**The Digital Strategy
Execution Company**

Supporting Lean Transformation
with IT

An Exploration of options

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ABSTRACT

Lean concepts have enabled organizations to improve their competitiveness significantly by improving productivity, quality, and services. Similar benefits have also been achieved through the implementation of information technology (IT) in the organization. Some people believe the Lean principles and the application of IT to be interdependent and complimentary. However, the implementation of IT solutions are often costly and time-consuming.

The traditional Lean approach considers IT solutions as a last resort in optimizing processes due to the costly, lengthy and multiple experiences with the non-deliverance of expected and promised improvements in quality and process efficiency by the IT systems implementation and customizations. Nonetheless the stubborn belief that IT solutions will improve business quality and efficiency is a steady tendency over the last twenty-five years.

More recently, significant improvements have been made in the speed at which IT solutions are delivered and the scope to which IT solutions apply, resulting in an ongoing integration into work, public and private life. This opens new perspectives for the way IT can facilitate the realization of Lean targets and puts the question forward how for instance AI, robotizing and collaborative working contribute to and accelerate Lean transitions. This IT potential is the focus of this research, specifically on the way IT can contribute to achieving Lean goals.

The study investigates the expected IT contributions in a Lean context with the final outcome and examines the best practices. The data gained from the practice applied in the organizations were analyzed with the theory to gain insights into the best practice to effectively implement IT. These insights may assist organizations to effectively optimize the benefits of IT and Lean concepts to improve efficiency and quality.

TABLE OF CONTENT

1. INTRODUCTION

One of the major concepts that have improved efficiency in organizations is Lean. The Lean concepts have their origin in manufacturing and focuses on eliminating waste and optimizing flow to deliver maximum value to the customer. Lean production has been developed in post-war Japan by Toyota and is originally called the Toyota Production System or TPS as described in Liker's The Toyota Way (2004) and conceptualized by Womack and Jones (1996) into Lean thinking. The Lean concept is characterized by the optimal balance between efficiency and quality.

In order to achieve Lean goals and characteristics, organizations need to comply with Lean principles. Womack and Jones (1996) established five key principles of Lean.

1. Identify value: Specify values from the customer's perspective.
2. Map the value stream: Identify all steps in that creates value stream and eliminate steps that do not create values.
3. Create flow: Manage the value crating steps in a tight and integrated sequence to allow smooth flow to the customer.
4. Establish pull: Let customers pull value from the stream activity.
5. Seek perfection: Continuous improvement in pursuit of perfection, in which maximum value is created with no waste.
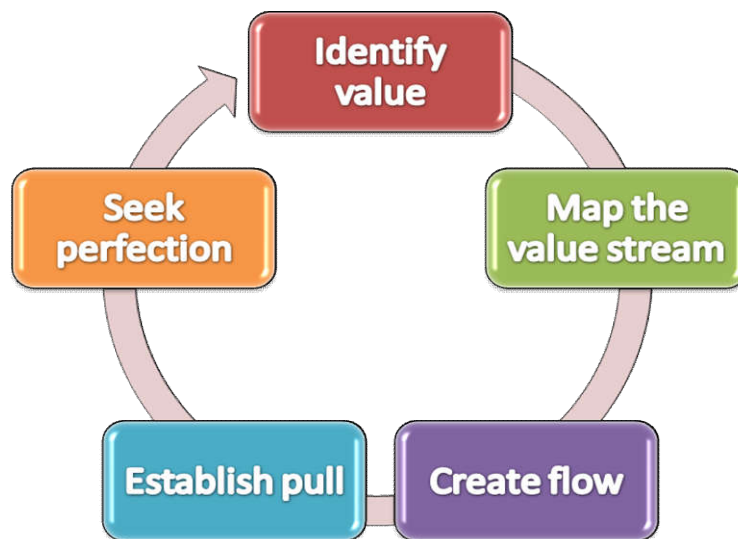

Figure 1. Continuous improvement process by Womack and Jones (1996)

Lean concepts offer a wide variety of tools that provide structure and consistency to identify waste and values. There are also Lean tools that can analyze problems, root cause, measurements and develop and implement improvement. However, the main approach remains the same: to eliminates waste and maximize customer values. It should be approached by people from different perspectives working together to improve processes using tools or technology.

Efficiency improvement resulted from Lean has also been achieved through the use of Information Technology (IT). The advantages of IT come from quality information which is an essential asset for organizations that guides behavior and good decision making. Despite the benefits resulting from IT applications, Lean remains critical to the role of IT. This is mainly due to the fact that IT solutions could be costly, hard to implement, do not live up to the promises and expectations and time exhausting. The original Toyota Production System actually prefers Kanban card system because of the simplicity and robustness of their information system instead of a computer system that they think would introduce unnecessary cost.

The Standish group CHAOS annual report on 2004 recorded around 20 percent of IT projects failed, 30 percent succeed, and the remaining 50 percent were challenged (Hartman, 2006). Although it shows a slight improvement over the years, this number clearly demonstrates the risk of implementing IT solution in organizations. The waste related to risks, cost, complexity, and effort needed to implement IT solution is something that contrasts the Lean foundation.

Nevertheless, increasingly fast-paced competition in the global economy has forced organizations to turn IT into a partner to drive business growth and value (Bell & Orzen, 2011). Moreover, significant improvements in IT delivery and cloud technology have unlocked IT potential that aligns with Lean principles. This improvement has open new perspectives on how IT can facilitate the realization of Lean goals.

The purpose of this research is to gain insight into IT contributions to Lean transition. This study will investigate how organizations effectively implement IT solutions to achieve Lean goals and the best practices in implementing these IT solutions. In addition, this study will also investigate which of the Lean elements are deployed effectively using IT solutions.

2. CONCEPT USE OF IT TO ACHIEVE LEAN

Although IT integration and Lean forms a complementing element in concept, they are often considered to be competing in practice (Piszczalski, 2002). The sense of competition stems from two major sources. First, the organizational expertise required for each approach is different. Secondly, both approaches require serious financial resources and top management attention. Even organizations with great capitals and human resources needed a severe amount of effort to balance the implementation of Lean and IT system.

The tension between IT approach and Lean approach is well established (Piszczalski, 2002; Bruun & Mefford, 2004; Ward & Zhou, 2006). Lean approaches advocate that less is better. Lean promotes for less inventory, less variability, fewer options, and choices in work and so on. While IT approaches advocate that more is often better. IT approaches argues that it should allow an organization to manage more information, more flexibility, more feature, and functions. As many organizations strive with global competition, they are forced to balance the investment in Lean practices and IT system, because both approaches require significant efforts and resources to handle.

Regardless of the importance, IT has not gained considerable support from the Lean community. However, recent rapid improvement in IT solutions and methodology has started to trigger a few Lean experts to explore the possibility of involving IT to empower the Lean initiatives. Daniel T. Jones, one of the authors of the influential management books that describe the principles and practice of lean thinking acknowledged this potential in his presentation on Lean and IT summit entitled, "How IT can support the Lean transformation." This study will explicitly use this perspective of IT supporting Lean transformation and explore the available options.

On the other side, a different perspective in the adoption of Lean manufacturing principles into IT known as Lean IT has also been recognized and incorporated into IT in the last 10 - 20 years. Schmitz (2017) highlighted "Lean ideas are truly at the core of Agile methodology and DevOps principles, where all frameworks emphasize the value of feedback, smaller production batches, and continual improvement."

Renowned experts of Lean IT, Bell & Orzen believes Lean IT concept emerges to reach beyond alignment of fundamental integration and collaborative partnership of IT and business. "Lean IT is more than a set of tools and practice; it is a deep behavioral and cultural transformation that encourages everyone in the organization to think differently about the role of quality information in the creation and delivery of value to the customer (Bell & Orzen, 2011)."

Lean IT engage information, information system and IT organization in partnership with the business to continuously improve and innovate business process and management system. Bell and Orzen further entail that Lean IT is accomplished through people, process, and technology in that specific

order. It should start with people from different perspectives working together to identify problems and their root cause in the business process. After the process is improved and simplified, people may find that the supporting system and technologies can also be streamlined or simplified. This system changes should be guided by a special team developed from a different perspective in terms of the requirement, design, development, and implementation.

Although Lean IT has a different perspective compared to IT supporting Lean, Lean IT has developed IT methodology and IT delivery significantly to the level that it improved the IT delivery and integration success rate. Therefore, Lean IT has indeed played a role in the development of IT which set off Lean experts to explore IT to support Lean transitions further.

2.1. IT solutions aligned with Lean concepts

Many IT solutions aligned to Lean concepts are closely related to business process, including enterprise resource planning (ERP), customer relationship management (CRM), and product lifecycle management (PLM). This is most likely linked to the history of Lean concept which rooted from manufacturing industries. Successfully implementing this large-scale integrated enterprise system enable continuous improvement by automating and error-proofing routine tasks, centralizing data and supporting the smooth and uninterrupted flow of information and work across all dimensions of the enterprise (Bell & Orzen, 2011).

Disruptive IT innovations such as the cloud technology, mobile devices, and the internet are also aligned with the Lean concept. These technologies enable efficiency and eliminate the waste of delay, distance, and infrastructure investment. These new trends of disruptive technologies will drive Lean IT solution in the future and have the potential to revolutionize Lean IT implementation.

Based on the theory of Lean, the best IT solution that supports Lean transformation is the one that can remove process waste the most and maximize the customer value. However, every organization have their own characters, therefore has a different type of waste and may need a different type of IT solution. Studies by John P.T. Mo in 2009 found that IT is not the cause of productivity improvement, however, IT is the key to support and sustain Lean activities. The studies found that changes in IT system would lead to significant changes in other aspects of business process. Literature and experience from the studies revealed that these non-IT related issues should be handled separately by the Lean project. Subsequent to the Lean initiatives, the changes in IT became a reinforcement of what had been improved, sustaining the outcome of productivity. The use of simple tools such as spreadsheet proved to be useful to "start the ball rolling". Once the actual

system defined and implemented, a customized IT system would further reinforce the outcomes and increase the efficiency by data automation and error reduction.

