SS programs do not have the ability to deal with radical type of innovation and fails to address the needs of new customer. Another finding was that SS programs tend to be easily applied to operations' processes, but not behavioral and change processes that are difficult to be quantified. Despite the interesting findings, the study did not consider factors related to the industry and market (Parast, 2011).

A paper by Chennupati, Laux, Newton, & McFall (2012) looked into the SS being a source and an influencer of innovation and creativity. In fact, achieving SS target, that is 3.4 defects per million opportunities, will definitely need innovation. One of the biggest challenges for SS programs is dealing with both organization's tangible assets, examples of which are the clear performance and financial goals, and intangibles assets, examples of which are employees' values, and knowledge management, which differ in regard to how easy they are to be quantified. It is noted that innovation is a base for SS tools, and an example is the DMAIC approach which is assumed to ignite innovation in the organization in way or another, and the paper proposes a model that explains this. Based on the proposed model, emphasis on innovation increases gradually as we move from problem identification stage to problem solving stage where it is at its highest level and where there will be a strong need for it. As we move towards the final stages of implementation and controlling, the emphasis on innovation reduces again (Chennupati, Laux, Newton, & McFall, 2012).

A study about process's innovation using LSS in health sector in Mexico was carried out by J., M.R., & A.B. (2008), where the target was to direct the attention towards the value-added activities and eliminate other elements that do not bring value to the process, example of which is the patient's waiting time in the case given. The methodology followed was based on analyzing the process using lean tools. A process analysis was carried out to identify the flow of the process, its stakeholders, non-value-added activities, and opportunity areas. The next step was

the identification of Kaizen for which the following elements were defined: the defect, its relative time, its owner, and the elimination possibility. A priority for each Kaizen was given, and accordingly an innovative solution was proposed using lean tools. The methodology found to be of very effective and helped in a better understanding of the process (J., M.R., & A.B., 2008).

The concepts of LSS and innovation are being looked at as being complements and not mutually exclusive. A paper by Polk (2011) introduced a model for blending innovation and LSS. Based on the model, organizations have to closely monitor the market and look for potential innovation changes and explore the possible opportunities for the same. Once an opportunity is identified, the process will be expedited and then standardized using SS tools. A continuous learning and evaluation mechanism have to be in place to measure the effectiveness of the framework (Polk, 2011).

A research carried out by Dimitrova, Selvamuniandy, Ishiko, Sun, & Panat (2014) has looked into applying LSS tools in driving innovation in research and development environments, where it can provide researchers and developers with the time they need to think innovatively by better utilization of the time, avoid spending it on non-value-added activities, and eliminate idle processes. Applying LSS has helped in a significant reduction in waste and increase in stakeholder's satisfaction in regard to investment being made (Panat, Dimitrova, Selvamuniandy, Ishiko, & Sun, 2014).

Browning and Sanders (2012) looked into the impacts of lean implementation in F22 production system, as an example of a complex and novel environment that heavily relies on innovation, but have encountered many process's stability related problems. To overcome these challenges and the difficulties that have been faced, F22 production system team has come up with five caveats to lean implementation, based on which it is preferable to apply lean at more stable conditions, and only after full awareness of the nature of the system and its level of novelty. In addition, lean improvement's efforts should be at an optimum level so that it can give a positive outcome, and should be done considering all parts and elements of the process, and not the only the part of concern. Such roadmap will ensure satisfying both of lean and innovation requirements (Browning & Sanders, 2012).

For a successful integration of LSS and innovation principles, leadership's commitment and enthusiasm towards innovation and making a change is of high importance. In addition, innovation's vision should be based on customer's input and organization's capabilities, and to be used as an alignment force for all stakeholders in the organization (Cuc & Tripa, 2007). LSS helps in dealing with new customer's demands by having the processes flexible in regard to their adaptability to new market conditions, or even introducing new and more innovative processes (Dumitrescu & Dumitrache, 2011). In an article published by Montgomery (2014), SS specialists are often being considered as innovation engineers which is an indication of the link between the two concepts. Moreover, SS business cases are found to be good examples for innovation cases as well (Montgomery, 2014).