Research by Brunn & Medford in 2002 showed that the Internet is a perfect tool for accomplishing the Lean supply chain with its open, easy, and affordable access. The Internet allows organizations to achieve greater coordination in their supply chain, resulting in substantial inventory reduction and faster adjustment to change in demand. Furthermore, advanced use of the internet has allowed supply chains move towards virtual corporation where all the participants are closely linked as if they operate as one entity. Cisco system is one example of a firm that strongly moves towards a virtual corporation. Cisco receives 80% of its orders from customers through the internet and contracts out most of their manufacturing activities to other electronic service manufacturers. Through this method, on many occasions from order to delivery, Cisco employees never physically touch the product, eliminating waste of resource and investment. These benefits of virtual manufacturing would not be practical without the Internet to link the supply chain together.

All these studies suggest that productivity improvement achieved through IT investments largely depends on the use of Lean principles, which means that Lean unlock the potential of IT integrations. In short, the findings show that the benefits derived from IT integrations can be attributed to the process improvement activities that precedes IT implementation. Therefore, IT integration without the Lean process improvement might not have much effect on improving the productivity (Ward & Zhou, 2006; Mo, 2009). Based on these studies, there is no such single IT solution which can best support Lean transformation, in general, on multiple organizations.

However, a study by Powell et al., in 2013 shows that ERP is the most widely accepted IT solution to obtain a competitive advantage and support the Lean transition. ERP systems are designed to provide seamless integration of processes across functional areas with improved workflow, standardization of business process and access to real-time data. The fundamental benefit of ERP systems comes from the ability to process transaction efficiently and provide organized records of those transactions.

Powell et al., (2013) observed first-hand on a case study at Noca, an electronic manufacturing and service supplier in Norway and suggested, "The ERP implementation process can act as a catalyst for the implementation of Lean practices, as many of the tasks are the same or similar, or they support each other's application." The study investigated various Lean practices to the Proven Path ERP implementation process and proposed a generalized process framework for ERP-based Lean implementation.

Audit / Assessment 1		Audit / assessment 2		Audit / assessment 3	
First-cut education		Initial education and training		Ongoing education and training	
Establish strategic vision		Sales and operations planning	Value Stream Analysis: Organize for flow & Vertical information systems		Continuous Improvement
Organizational structure		Demand management, planning, and scheduling processes		Pull system	
Cost-benefit analysis		Define Products & Processes (VSM)	Pilot and Cutover		
Go/no-go decision		Data integrity			
Define and establish teams	Project Organization	Finance and accounting processes (Lean accounting): Process definition and implementation			
Implement lean foundations	Performance Goals				
Software selection		Software configuration and installation		Ongoing software support	

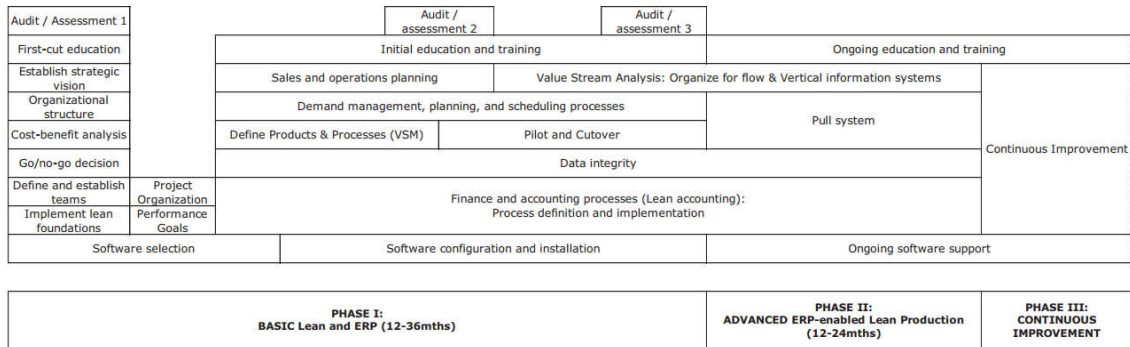| PHASE I: BASIC Lean and ERP (12-36mths)	PHASE II: ADVANCED ERP-enabled Lean Production (12-24mths)	PHASE III: CONTINUOUS IMPROVEMENT

Figure 2. ERP-based Lean implementation framework proposed by Powell et al., (2013)

The ERP-based Lean implementation process framework described in the figure is divided into three major phases. Phase I: basic Lean and ERP; Phase II: advanced ERP-enabled Lean production; Phase III: continuous improvement. The horizontal axis represents time on these phases. The vertical axis identifies a variety of significant individual tasks that should be accomplished simultaneously.

The study by Powell et al., (2013) further believes that the future perspective of Lean transition should consider the ERP system as one of the tools in the Lean toolbox as the research placed ERP as an imperative element of the Lean implementation process.

2.2. Feasible Lean concepts using IT

Fundamentally, Lean IT supports process improvement by providing the right information, at the right time, in the right format, to the right audience (Bell & Orzen, 2011). The study by Bell & Orzen discovered the power of Lean IT also includes knowing when not to use technology because the majority of problems are not caused by technology nor people, but a faulty process. Unfortunately, many organizations often lead with technology solutions prior to improving process, adding complexity to bad processes. Because existing technology can establish bad practices, it would most probably recommend as a first step to remove technology rather than adding them. At Toyota, innovative technology is considered only after the processes have been evaluated and tuned by a cross-functional team (Liker, 2004). Technology integrations are evaluated on their capability to support work process while not distracting attention from the value-added activity.

Bell & Orzen pointed out that information system plays a vital role enabling the coordination of activities throughout the organizations and providing the means by which information and

knowledge are collected, processed, analyzed, stored and shared. IT serves as a catalyst for change, an agent that enables, accelerates, and facilitates communication and coordination. It is a misperception to think IT "owns" information, when in fact process owners themselves are responsible for data quality and determining what information is needed to run the business. These support other studies by Ward & Zhou, 2006; Mo, 2009 that IT is not the cause of productivity improvement, but IT is the key to support and sustain Lean activities.

Only in a specific order of people, process and technology, can Lean and IT work together the most, and IT can never replace the role of people and process in the Lean transition. All the five principles of Lean established by Womack and Jones (1996) requires an intensive role of people which IT can only support. However, Lean and IT studies by Ward & Zhou, 2006; Mo, 2009; Brunn & Medford, 2002 implies that IT works best to support Lean in eliminating waste. The internet eliminates the waste of inventory and communication in the Lean supply chain study by Brunn & Medford. Studies by Mo, Ward & Zhou found IT integration improves customer lead time in manufacturing companies by eliminating the waste in the process and reinforcing the improved process.

2.3. IT implementation to achieve Lean principles

The Lean IT journey begins with the order of people, process, and technology (Bell & Orzen, 2011). The order clearly specifies productivity improvement achieved through IT investments depends on the use of Lean practices by the people to improve the process. The current reality is people are far more creative and agile than computers. Therefore, people must lead the way through transformation. Although, the three essential elements of people, process and technologies must be kept in balance as illustrates in figure 3.

Process and Technology without People
Alienation and turnover
Under-utilized systems

PROCESS

Alienation

TECHNOLOGY

SWEET SPOT

Frustration

Automated Chaos

People and Process without Technology
Frustration and inefficiency
High cost of operation

PEOPLE

People and Technology without Process
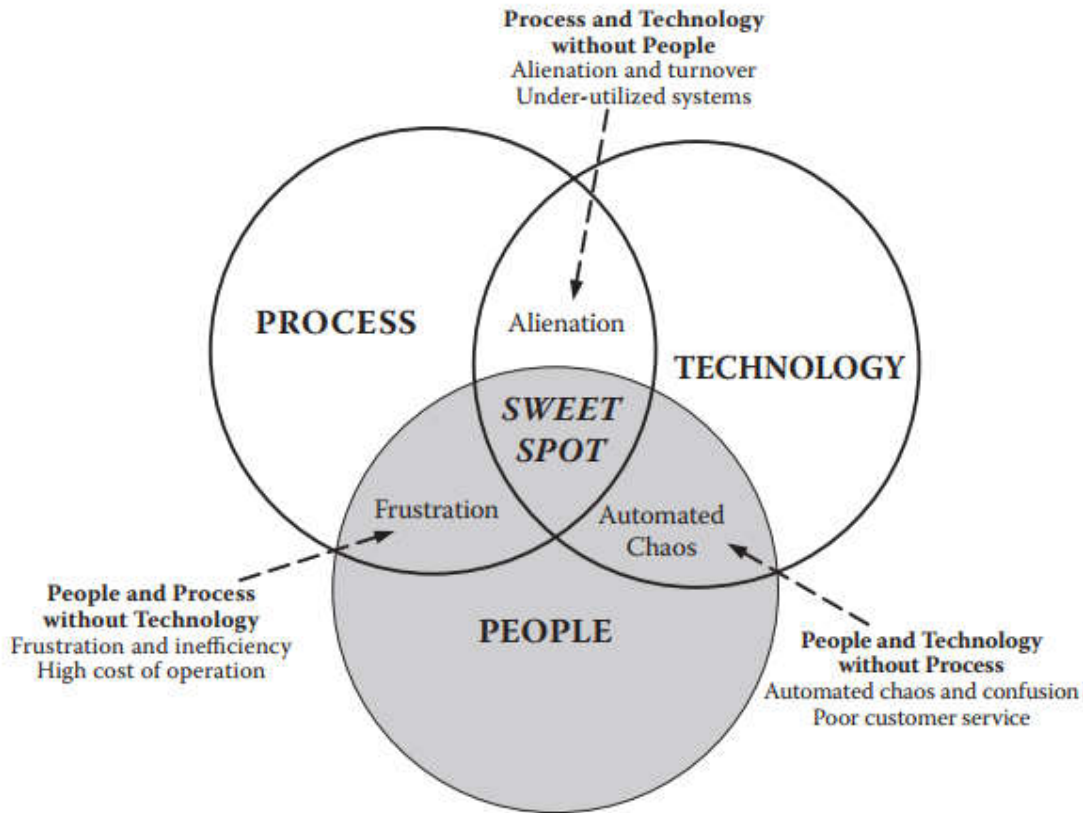Automated chaos and confusion
Poor customer service

Figure 3. Balancing people, process and technology by Bell & Orzen (2011)

In order to achieve integration of IT and business, they need to work closely together on critical business process. These efforts of working together should be a two-way street: business must take an active interest in information and information system and IT must learn to see information waste and value, listen to the customer and experience business process firsthand. This working partnership is a catalyst for enterprise transformation (Bell & Orzen, 2011).

There is a great deal of literature describing what Lean organizations should look like and provide an encouraging prescription to achieve Lean transformation although the principles are the same for any organization. Nevertheless, the actual process is very difficult and even more difficult to sustain. In the end, there is no such thing as one fits all prescriptive approach to Lean transformation. Lean organizations should have a fine balance of social and technical, process and practice and continuous adaptation and innovation. Every situation is different and requires a different approach. Murman, et al quote Hajime Ohba, general manager of Toyota Supplier Support Center which stressed, "Lean is a way of thinking, not a list of things to do." The first step should include understanding its own process, strength, and weakness before suggesting a specific course of action. The study supported

John P.T. Mo research in 2009 which emphasize that IT integration should be subsequent to the Lean initiatives to reinforce the improvement that has been made.

Bell & Orzen argues that the reason for many model-based efforts to transform and align IT have been disappointing is because the change is prescribed from without, rather than evolving from within. This is why Lean thinking does not impose a prescriptive approach but instead offers guidance through structured experiential learning based on timeless universal principles. However, a transformation roadmap can be used to provide general guidelines, allowing autonomy and flexibility for teams and individuals to adapt to each situation. The roadmap should be easily understood, adapt to imbalanced acceptance and quickly adjusted to new facts and circumstances. Bell & Orzen recommended a cyclical three transformation stage roadmap: strategy, planning, and execution which continuously feedback into each other.

2.3.1. STRATEGIC STAGE

Strategic intent and drivers must be articulated explicitly by senior management in the strategic stage of the transformation roadmap. This need to be done so that the stakeholders can focus Lean transformation activities on issues that will most affect outcomes. However, before setting a strategic vision, the fundamentals of Lean concepts must be comprehended by the top management. Across many industries, substantial investments are spent each year on IT that do not add value or offer differentiation to the customer. Evidence from a study by Markus & Keil (1994) indicates that IT-lead projects are often unsuccessful in capturing the business and human dimension of the process, and more likely to fail. Therefore, in integrating IT to support Lean transformation, the importance of capturing the human dimension in early stage should be emphasized by ensuring initial Lean education for all, and continuous Lean learning throughout the integration process (Powell et al., 2012).

Powell studies on the best practice framework to ERP-based Lean implementation system suggested that after the top management has been educated in the basic Lean concepts, implementation approach should continue with setting the strategic vision and values of the company. Clear strategic vision should be communicated throughout the organizations along with Lean education so that everyone can understand the Lean principles and have a common vision of why they need to integrate Lean into their work. This is due to the fact that lasting transformation is not just controlled from the top-down and follow the methodology, it must grow from the inside-out.

2.3.2. PLANNING STAGE

After the whole organizations shared a common vision and understand Lean principles, the next step would be to establish a cross-functional team and implement Lean foundation. It is significant that the IT associates are represented well in the team. This step begins the planning stage in the Bell & Orzen transformation roadmap. Although some studies suggest that the basic elements of Lean should be established before the IT integration, a catalytic effect can be attained by understanding the necessary information process for the IT integration (Powell et al., 2012). The finding suggests that the implementation of ERP can act as a catalyst for the application of Lean practices, as many of the tasks are similar or they support each other. For example, value stream mapping and standardize work as part of Lean practices support the development of process definition for the ERP implementation.

The planning stage should also include the key enterprise value stream assessment. Value stream map should be defined to identify and quantify the flow of work and supporting information of enterprise-wide core process. Strategic goals then need to be developed by the cross-functional team from the strength and weakness of these value streams. This process should enlighten the cross functional-teams as they learn to see their contribution in the big picture of enterprise and its customer.

2.3.3. EXECUTION STAGE

Initial pilot project to gain attainable success on an essential problem should start the execution stage. The focus should be areas of the organization that is most likely demonstrate early support of Lean transformation instead of toughest problems. This initial project was meant to build momentum in the organization. The initial pilot project should also be used to standardize the communication method, basic tools, training, and measurements.

After the initial project executed, the next phase is to measure the result, assess the Lean comprehension, and assess the acknowledgment of the Lean initiatives. The measurement and the open communication observations are meant to send a clear message that the Lean transformation is a strategic priority. Starts with the managers and supervisors to assess their level of comprehension of strategic objectives and clarify the connection of their role with localized objectives and daily behavior. Use one-on-one discussion with people on the shop floor to assess their level of comprehension and find is there a clear understanding of strategic intent and objectives. Adjust communications with the goal of everyone in the organization understanding

what they need to accomplish to support the strategic intent and why they must be part of the transformation (Bell & Orzen, 2011).

During this execution period, the IT integration should be intensified. IT members should regularly attend Lean project events and meetings. Most of the time, when IT associates are not involved, inappropriate technology solutions are often unusable because it does not account for the underlying systemic complexity of the process. However, if IT associates engage in this events and meeting from the beginning, it significantly improves the overall team understanding of the situation and the effectiveness of the solution delivered. Similarly, business stakeholder should regularly visit IT team meetings to better understand how IT thinks and works. Bell & Orzen believe that this mutual understanding and empathy helps to integrate IT and business, moving toward continuous improvement and innovation that create real value. The combined Lean and IT approach is a slow process because it has more steps and requires more time to complete, however, the result could justify all the effort.

3. RESEARCH METHODOLOGY

Overview of the methodology used in this study will be defined in the research strategy, research approach, data collection method, interview protocol, data analysis, and ethical consideration. The data derived from semi-structured interviews from IT and Lean expert having experience in implementing IT in Lean initiatives along with articles and conference videos. A qualitative approach will be used in this study along with literature review was meant to gain insight on the quality of IT contribution to Lean transition.

3.1. Research strategy

Most of research and literature in Lean was mainly conducted in manufacturing industries. On the other hand, IT has emerged from technological industries and has grown significantly in many sectors of industry. This research will investigate how this rapid growth in IT can now contribute to Lean transformation. Furthermore, this study will also examine the gap in how the literature mainly developed from manufacturing industries are applicable in practice to other organizations.

3.2. Research approach

The inductive approach used in this research started from theory on the literature correlated with data gathered from experts in practice. The inductive approach was chosen because it is suitable for research based on experience, observations, and research questions. Inductive reasoning is often referred to as a "bottom-up" approach to knowing, in which the researcher uses observations to build an abstraction or to describe a picture of the phenomenon that is being studied (Spaulding et al., 2013). Patterns emerged from the data are analyzed and constructed to develop a framework and working theory to answer the research questions.

3.3. Data Collection Method

The data collection for this study comes from semi-structured interviews with IT and Lean experts having practical experience in integrating IT to Lean transformation in the organization. The interviews are recorded and transcribed as given permission by the participants to gain a better understanding of their opinion, knowledge, and perspective on how IT contributes to Lean transition. The interview is guided by a structured list of questions based on the literature and provide an opportunity for more detailed follow-up question based on the answers given by the participant. The interview questions are designed to gather information to answer the research questions from the perspective of the interviewee.

Interview participant was chosen based on their experience, knowledge, and expertise which will add more value to the insight gained from this research. The criteria would be the experts in Lean and IT and have sufficient and relevant work experience in an organization. The criteria would include experts from organizations and consultants who have working experience in integrating IT with the organizations to gain more perspective on how IT contributes to a Lean transformation. Furthermore, journal, articles, and conference video from Lean and IT summit was analyzed to gather more perspective from experts all over the world.

3.4. Interview protocol

The semi-structured interviews were conducted in June and July 2018 with Qhuba consultants and three experts in Lean and IT which have practical experience in integrating IT into organizations which undergone a Lean transformation or already completed their Lean transformation. The purpose of the research and the procedures were explained to the participants. They are also assured that the privacy and ethical aspects will be maintained along the research. A consent document along with the procedures and list of questions were sent to the participants before the interview session to prepare the participant on the topics and the research process.

The same set of questions were asked towards the experts, and few follow up questions is asked based on the answers of the respondent. The interview questions are designed to gather information to answer the research questions from the perspective and experience of the interviewees. The interviews start with a brief introduction, followed by an explanation of the research purpose, research procedure, consent, and a series of semi-structured questions. Each interview is recorded with the consent of the participant.

The following set of interview questions are meant to help answer the first research question about which currently available IT solutions have a significant positive impact on the efficiency and output quality of the organizations delivery process? And how does IT achieve it?

1. What do you think is the best IT solutions that can help organizations improve their process/efficiency?
2. How do you think this IT solution manage to do it?
3. How is the new situation after IT implementation? Did the IT solution work as expected?
4. Which other organizations do you think could gain benefit from this IT solution? Why?

The second research question about what is the effective way to implement IT solutions to achieve Lean is addressed by the following set of interview questions.

1. Do you agree that IT integration should be subsequent to the Lean initiatives to reinforce the improvement that has been made?
2. What do you think are the significant steps to implement IT solution to achieve Lean?
3. What kind of situation is best suited to use these steps? Why?
4. Do you think this approach is the most effective method in practice?

The last research question on which of the Lean principles are delivered effectively using IT solutions is addressed by the following questions.

1. What do you think is the biggest contribution delivered by IT to improve efficiency in organizations?
2. How do you think IT make this contribution?
3. Do you think this contribution by IT applies to other organizations?

3.5. Data analysis

The sample of data used in this study may not represent the whole population and industries and did not help with the reliability and generalizability of the research. However, the same interview questions asked towards the Lean and IT experts would increase the reliability of the research. Additionally, the findings of this study should be generalizable to the theory in the literature. Moreover, a consistent general conclusion drawn from all the interviews shows that the reliability and generalizability of the research are accountable.

Secondary data source coming from conference video on Lean and IT summit and articles on the internet proved to be very useful in this study. The video titled "How IT can support the Lean transformation?" from Daniel T. Jones, founder of the Lean enterprise academy and Lean thinking

provides a great perspective to the study. Other video and article were also valuable to investigate how IT has been supporting the Lean transformation in other organizations. All of these secondary data sources are analyzed together with the primary data to answer the research questions and develop a framework.

The first interview with Qhuba consultants provides a general description of how the industry has been using IT to improve efficiency and how the Lean transformation process performs. However, practical perspective was still needed to analyze how these kinds of solutions of using IT are perceived. The interviews with Lean and IT experts having practical experience in integrating IT shed much light on this perspective and generate a lot of insights.