The above is in line with the results of many studies that have been carried out to identify the critical success factors of LSS implementation. One of them was the work done by Coronado and Antony who identified eleven factors, most of which were related to management's commitment and ability to make and communicate the change to the people in the organization. In addition, there were some other factors related to linking SS program to its different stakeholders, and the use of project management techniques. There were some other works as well in this regard, but they all share the same basics. Furthermore, one of the approaches that are used for designing an implementation framework of SS is the diffusion of innovation theory, based on which the success of adoption of an innovation is subject to the attributes of the innovation that are related to its value to the organization and its applicability in the context of interests. The party responsible for taking the innovation adoption decision, the way the innovation gets diffused and communicated, and the cultural system and social spirit of the origination are also considered (Amar & Davis, 2008).

In his research about how to ensure the success of SS implementation, Maxfield focused on the role of leadership in creating an organizational competence that overcomes the different challenges and difficulties imposed by the deployment of SS. That can be achieved by creating an organization climate that supports the adoption of such quality tools, and ensuring that different team members across the organization are qualified with the soft and hard skills needed to adopt to such new trends. Leadership should be also committed in continuously monitoring the behaviors of staff ensuring that efforts are being constructive towards the success of SS project (Maxfield, 2010).

Knapp (2015) investigated the relationship between four organizational culture types and three components of LSS implementation that are management involvement, statistical methods, and supporting infrastructure. Organizational culture is defined as the set of shared values, believes, and assumptions that determine the way staff act and unify them towards one purpose. Organizational group culture is internally focused, has less management levels, and supports flexibility, teamwork, loyalty, and employee involvement. Developmental culture does emphasize flexibility as well, but it is externally focused. It encourages innovation, risk taking, and change adaptability. The hierarchal organizational culture type is where a strict compliance to organization rules and procedure, authorities'

levels, and jobs' roles exist. Unlike the previously mentioned type, the rational culture is externally focused to ensure high level of productivity, profitability and customer focus to achieve and sustain market success. It was found that the group and developmental culture types support the implementation of LSS as they support teamwork, flexibility, risk taking, and innovation which are needed for a successful implementation of SS (Knapp, 2015). In another research by Pakdil & Leonard (2015), it was found that Lean does need a culture that is heavily based on group works, empowerment, and attention to external involvement including suppliers and customers. In line with the previous study, a balanced culture that combines the strengths of group, developmental, hierarchal, and rational culture types, will be the most desired because of the duality of its concept that emphasizes innovation and the need for control, which as a result will ensure a successful implementation of Lean and sustain it as well (Pakdil & Leonard, 2015).

The relationship between organizational exposure to information sources and the implementation of Lean in manufacturing sectors was examined by Boyle, Rathje, & Stuart (2011). Information sources, external and internal, are being used by managers as a guidance and so that they can better understand the implementation process of Lean and its tools. It has been found that innovative organizational climate, that is characterized to be transparent, open to new ideas, of low resistance level to change and of high cross functional collaboration, is preferable for Lean implementation. An innovative climate blended with some other internal and external factors are critical drivers for management commitment to Lean (Boyle, Rathje, & Stuart, 2011).

Controlling costs and improving quality of services are continuously pressurizing healthcare systems to improve their processes. Timmons, Coffey, & Vezyridi (2014) discussed the implementation of Lean in emergency department in hospital, that was not widely applied within emergency departments in UK hospitals, and the role of professions in the process. Overall, Lean was positively perceived by emergency department's clinicians in terms of acceptance, and has helped in achieving service innovation through increasing efficiency, eliminating waste, and speeding up processes while ensuring high quality services (Timmons, Coffey, & Vezyridi, 2014).

Choi, Kim, Leem, Lee, & Hong (2012) investigated the impact of SS based management activities on organizational competitiveness, process innovation, and quality improvement. SS has indeed helped in achieving a cultural transformation and adopting international business strategies. SS had also a positive impact on process innovation as it is based on measuring and analyzing processes, and requires the systematic and scientific problem solving approach that SS can provide. As a result, a positive impact on organization competitiveness was reflected (Choi, Kim, Leem, Lee, & Hong, 2012).