The interview recordings were analyzed based on the theory from the literature and research questions. It is interesting how most of the literature and theory of Lean IT coming from manufacturing industries analyzed with interview data from other industries. The gap between perspectives of consultant and client is also considered in the analysis related to IT contribution to Lean.

The coding process started with open coding with part of sentences as the unit of analysis. In the earlier phase of analysis there are several groups of codes, then the transcription was coded a few times to adjust to with the groups. The codes were also regrouped for a few times in the analysis process and eventually formed into four final groups: Requirements to involve IT, Types of IT solutions, IT contributions, and IT implementation.

3.6. Ethical consideration

The interview participants are aware of the research objective, scope, and the possible duration of the interview. The participants have also been informed on the potential effect of their involvement and aware about their options to withdraw from the interview at any time.

The respondents were assured from the beginning of the interview that their answers are fully confidential and will be used for academic and research purpose only. These steps are essential to make the respondents comfortable and talk freely in expressing their knowledge especially in case some sensitive issues come up. Anonymity and privacy options were also offered to the participants in the consent document. The respondents have also agreed on the way the information is processed and used by approving in the interview consent part.

4. RESULTS

Total of five interviews consist of two interviews with Qhuba consultants and three interviews with Lean and IT expert participate in this study. All of the interview participants fulfill the requirements of Lean and IT expert with more than two years of experience. The interviews have given insightful knowledge on how IT contributes to the Lean transformation and supplement the literature in answering the research question.

Due to the time limitation, the interviews were conducted via phone and some of them via a Skype video call. The interview lasted around 40 minutes to one hour. The interview consisted of a brief introduction, followed by an explanation of the research purpose, procedure, consent, and a series of semi-structured questions. Each interview was recorded with the consent of the participant. The following table presents the details background and experience of each Lean and IT expert respondents participating in the interview sessions.

Respondent	Roles	Experience	Time of interview	Duration	Information
Francois van Heurn	Qhuba Consultant	IT Manager, Project Management [15+ Years]	19th June 2018	41 Minutes	Quotes allowed
I2	Qhuba Consultant	IT Manager, Project Management [15+ Years]	25th June 2018	53 Minutes	Quotes allowed, Anonymized
Jeroen Visser	Process Miner Consultant at Promineth (Founder)	IT Specialist, Strategic Consultant [20+ Years]	5th July 2018	44 Minutes	Quotes allowed
Jaroslav Procházka	Agile/Lean/Start-up coach and mentor	IT Programmer, Product Manager, Trainer [14+ Years]	16th July 2018	39 Minutes	Quotes allowed
Miles Herrera	Program Manager Lean IT Transformation, Lean and Six Sigma Trainer	Program Manager Lean IT Transformation, Lean and Six Sigma Trainer [5+ Years]	23rd July 2018	38 Minutes	Quotes allowed

Table 1. Respondent's background and interview details

In addition to journals and interviews, conference video and articles on the internet were also used to gain insight on how IT and Lean have been working together in the context of the research. It is surprising to see various insights for this research gathered from those conference video and articles has enriched the context of the study. This study further compares the data gathered to the theory from the literature and the research questions for analysis.

4.1. IT in Lean transformation

Although there is a consistent belief in the Lean communities on IT as emphasized by Miles Herrera, "If you ask me the best tools to achieve Lean, I prefer not to use tools, only paper, post-it, and markers." Numbers of big IT companies have been growing rapidly with the use of technology in the last decade. Some people may think this could be a new way of management that would provide a different strategy to running a business in the future. Daniel T. Jones in the European Lean IT summit 2012 on his panel titled "How IT can support the Lean transformation?" discussed these phenomena. He noticed as those companies grow into the second generation, those companies are facing very similar problem to traditional manufacturing business or service businesses that have grown up maybe more slowly in the past. Those companies grew very rapidly and experienced all the exact problems. It is very interesting that many of those companies are reaching for experts in Lean from traditional industries to help them out answers to their problems.

Jones further elaborates that actually all of the problems that a second-generation organization which mostly are large and substantial globally are very much the same kinds of problems. Based on these facts, Jones is not convinced that there is a different model of management. Instead, there is a different style which is very interesting. Furthermore, Jones is more and more convinced that the problem of running big existing organizations are actually common.

Based on the fact that running large IT organizations and transforming those organizations are actually common whether it is software business, manufacturing business or service business. Jones explores the contributions coming from three perspectives that need to come together, understand each other and cross teach each other. Following are the three perspectives according to Jones in Lean principles of value.

- IT: Think forward from the capabilities of technology.
- Lean: Think back from the circumstances of the customer
- CEO: Grow sales through better product / service

There is a need for alignment from those three perspectives, because if they all pulling in different directions, then it will not be possible to achieve the result that we are looking for. Jones uses the five principles from the Lean thinking to align these three perspectives because it has been proven to be very robust and a very useful framework to test on these new ideas.

Based on the five Lean principles on those three perspectives, Jones believes the path to use IT in Lean transformation is about understanding the wider context of not only the process but the business itself and what the technology allows the business to do now that it could not do before to exploit those opportunities. Furthermore, Jones believes that IT and Lean have a great potential to contribute to organizations, but it could only happen if we are able to think our way to explore and experiment into a new way of thinking. The imposing obstacle of these potentials are the thought processes that we all come with from our different perspective. To overcome the obstacle, we need to open our mind and learn from each other.

Pierre Masai, VP & CIO Toyota Motor Europe on another panel in European Lean IT summit 2012 elaborates the Toyota Way in IT. Masai suggests to eliminates all concepts of IT and enterprise alignment because it is all based on the idea of IT and the business as a separate system. IT and the business need to grow as one team with one aim and supporting each other.

Masai further describes how they link Toyota Production System (TPS) Lean values and IT system in Toyota Motor Europe in the following table.

Toyota Production System	IT links to TPS
Implement continuous flow to highlight problems	Design software deliverables with small lot sizes, with a short PDCA cycle to highlight issues very quickly after they occur.
	Encourages Heijunka and allows Jidoka
Go and see (Genchi - Genbutsu).	In requirements gathering – ensure that the IS member spends time with the business, engaged in their process.
	In Software development and Project management create Virtual Gemba and deliver meaningful KPIs to clarify the facts.
Stop to fix problems & Jidoka	By using continuous flow and Heijunka encourage frequent lines stops early in the project to fix problems.
	Maximize value of human checking by automating where possible
Develop the team (including Suppliers)	Encourage team members to understand the entire process, by job rotation and special assignments.
	Involve suppliers fully, being open about process and measures.
Use technology to help the process	Once basic principle and operation are clear, use technology to support it.
	Don't follow a product's operation without thought.
Visualize your process and Results	In Software development visualize defects and causes.
	Visualize entire project using one document Plan, Issues/Risks, Costs and Quality.

Table 2. Linking TPS and IT by Pierre Masai (2012)

Interestingly, Masai showed how Toyota Europe links TPS and IT not only by integrating IT solutions, instead most of them are done by incorporating Lean method into the IT department. This argument implies the IT solution itself is only a small part of how IT contributes to the Lean transformation. How the IT solution was designed, integrated and managed to support the organizations holds significant roles.

Furthermore, Masai emphasizes "If we only make the IT system process Lean – this benefits IT and has some benefits for the business, but if we can implement systems that make us Lean as an Enterprise - this benefits the whole company." The system meant by Masai is more than a system of IT solutions supporting Lean in the organization. Instead, it is a system of the whole IT elements in the organization merged with the business process, learn from each other and support each other to reach the same goals.

Both Jones and Masai concludes that to use IT to support Lean transformation, they need to do more than just working together in alignment. IT and business need to remove the barrier and grow together, keeping an open mind and learn from each other to achieve the same goals. The existence of Lean and IT forums, summits and conference around the world acknowledge the great potential of the combination IT and Lean. Recent IT developments cover more than just technologies. IT has adopted so much from Lean philosophy creating a substantial improvement in IT quality and delivery such as Agile methodology, DevOps, ITIL, and Lean IT concepts. The time has arrived for Lean practitioners to explore the capabilities of improved IT solutions and methodology much further.

Recent emerging BizDevOps (business, development, and operations) concept posses relatively similar objective with Jones and Masai vision of Lean and IT collaborations. Ismail (2018) describes, "The objective of BizDevOps is to facilitate this collaboration and steer projects towards not just a speedy and efficient outcome, but a successful conclusion from a business value perspective. Business team and IT need to share ideas and engage in feedback loops throughout the project lifecycle, from application conception to release and continuously thereafter."

4.2. IT solutions supporting Lean transformation

Many IT solutions have great potential to support Lean transformations. Lean and IT experts from organizations acknowledge some of the potential software which could have a significant positive impact on the efficiency and output quality of the organizations' delivery process thereby answering the first research question.

Additional data regarding the details and the use of these applications mentioned in the interviews were gathered from internet articles and academic journals to gain more perspectives. The aspects of the solutions and their potentials are described in the following sections.

Categorizations on these applications were created to simplify how they contributed and aligned to the Lean principles. Four categories of the IT solutions are defined in this study. The categories are Lean thinking process, Analysis and optimization, Optimizing operations, Virtual assistant.

4.2.1. LEAN THINKING PROCESS

IT solutions categorized on Lean thinking process are solutions which mostly used since the start of the Lean transition to brainstorm and plan the entire process. Samples of solutions in the category are mind mapping software, electronic kanban, and project management applications.

These IT solutions hold the potential to support the cross-functional collaboration activities and continuous improvement process to identify values and map value stream. Identifying values and mapping value streams are vital to Lean transition as they define the fundamental platform for the whole Lean transitions. Thereby, supporting these activities can indeed empower the Lean transformation process.

Although, Lean concepts already have specific tools and methodologies such as the value stream mapping (VSM), A3, or 5S to support these activities. VSM, for example, is a Lean method to analyze all the steps in the current situation and design a future state of processes from its beginning through to the customer with reduced wastes. The goal of VSM is to identify and remove waste in value streams, thereby increasing the efficiency of the production process. Furthermore, the methods only required a pen and paper.