Antony, Snee, & Hoerl (2017) provided general academic and industrial highlights and perceptions towards LSS. In public sector, LSS has helped in better understanding of customer's requirements, increasing the efficiency of the processes, transforming organizational culture and increasing its readiness for change. It is also highlighted that the use of LSS in innovation related projects enhances potential savings and return on investment. In addition, application of LSS approaches and tools requires creative and innovative thinking and therefore it can provide opportunities for incremental innovation, and drive innovation capabilities in organizations. Drivers of innovation in LSS include management support for and openness to new ideas, communication mechanism to ensure a smooth flow of ideas, and a learning culture (Antony, Snee, & Hoerl, 2017).

4. Discussions and Conclusions

Most of the literature reviewed proved that the relationship between LSS and innovation is positive and that it is mediated by a number of contextual factors. LSS is a source and a driver for innovation and they can be looked at as complements of each other. In fact, some of the theories used for designing SS frameworks are based on innovation concept. Applying LSS in innovation projects found to enhance the financial returns. It was also proved that both of Lean and SS have positive impacts on service and process innovation. LSS requires an organizational culture that supports teamwork, flexibility, and risk taking, which are the same requirements for innovation. To gain advantage of the positive relationship between LSS and innovation, they have to be well integrated and that would require management commitment, and enthusiasm towards innovation that should be based on market's demands and takes into consideration organizational capabilities.

In terms of research gaps, it is to be highlighted that investigating the relationship between LSS and innovation performance is relatively new research area, and was limited to certain types of industries and processes like manufacturing, pharmaceutical, imaging in health sector, research and development in specific countries like Malaysia, USA, Mexico, under stable environments and condition, and dealing with existing external customers only. In addition, there are some intangible benefits and impacts of LSS, and other psychological, contextual, and human sides of it that influences the innovation process which have not been looked into, investigated, measured, and utilized. The focus was on LSS's impacts on incremental technological process innovation types, but not on other innovation aspects in an organization like the innovation climate. In addition, there are challenges in regard to LSS effectiveness

when it comes to behavioral and change processes innovation. Table 1 summarizes the scope, results, and gaps of the literature reviewed in regard to the relationship between LSS and innovation.

In conclusion, this is a highly potential and promising research area that should be deeply investigated as it can change the perspective towards process improvement tools from being profit generating tools to more of tools that enhance organizational aspects like innovation. Future research may focus on filling the mentioned research gaps and developing frameworks that can assist organizations in using LSS as a tool for promoting innovation.

Table 1: Summary of the literature on the relationship between LSS and innovation

Reference	Scope	Results	Research Gaps
(Yusr, Othman, & Mokhtar, 2012)	- Proposed a conceptual framework for the relationship between SS and innovation, by testing the relationship between them and examining the role of absorptive capacity in mediating it	- SS found to have a positive relationship with innovation performance, and absorptive capacity proved to have a positive role in mediating the relationship	- Considering other antecedents of innovation - Using other data analysis tools than what have been used
(Johnstone, Pairaudeau, & Pettersson, 2011)	- Looked into how to achieve creativity and innovation while meeting LSS principles	- Found that the impact of LSS on innovation is not direct and it is observed through the culture and the atmosphere that result from implementing LSS tools which will help as a result in fostering innovation	- Deep investigation about the intangible impacts of LSS and how such impacts are related to innovation
(Nicoletti, 2015)	- Introduced the 7 Ds approach (define, discover, design, develop, digitize, deploy, and diffusion) to digitize innovation process	- The approach was adopted by General Electric and found to be beneficial	- Testing the approach in other sectors and in other than process innovation
(Byrne, Lubowe, & Blitz, 2007)	- Discussed the importance of having an operational strategy that focuses on both efficiency and innovation	- Provided examples of companies who have successfully managed applying LSS while meeting innovation objectives	- It was more of a subjective kind of research, and was not based on any data
(Parast, 2011)	- Provided theoretical base for the effect of SS projects on innovation and firm performance by testing the relationship between them	- SS programs do not have the ability to deal with radical type of innovation and fails to address the needs of new customer. - SS programs tend to be easily applied to operations' processes, but not behavioral and change processes	- Consideration of factors related to the industry and market - Looking into the impact of SS on behavioral and change processes innovation
(Chennupati, Laux, Newton, & McFall, 2012)	- Discussed SS being a source and an influencer of innovation and creativity - Proposed a model based on the idea that LSS ignite innovation in the organization	- A model	- The proposed model was not tested and verified
(J., M.R., & A.B., 2008)	- Proposed a methodology for process's innovation using LSS	- The methodology found to be of very effective and helped in a better understanding of the process	- Application and implementation of the proposed methodology
(Polk, 2011)	- Proposed a model for blending innovation and LSS	- A model	- Measurement of the effectiveness of the framework
(Panat, Dimitrova, Selvamuniandy, Ishiko, & Sun, 2014)	- Discussed applying LSS tools in driving innovation in research and development environments	- Achieved significant reduction in waste and increase in stakeholder's satisfaction	- It might be interesting to look how effective are the other LSS tools