IT solutions could empower those methodologies by providing better visualization, accessibility, collaboration, and automation. Miles Herrera emphasized in the interview, "You really need to make it visual, you need to make it easy for people to get access to it." Although in some cases the best visualization and accessibility may come with pen and paper, yet when the organizations grow into more complexity, the best visualization and accessibility might no longer be achieved using simple pen and paper.

4.2.1.1. Mind map

One of the IT solutions proposed by respondent I2 that could contribute to Lean transformation is the mind mapping software. Mind mapping is a technique to visualize connections from many related pieces of information or related ideas (Roussel, 2014). Mind maps take the form comparable to a tree, starts with the main thought as a trunk and connecting it to related ideas as branches and twigs. Images and colored connections are used to make meaningful visualizations. Roussel believes that mind mapping frees the brain from complex associations and allows room for out-of-order, out-of-proportion thoughts to be captured and then stitched back into the tapestry of the whole thought.

Furthermore, Roussel suggests mind mapping could be helpful for teams or individuals that are brainstorming ideas for improvement. The visual structure makes gaps in information quickly apparent and relationships between ideas clear. The technique can be applied anytime fresh thinking is needed and works well for process development, product improvement or any other opportunity for improvement.

Mind mapping software is a tool that enables people to lay out thoughts and brainstorms a new idea for improvements. Mind mapping software uses visual shorthand to capture in one screen the kind of complexity and depth that might otherwise take many pages of text to represent (Swan, 2012). The software provides a library of icons that can be used to express graphically what otherwise requires word and enable users to place each piece of data into spatial context with related pieces.

Swan study in 2012 gathers insights from Ralph Jarvis of Jarvis Business Solutions and his staff who used mind-mapping to kick off and manage a Lean implementation that resulted in a dozen ways for a hospital in Texas in 2010 to improve insurance validation process. Jarvis and team started with initial brainstorming sessions with key hospital stakeholders to gather ideas and insights that would help identify potential trouble spots. Jarvis experiences discover that one of the best ways to manage the kind of divergent-to-convergent thinking typical of brainstorming was using a mind map. Using visual metaphor in the software to capture their thinking, the team discovered that what they thought was one problem was, in fact, three separate but connected problems.

Mind mapping note was produced from each of the meeting processes. The mind map note was projected on a screen to share, giving the team instant feedback on its thinking process. The notes turned into agendas for subsequent meetings with assigned tasks and due dates. It provided a concise, content-dense way to archive team thinking. Unlike typically static meeting notes, mind maps are alive and dynamic as they added new thoughts to the map and revised old ones.
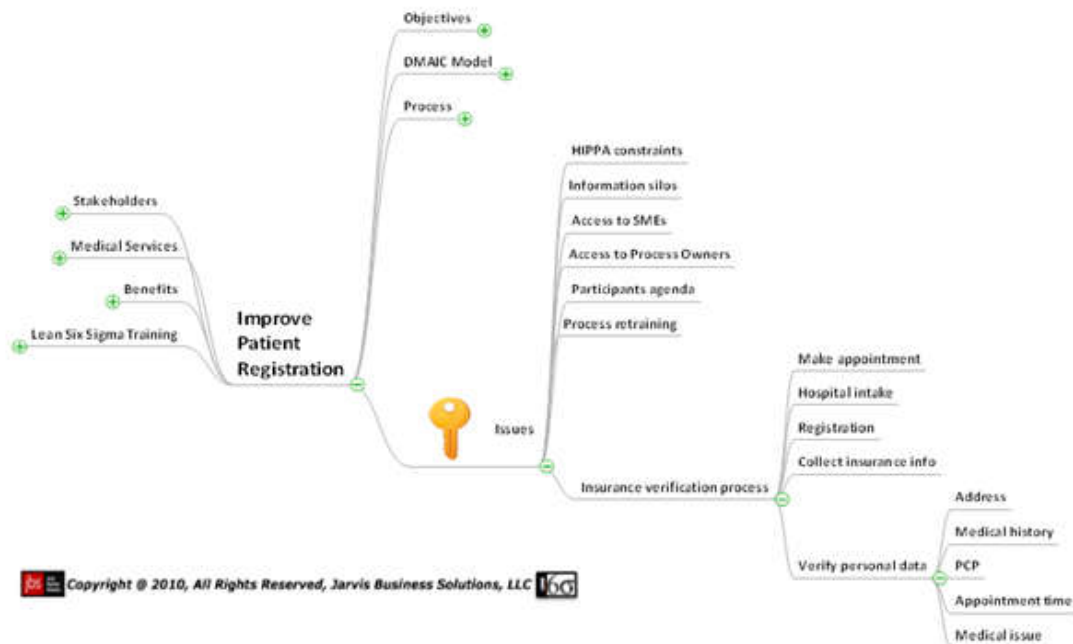
Figure 3. Mind Map by Swan (2012)

Swan discovers the mind map's functionality enabled the team to place supporting data immediately adjacent to the relevant insight or idea. Mind maps treat each piece of data, each idea, as pieces of a jigsaw puzzle that can be moved around at will to find the place where they fit best. This kind of flexibility triggered creativity as team members could see, understand and build on each other's thinking.

Swan noticed Jarvis used a mind mapping software that included both mind mapping and project management capabilities for the project. Mind mapping's ability to transform unstructured brainstorming into a highly structured project plan enabled the team to move quickly while maintaining the main objectives established at the early phase of the project. The powerful combination of mind mapping and project management supported his team through the entire project and made it possible for the team to provide hospital management with 12 critical recommendations for its customer satisfaction improvement.

The Lean concept places idea brainstorming, cross-functional collaborations and continuous improvement as a vital part of the Lean transformation journey. Lean processes highlighted the importance of idea brainstorming from different perspectives in a cross-functional team to lead the Lean transformation.

Based on these terms, mind mapping software has the potential to make a significant contribution to Lean transformation in an organization. Although mind mapping could also use pen and paper in the process and cost cheaper, the downside of using paper is the inability to move the idea around easily and to rearrange the mind map on paper might need more effort. Another alternative to mind mapping solution is a spreadsheet or diagram modeling software which provides generally similar flexibility in taking notes for brainstorming. However, mind mapping software would have richer functionality and focus. Furthermore, it's capability to combine with project management is something that could significantly help Lean transformation process.

4.2.1.2. Electronic Kanban

Kanban originated from Toyota Production System (TPS) back in the late 1940s to control inventory, production, components, and materials. Womack and Jones (1996) highlighted, "Kanban is a visual tool that forms an important part of the communication process which drives Lean factories." Kanban has always been part of Lean tools and has been used worldwide utilizing cards to manage the delivery or productions of parts, items or materials. In summary, it can be concluded that Kanban is a method to manage and visualize work using a board with spaces for sticky notes or cards representing tasks.

Physical Kanban board with cards are still an effective Lean method that some of Toyota factories are still using it. Additionally, a physical board is an inexpensive way of practicing Kanban for co-located teams or individuals whose work doesn't intersect one with another. However, for a distributed team, or enterprise organizations with multiple teams, a physical board could be no longer effective, a virtual Kanban board or e-Kanban board is currently required.

Mackerron et al., (2013) in the study of e-Kanban revealed many benefits of the e-Kanban over manual Kanban. The simplest benefits come from the digitalization to overcome the physical distance limitation, and no physical card means no chance of lost cards or important information. Additionally, e-Kanban creates a standard and formal communication process and eliminates the manual errors. Mackerron et al., (2013) further highlighted, "E-Kanban acts like a control panel, enabling real-time visibility of demand signals and provides an overview of the status of every Kanban in the system."

The Lean thinking principles by Womack and Jones (1996) played a role in the application of Kanban into knowledge work. The Kanban principal cores are essentially the same in many industries, triggering the implementations of Kanban in many industries such as human resource management and particularly software management. The principal core of Kanban includes work visualization, focus on flow, and continuous improvement.

Arising from Lean principles, the agile methodology in software development is one of the essential factors that boost the popularity of the digital Kanban board on software development industries. The rich features offered by the digital environment such as the possibility to include complex information in a single card, deadlines, alert, automatic reports on works and the capability to integrate with other enterprise systems fit perfectly on the software development industries. These rich features structured by Lean concepts may hold vast potential for the use of the digital Kanban on a lot more industries.

4.2.2. ANALYSIS AND OPTIMIZATIONS

IT solutions under the category of analysis and optimizations explicitly analyze data owned by the organizations to generate deeper visibility and insight thereby supporting the decision-making process. Participant I2 on the interview session believe this IT capability to process information and present it in a clear and usable way is one of the greatest contributions of IT towards Lean transformations.

The goal of IT solutions in this category is to provide valuable information to optimize the production process which aligns to identify value on the Lean principles. Furthermore, Fogarty (2015) in his study on Lean and big data argues that some of the valuable insights can only be produced by analyzing data using IT solutions.

4.2.2.1. Process Mining

Another IT solution proposed by some of the consultants in the interview that could contribute to Lean transformation is the process mining tools. Process mining tools extract information from business process and analyze them to identify trends, patterns, and details. Process mining aims to discover, monitor, and improve real processes by extracting knowledge from event logs readily available in today's information systems (van der Aalst, 2011).

Process mining emerges as a new technology due to the growing availability of event data and new process discovery and conformance checking techniques. Process mining focuses on end-to-end processes and enables evidence-based process analysis. Van der Aalst study in 2011 feature three stages of process mining. The most prominent technique of process mining is process discovery. A process discovery technique takes an event log and generates a model without using any a priori information. The second stage of process mining is conformance. This stage compares process

model with an event log of the same process. Conformance is used to check the actual process, as recorded in the log, conforms to the process model generated and vice versa. The third stage of process mining is the enhancement. This stage focused to improve an existing process model using information about the actual process recorded in the event log. For example, using timestamps in the event log one can extend the model to show bottlenecks, service levels, and throughput times.
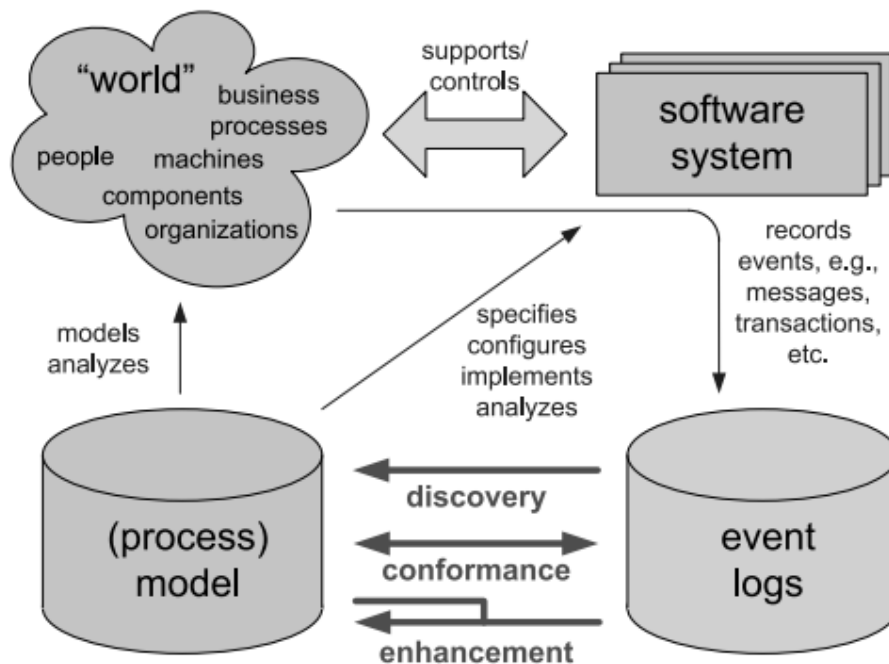

Figure 4. Process Mining stages by Van der Aalst (2011)

Recent studies by Visser (2017) argues that process mining helps to be more efficient in the steps of the DMAIC (Define, Measure, Analyze, Improve, Control) cycle of the Six Sigma. Visser claims, "DMAIC cycle is commonly used by Lean Six Sigma practitioners to improve, optimize and stabilize business processes and designs." DMAIC is a proven guide and not only used by Lean Six Sigma. It can easily be used for other improvement projects due to its general nature.

Process mining discovery generates a process model which provide instant fact-based insight into how the different process activities are related and statistics regarding the frequencies and duration of the process steps. Thereby, process mining could instantly discover where the bottlenecks and loops in the processes are. Process discovery capabilities and the ability to quickly identify loops and bottlenecks are of significant help in defining the process and the potential problems in the Lean transformation process.

The process statistics capabilities in process mining tools empower accurate formula for process characteristics like mean/median/total duration of process activities, frequencies of events that occur, number of steps per case, and many more. Utilizing this capability, the measurement step of Lean transformation will no longer be a tedious effort from scratch but an efficient search in the information that is already available. The combination of statistics capabilities and discovery capabilities of process mining could easily trigger ideas for process improvement which is the focus of Lean transformation.

Antonelli and Bruno study in 2015 on the application of process mining and semantic structuring towards a Lean healthcare network, notice the complexity to build a value stream mapping of the complete healthcare network because of the number and variety of services provided by the system. They manage the problem by analyzing the database of all the accesses to the services in a local health agency with a process mining software. They produce a raw process map with a large number of links and closed loops which enable them to filter out irrelevant process flows. Subsequently, they use a knowledge base structured from the logic behind the health service provision to further simplified and clean the process map. The resulting process flow then fed to the Value Stream Mapping and formed a groundwork for identification and improvement of redundant and non-value-added flows among healthcare services.

Interesting fact from the interview with Visser highlighted organizations with larger process data could gain more benefits from the process mining solutions. Particularly, financial organizations working with numbers, massive data, and a time-sensitive process would be able to gain a faster return on investment from this solution from the optimized process gained. For example, if an organization have 10.000 processes every day, a single minute process improvement can save 10.0000 minutes of time and would worth a lot of money and resources. However, other industries could also gain significant benefit from process mining solution. Visser's experience in the healthcare industry showed an improved process in a hospital could help in saving patient lives.

Process mining software is fundamentally a support tool to improve the business process which is an essential part of Lean. Therefore, the potential of process mining tool in Lean transformation is not something that can be ignored. However, process mining requires existing IT system which generates sufficient process event log. In short, only organizations met this requirement can gain benefits from this solution and implementing IT solution which generates process event log is not a simple task.

4.2.2.2. Big Data and Internet of Things

Big Data definition has many variations though it has similar themes and often defined as more data made possible by the internet and every time somebody uses a wireless device (Fogarty, 2015).

Experts and futurist have viewed Big Data as the technology that holds the potential to solve some of the greatest problems in society and create new business innovations. The significance of Big Data to business and governments has attracted many attentions around the world and become topic of interest at World Economic Forum.

The advantages of incorporating Big Data into the Lean concepts are highly related to the capability of big data to identify customer values in the organizations. This capability is vital to the Lean transformation process as it enables visibility to complicated business data thereby reveals opportunities for improvements. Recent evidence in the study of Fogarty (2015) implies by linking Lean with advanced analytics to the world of Big Data will enable practitioners to gain benefits from the massive information acquired to measure the process better and gain insights to fuel process improvements and innovation. Furthermore, Fogarty hypothesizes, "Some of these insights will unable to be unlocked except through analyzing Big Data."

Manenti study in 2014 on benefits of using Big Data for process improvement reported that Intel has saved $3M in 2012 by using Big Data for preventative analysis on a single microprocessor chip production line. Moreover, Intel estimates a savings of over $30 million over the next few years once they apply the technology to their other production line. Manenti also reported through the use of big data analytics to enable in-process inspection, GE Aviation could increase production speeds by 25%.

The Internet of Things or IoT is a system of connected physical objects such as devices, products, vehicles, corporate assets, buildings and other "things" through the Internet. These objects are embedded with electronics, software, sensors, actuators, and network connectivity that allow them to connect, gather and exchange data and respond to control messages. This connectivity enables direct integration of physical objects with digital systems. The potential benefits of IoT include improved efficiency and product development gained from real-time data sent from the connected devices. For example, information about product usage can be sent back to the companies to make improvements without customer interference.

Dean Hamilton wrote an article in 2017 about "Industrial IoT all set to turbocharge Lean manufacturing" believe that "IoT intersects with Lean methodology and has the potential to take Lean to the next level." Crawford (2017) gave an interesting example on the use of IoT to support Lean, "With machine-to-machine communication and real-time data transmission, these sources of waste can be identified with a computer as they happen—and be immediately corrected—without needing eyes on the process."

Supporting Hamilton and Crawford, Stephanie Peitzker (2017) of Bosch Software Innovations argues "Real-time value-stream mapping should be the basis and focus of all improvement measures, whether with Lean production or Industry 4.0 methods." Incorporating IoT into Lean production in the real-time value-stream mapping could serve as a great foundation for improvements.

The future of Lean envisioned by Crawford, Hamilton, and Peitzker is clear. Lean will be data-driven in the imminent future to boost the efficiency improvement further. The capabilities of advanced analytics and artificial intelligence technologies, combined with the flexibility of cloud computing, will give organizations the capacity to optimize IoT data and empower it as part of the Lean methodologies. Nevertheless, Hamilton emphasizes that this turbocharge Lean promises will ultimately depend on the ability to derive meaningful insight from data by the organization itself.

4.2.3. OPTIMIZING OPERATIONS

Optimizing production operations is one of the ultimate goals of Lean principles. In a simple sense, having an IT solution that can specifically optimize operations should be significantly beneficial to Lean initiatives. However, the fact is there are still many conflicts of opinions whether IT can actually support Lean initiatives.

François van Heurn in the interview believes that IT solutions can optimize operations by automation and enforce standardization. Automation and standardization are unquestionably beneficial in eliminating waste of resource which is one of the goals of Lean. However, François also mentioned, "The pitfall of ERP is over-automation and over-engineering." These conflicts imply that even the best IT solution was proven to be effective in optimizing operations in an organization, it doesn't mean that it would work as well in other organizations. IT solution might actually require Lean concepts to drive the solutions to optimize the operations accurately.

4.2.3.1. ERP

Enterprise Resource Planning (ERP) and Lean concept are intimately related due to their origin in the manufacturing industries. This condition matches the interview result from Lean and IT expert where both ERP and Lean are well recognized for performance and efficiency improvement in a production system. However, there are many discussion and literature that explores the conflict whether Lean and ERP are complementary or contradicting each other.

ERP origins grew from material requirements planning (MRP) systems that were developed in the 1970s with a focus on materials planning, inventory accounting, and purchasing (Powell, 2013). Eventually, ERP rise in the 1990s with the integration of planning, management and the use of all resources within an entire enterprise. ERP systems focused on promises for seamless integration of all information flowing through a company – financial, human resources, supply chain, and customer information (Davenport, 1998).

Powell studies in 2013 discover that traditionally, ERP systems have been implemented to integrate business processes and support managerial decision making. While the integration objective seems to align with the Lean approach, ERP systems have often been identified as sources of waste within Lean production literature (Bell, 2006; Bruun and Mefford, 2004; Hicks, 2007). Moreover, Halgeri et al. (2011) revealed, "In early incarnations, ERP systems were considered a hindrance to Lean manufacturing efforts and were criticized for encouraging large inventories and slower production. Over time, ERP vendors recognized the power and advantages of Lean manufacturing and developed ways to incorporate Lean-related features into their software."

An argument from François van Heurn from the interview generally agreed on the investigation by Bartholomew (2012) that indicated that the principal conflict of Lean and ERP lies in materials planning and production scheduling. ERP depends on sales forecasts for materials planning and its top-down approach. Contrarily, Lean adheres to a pull-based production-scheduling approach, with inventory kept to a minimum via an in-plant kanban system that replenishes materials and parts as needed. In summary, it is the classic conflict of "push" and "pull" manufacturing.

Although in the traditional sense ERP systems have been considered as an obstacle in Lean production, Riezebos et al., in 2009 learned that modern advances in IT and the improved capabilities of ERP have caused some authors to think differently. The improvement in IT and ERP allows more flexible implementation of ERP to support Lean production through straightforward customization and agile software development.

An interesting article by Bartholomew in 2012 on whether Lean and ERP can work together indicated that despite the disputes of ERP and Lean, manufacturers are finding ways to enable their Lean initiatives and ERP systems to coexist, and even work together. Powell (2013) conclude that the main reasons companies are applying both ERP and Lean approach are to gain a competitive edge in the global marketplace.