Table 1: Summary of the literature on the relationship between LSS and innovation (Continuation)

Reference	Scope	Results	Research Gaps
(Browning & Sanders, 2012)	- Looked into the impacts of lean implementation in complex and novel environment that heavily relies on innovation	- Introduced Five Caveats to lean Implementation ensure satisfying both of lean and innovation requirements	- Consideration of other working environments types
(Cuc & Tripa, 2007)	- Discussed the requirements for successful integration of LSS and innovation principles	- A list of requirements was provided	- Implementation and results' verification
(Dumitrescu & Dumitrache, 2011)	- Discussed how LSS helps in being innovative in regard to dealing with new customer's demands	- LSS proved to be useful in dealing with new customer's demands	- Generic and not specific
(Montgomery, 2014)	- General overview of the subject	- SS specialists are as innovation engineers - SS business cases are found to be good examples for innovation cases	- Generic and not specific
(Amar & Davis, 2008)	- Discussed critical success factors and implementation frameworks of SS methodology	- Found that they are based on innovation concepts and requirements	- Using other approaches for the analysis
(Maxfield, 2010)	- Discussed the requirements for a successful implementation of SS projects	- Highlighted the most crucial problems that are usually being faced during implementation of SS projects	- Instead of discussing this matter from the point of the preventive measure that should be take to avoid the implementation problems, it would be also valid to discuss the success factors
(Knapp, 2015)	- Discussed the relationship between LSS implementation frameworks and different types of organization culture	- LSS needs an organizational culture that supports teamwork, flexibility, risk taking, and innovation	- Looking into how an organization can assess and enhance its organizational culture to meet the LSS desired culture
(Pakdil & Leonard, 2015)	- Discussed Lean's cultural requirements	- Lean needs a culture that is based on group works, empowerment, and attention to external involvement	- Applicability of the results on SS and LSS
(Boyle, Rathje, & Stuart, 2011)	- Examined the relationship between organizational exposure to information sources and the implementation of Lean	- Innovative organizational climate is preferable for Lean implementation	- Applicability of the results on SS and LSS
(Timmons, Coffey, & Vezyridi, 2014)	- Discussed the implementation of Lean in emergency departments	- Lean helped in achieving service innovation	- To study the impact of Lean on other innovation types
(Choi, Kim, Leem, Lee, & Hong, 2012)	- Investigated the impact of SS based management activities on organizational competitiveness, process innovation, and quality improvement	- SS helped in achieving a cultural transformation, had a positive impact on process innovation, and enhanced organizational competitiveness	- Consideration of corporate level data
(Antony, Snee, & Hoerl, 2017)	- Provided general academic and industrial highlights and perceptions towards LSS	- LSS enhances potential savings in innovation related projects - The application of LSS requires creative and innovative thinking	- Consideration of future globalization trends and customer's requirements - The study has covered only two continents; hence the cross cultural impacts to be considered

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