Bartholomew further describes some manufacturers have kept ERP and Lean apart to make both approach work without conflict. For instance, TRW's European Foundation Brakes Division have utilized ERP primarily as a records system, recording orders processed, materials utilized, and products delivered, all to keep ERP principally outside the plant. While pull-based kanban system works within the plant and communicates with ERP as a separate system to gain information of customer orders.

Another method reported by Bartholomew to make ERP and Lean to coexist is by forcing ERP to support Lean. Durabuilt Windows and Doors found a creative solution to the Lean-ERP conflict and has succeeded in combining ERP and Lean by implementing a customized ERP and then tweaking it to work with Lean on the production floor. Adapting the ERP system to support the plant's adoption of Lean-management principles was one of the first and crucial things that need to be done by Durabuilt. Randhawa, the general manager of Durabuilt told Bartholomew, "It's a faster process, and

we're not missing anything due to human error. And now we have materials lead time built into the system, so we can provide an accurate delivery date to the customer up front."

In summary, ERP indeed holds significant potential in supporting the Lean transition. However, it is crucial that the ERP integration should be driven to support the Lean initiatives, else there would be a good chance that ERP would conflict with the Lean initiatives instead.

4.2.4. VIRTUAL ASSISTANT

A virtual assistant category definition in this study is IT solutions that can perform tasks or services to assist individuals or a process. The idea of this category comes from the chatbot solution which currently utilized to provides customer support service and assistant. Although the idea comes from chatbot, IT solutions providing virtual assistant to empower Lean initiatives are not limited to the chatbot technology. Other forms of artificial intelligence that can assist individuals or processes can be incorporated in this category.

The main objective of IT solutions in this category to support Lean is providing forms of automation at an advanced level. As with other automation in the industries, automation produced by the virtual assistant and AI is driven to eliminate waste of resource in the production process.

4.2.4.1. Artificial Intelligence and Machine Learning

New rapidly developing technologies of Artificial intelligence (AI) and machine learning (ML) cannot be stopped, inevitable and will happen whether we are ready or not. Quibell (2018) predict these technologies will revolutionize the manufacturing industries with its rapid integration in the next ten years. There is no concrete literature so far that reported the use of these technologies within the Lean concept, however there already studies that reported the advantages of using these technologies for innovation and improvement in the industries.

Larry Fast wrote an interesting article on "Analytics and AI Play in the Future of Lean Manufacturing" in 2017 that defines "lights out" manufacturing as an advanced state of operations where machines run with no human interaction, such as robots. This manufacturing method has been done modestly in factories the last several years but has not yet been widely adopted. This method requires the machines to be programmed by humans and are still subject to human inefficiencies.

Furthermore, Fast wrote that in other forms of AI, on the other hand, machines can actually learn and teach themselves how to optimize their performance as they can run through various scenarios at tremendous speeds, identify the best processes and train themselves to achieve the desired outcome. There is a vast potential that AI will ultimately be the real game changer in the factories, but this may still be a decade or more away. Imagine the potentials of manufacturing systems that can absolutely guarantee six sigmas, every time, on the customers' critical-to-quality requirements. This enormous potential should worth all the effort.

Considering the potential of these solutions and technologies to revolutionize the industry towards great improvements and the lack of the structure around the use of these technologies, Quibell (2018), Fast (2017) and Fograty (2015) all agree that the linking of these concepts and solutions are extremely promising. Quibell suggested the Lean experts and community to take a leap of faith into the unknown towards the use of these technologies. Fogarty believes the combination of these technologies into the Lean principles will yield some new knowledge of business processes which previously unobtainable due to technology and methodology limitations.

Quibel (2018) believes the capability of these technologies to slice and dice the data into more meaningful pieces of useful facts to act upon is an underutilized potential in various industrial sectors. Most companies in the present time only use a fraction of the benefit from the data they have. The key to unlocks this potential is owning the vision to perceive how you can manage the data you have to frame customer need in the future and expectation beyond today's norm. You need to get off the carousel, stand back, and observe what's going on and where is or is not the sector moving. Quibel further believes in the areas where artificial intelligence (AI), machine learning (ML), the internet of things (IoT), and big data can have the greatest advantage are:

1. Designing a better product as customer data has been manipulated to anticipate the next best thing they need (or don't know they need as AI has anticipated they will want it).
2. Aggregating customer data to improve service as the second step to the anticipated better-designed product.
3. Virtual sourcing and developing a collaborative supply chain structure that rapidly advances e-tender virtual auctions with strategic and preferred supplier groups.
4. Advancing forecast demand modeling -- predictive and directional market trending analysis to identify what manufacturing technology you need to meet current or future product designs and customer anticipated needs.
5. Blueprinting the digital factory by creating a very transparent view of operations, where minimal human involvement is needed or wanted in very fast and repetitive tasks; apply Lean flow, pull, and optimized automation and robotic integration to run lights-out as needed. In essence, AI will design processes extracting pertinent Lean principles as needed without human involvement.

6. Enhancing analytics capabilities that are perpetually working to predict and anticipate market trend conditions; modeling and simulating the perceived need in order to have the internal capability and manufacturing capacity within your existing digital factory or extended supply chain (third-party fulfillment) to meet market needs should this need be realized as per the predictive modeling applied.

7. Deploying self-learning and intuitive algorithms functionality to detect design flaws and fix them before the product is integrated into the hard manufacturing workflow where we start to add value, which can translate into waste of the design is wrong.

Figure 5. AI and Lean sketch by Andrew Quibell (2018)

Quibell sketch on AI and Lean shows great potential on how these new IT technologies can revolutionize the industries. Although these concepts would require tremendous investments and

efforts, the Lean principles should help to minimize the risk by providing structure to the implementation of these technologies. The time has arrived for these technologies. We just need to let go of the out of date thinking, have an open mindset and learn from each other.

4.3. Best IT solution for Lean

Interestingly, all of the Lean and IT experts in the interview beliefs that the best IT solution which could have a significant positive impact on the efficiency and output quality of the organizations' delivery process actually depends on the organizations' mindset, process and their business context.

Jaroslav Procházka highlighted the importance of the mindset of the organizations in the interview. Jaroslav emphasized, "Without a proper mindset of Lean in the organization, IT integration might not be able to help the organization." Moreover, they could go back to their old habits and consider Lean as simply another color of the day. Jeroen Visser mentioned in the interview on the question of the best IT solution to improve efficiency in organizations, "If you have a process and you want to make it more efficient using IT, it depends on how the process is being run." Additionally, François van Heurn answered the question in a similar term, "That depends on what the processes are and what your portfolios are."

These expressions align with the Lean concept emphasized by Hajime Ohba from Toyota "Lean is a way of thinking, not a list of things to do." The initial phase of implementing IT to support the Lean transformation in the organization should include understanding its own process, strength, and weakness before suggesting a specific course of action.

Once the business process and the context are perceived, the next phase would be to start the Lean initiatives to improve the processes and then determining the perfect IT solutions to support those Lean initiatives. It is indeed a long and complicated process, yet the Lean and IT experts in the interviews and numerous literatures showed that implementing IT in supporting Lean initiatives has proven to be very beneficial.

The experts from the interviews suggested several IT solutions which have a great potential to support Lean transformation in organizations. This study collected additional data on these solutions from journals, articles, conference videos and generate a framework which describes what concept of Leans would be best supported by these solutions.

Lean Principles	Support Category	Lean Functionality	IT Solution type	Sample Solution
Identify value, Map value stream	Lean Thinking process	Cross-functional collaboration, Continuous Improvement	Mind Map, Kanban Applications, Project Management applications	ConceptDraw MINDMAP, Trello, Jira
Identify value	Analysis and Optimization	Data analytics for visibility	Process Mining, IoT, Big Data, Machine learning, Business Intelligence	Disco, Microstategy, Tableau
Eliminating waste	Optimizing Operations	Automation, Standardization	ERP, APS	SAP, Oracle
Eliminating waste	Virtual Assistant	Automation	AI, Chat Bot	IBM Watson

Table 3. Framework of IT solutions supporting Lean

In addition to the solutions mentioned in the interview, this study found other solution which has the potential for supporting Lean transformation and add them to the framework. This framework was meant to guide organizations to find IT solutions to support their Lean transformation based on the Lean approach required.

4.4. Best practice to implement IT

The interview question asking whether the interview participant agree that IT integration should be subsequent to the Lean initiatives was intended to find the effective way to implement IT solutions to achieve Lean. Interestingly, all of the Lean IT experts agree with this statement from John P.T. Mo in his study in 2009. This data confirms the theory that the organizations need to work on their Lean initiatives first before involving any technology, or even remove existing technology first.

One of the IT and Lean experts further described that more valuable information could be gained by implementing the Lean initiatives prior to the IT solution. The information gained from the Lean standpoint could be inspiring and very useful as an input to determine the most suitable IT solution or design the IT solution to better support the Lean initiatives.

Although, one striking feature of process mining mentioned by Visser in the interview suggested that the process mining tools can analyze existing process to focus on by the Lean initiatives improvement. By considering the benefits of this feature, process mining solution can be applied almost at the same time as the Lean initiatives process improvement. Visser highlighted, "Although you can achieve many good results without process mining tools, yet when processes are already fully automated, it is really hard to see what is going on in the process." This condition is the exact reason why the process mining tools could be very beneficial to improve business process. Furthermore, by using the process mining at the early step of the Lean improvement, organizations could measure how effective the effect of the Lean improvement by running the process mining after executing the Lean initiatives. Jaroslav Procházka supported this idea of Visser and emphasized, "It did not have to be a sequential process like mindset, the process, then IT solution, instead all three of them can go in parallel because they enforce each other."

Generally, all of the interview participants insinuated that the significant step to implement IT to Lean initiatives is by having the Lean initiatives progressing prior to involving any IT solutions. Only one participant expressed it differently in a specific practical term. Nevertheless, these practical terms could be generalized to the same conclusion. It is crucial to keep in mind to position IT as a facility or a supporting tool to achieve your Lean goals, not the other way around. Because in some cases, the goals might shift as the IT integration started to get complicated, thereby creating more problems.

François van Heurn specifically entails in the interview that the organizations should have the process flow in a rather mature level of Lean working at least 80 percent first, then model the flow into the IT solutions. Furthermore, another expert, I2 emphasizes many important aspects of the IT solutions should also be kept in mind to fit the Lean initiatives. These aspects include the lifecycle of the solutions, the flexibility, return on investment and the people or resources needed to implement and maintain the solutions.

Considering the cost of IT and the resource needed could be significant, a clear view from the management of the Lean initiatives and their support is essential. More importantly, not only the top management, the whole management including the middle managers need to be aware of what they want and the consequences of the Lean initiatives. The management support is a vital requirement prior to involving any IT solutions to the Lean initiatives. Gaining the whole management attention and support is likewise crucial for the Lean initiatives, and it is a long-term process.

Surprisingly, all of the Lean and IT experts believe that having the IT integration following the Lean initiatives is one of the best practices based on their experience implementing IT to support Lean. The best approach in practice to implement IT in Lean transformation could be anything such as ITIL or agile, but it is important to choose the approach based on the processes of the organizations. In

summary, There is no single best approach in practice, it depends on the process of the organizations. However, it is best if to have the Lean initiative's progressing first to see the organization process flow, then choose the best IT solution and the approach to implement it based on the information gained. François van Heurn argues, "The biggest gain in Lean implementation are organizing things and processes to make it effective and efficient, and in some cases, you might don't even need IT to do it."

4.5. Best Lean principles supported by IT

Automation is indisputably one of the brilliant contributions of IT. Automation reduces human error to a great extent and improves the resource efficiency. All of the IT and Lean experts agree on automation as one of the significant contributions made by IT solutions. Automation fits very well with Lean principles as it improves efficiency by removing the waste of human error and resources.

François van Heurn felt that the most significant contribution by IT is that it helps the organizations manage complexity by doing automation. In his argument, he explained how ERP managed various items used in the production which no longer possible to be done manually. This item management functionality has a significant role to minimize the number of defects in the production process and faster calculation for inventory management.

Another significant IT contribution in these current days and for a few coming years is the IT capability to manage and process information and present visibility in such a manner that it helps people to make a decision. Well-known examples of these sorts of capability by IT solution are business intelligence, big data, and process mining. Although these kinds of solutions do not directly contribute to improving process efficiency, it has significant potential to generate valuable information to improve process efficiency further. Some studies even argue that this potential could even surpass the improvement made by Lean initiatives itself.

The data analytics capability of IT enables visibility and matches the Lean principles in the context of identifying value in a production process. On top of improving efficiency, these capabilities have the potential to improve the quality of products or services to match the customer values better. This capability is indeed a significant contribution of IT towards Lean initiatives and it is suggested by the majority of the Lean and IT experts in the interviews.

The results obtained by the interview revealed that automation and data analytics are the most significant contribution made by IT so far. One of the participants even believes that these contributions will still be notable for the next ten to twenty years. Overall these results provide

substantial insights into the contributions made by IT to Lean initiatives. Automation creates efficiency by removing waste in the business process. Additionally, data analytics provides valuable information for the Lean initiatives to identify hidden value in business process or in the customers' data.

Another striking result of the interview with Lean and IT experts shows that all of them agree on these contributions made by IT can be applied to all industries. Automation and data analytical capabilities according to the participants could be harvest by any organizations. As mentioned in the previous chapter, there is no such single solution that can support various organizations with their Lean transformation. The best IT solutions to support organizations depends on the business process and the context of the organizations. Although not the same IT solutions might be suitable for all organizations, it generally implies that IT solutions have the potential to help the Lean transformation in any organizations.

5. CONCLUSION AND DISCUSSION

5.1. Conclusion

Companies, especially in the manufacturing industries, have been striving to create more efficient processes for many years using the Lean production methodologies. The primary goal of Lean is to get the right products to the right place at the right time and in the right quantity, by achieving the perfect workflow, minimizing waste and being flexible. This research presents clear evidence that IT can provide a significant contribution towards Lean transformation. Lean incorporates sets of tools to identify and remove waste such as value stream mapping. These tools are still valid today, however, with the recent rapid development of IT technology and methodology, Lean goals can be achieved faster and possibly with less resource.

Integrating IT into the Lean transformation nevertheless is not simple and requires a long process. Many IT integration project has failed miserably and costly due to many factors. Studies by Quibell (2018), Fast (2017) and Fograty (2015) believes that Lean can provide a better structure for the integration of these IT solutions, thus improving the successful integration rate.

This complicated process is one of the reasons why there are no single IT solutions that can generally help organizations improve their efficiency. Lean is a way of thinking, not a procedure or steps. Thereby, every organization might have their own approach. Every organization have a different

process, mindset, and values, therefore, requires a different solution. The insight gained from this research shows that generally, an organization needs to have a mature Lean process, mindsets, and values prior to integrating IT solution. The business process, mindset, and values are essential factors that determine the outcome of the Lean transformation and the IT integration.

There are some IT solutions reviewed in this research that has been proven effective or have great potential in supporting Lean transformations such as ERP, process mining tools, Big Data or others. A framework of these IT solutions to support Lean transformation was formulated in this study based on the interview, journals, articles, and conference videos. This framework was meant to guide organizations to find IT solutions to support their Lean transformation based on the Lean approach required by the organization.

Surprisingly, the process mining tools and mind mapping presents significant features to support the Lean transformation process. These tools have been used by consultants to help their client in achieving Lean goals and can be used from the early phase of the Lean transformation. Although the process mining tools can only be used by organizations having existing IT solutions in their business process and having a significant amount of data, the valuable insight gained from the process mining tools might only be visible by using the tools.

Although the development of cloud computing and agile methodology has significantly helped the IT integration process, IT system integration has never been a simple matter. The insight gained from the literature shows one of the keys to integrate IT to support Lean transformation is by having the IT integration subsequent to the Lean initiatives. This study has confirmed this finding on how to integrate IT from the interview data, and it is one of the best practices based on their experience. Generally, all the IT and Lean experts agree on this finding because it is important to have a mature Lean mindset, process, and values prior to involving the technologies. This argument is also significant to ensure the IT system will support the Lean transformation to reach the purpose, not the other way around.

Interestingly, some of the Lean and IT experts emphasize the Lean initiatives and IT integration can also run in parallel. This hypothesis is consistent with Pierre Masai and Daniel T. Jones panel in Lean and IT summit 2012. Both of them encourage the idea that IT needs to do more than working together in alignment with the business. IT needs to blend in and grow together with the business, learn from each other and supporting each other. This finding confirms that although it is important to have a mature Lean mindset, process, and values prior to involving the technologies, having the IT integration run in parallel and grow together with the Lean initiatives is also advantageous.

Another significant finding from this study is the contribution that has been made by IT towards Lean transformation. The data revealed that automation and the visibility gained from data analysis are the greatest contributions of IT. Automation improves efficiency by eliminating waste of resources and human error in the production process. Automation fits very well with Lean principles as

improving efficiency is one of the ultimate goals of Lean. Additionally, data analysis manages and processes numerous information and present visibility in such a manner that it helps people to make a decision. The visibility contribution by IT empowers the value identification process in Lean significantly.

5.2. Interpretation

The findings from this study conclude that the current development in IT technologies and methodology has indeed produced great potentials to empower Lean transformation. These potentials are so extensive that it could challenge the traditional Lean consideration of IT solution as a last resort in realizing optimal processes becomes no longer valid. The emergence of global competition is one of the significant factors that force the organizations to change their perspective of IT and embrace IT to empower their Lean initiatives. The time has come for organizations and Lean practitioners to explore the capabilities of improved IT much further to empower the Lean transformations.

Although IT has a vast potential to support Lean transformation, the process of integrating IT into a Lean initiative is not simple. Mature Lean mindset, process, and values are needed preceding to involve IT solutions. The framework of IT solutions presented in this study should then provide a guide for organizations to determine the best IT solutions matching their Lean requirements.

This study provided a guide in integrating IT into the Lean transformation. The fact that Lean is a way of thinking, not a list of things to do makes every organization would have a different approach suited to the condition of the organization. However, the essence of those approaches remains consistent. The organizations need to figure out their Lean mindset, process, and value preceding the IT involvement. This finding will hopefully guide the organizations in building a suitable approach for the organizations on integrating IT to their Lean transformation.

There are many contributions made by IT to reach Lean goals. However, the two dominant contributions of automation and visibility revealed in this study should present an initial guide for the organizations on how to optimize the use of IT to support the Lean initiatives. Furthermore, in terms of visibility, valuable insight gained from data analytics can even lead the Lean initiatives to a better improvement that possibly can only be identified by the help of IT solutions.

The findings of this study confirm that IT has indeed developed rapidly not only in terms of technology but also in methodology that it possesses vast potential in empowering Lean transformation. These findings should be able to provide a better perspective to organizations and

Lean practitioner to explore and gain benefits from the capabilities of improved IT. In addition , this study can also help IT professionals to comprehend that technical knowledge, features, specifications, and deployment may not always provide the best answers. An understanding of the business process, to experience what really is needed, and to learn from each other is critical to enable improvement and innovations.

5.3. Limitations

This study covers the general implementation of Lean and IT in all industries. Although most of the literature is based on manufacturing industries, the data is gathered from all kinds of industries and analyzed based on a general framework.

The size of the sample is relatively small for such vast and general scope. A larger sample with more specific industry could probably deliver better accuracy and reliability of the research. Majority of the Lean and IT experts participating in this study accommodate the role of the consultant in the Lean transformation, having more experts within the organization itself could generate an interesting perspective.

The qualification of Lean and IT experts required on this study are Lean and IT professionals with more than two years experience and having practical experience in integrating IT solution on Lean transformation. These are not simple requirements because Lean and IT is traditionally a different branch of knowledge, thereby there are not many experts having an experience of an expert on both of them. Due to these complex requirements, few of the respondents might not have practical experience in implementing IT on Lean transformation in an organization but still have enough expertise and experience in both Lean and IT. Furthermore, the majority of these experts are consultants which helps the organizations as an external party to the organizations.

5.4. Recommendations for future research

Future studies in the contribution of IT on Lean transformation is still needed, particularly concentrating on a specific industry as related to the limitation of this study. In order to have more focused and detailed perspective on IT contribution in Lean transformation, one should explore on a concentrated scope such in a specific industry. It is important to emphasize that narrowing the scope of studies would increase the difficulties to gather the source of information, nevertheless, at the same time it could gain deeper insight and increase the reliability of the data. More perspective of Lean experts within the organizations with practical experience in integrating IT solutions would provide more insights, although it would be more difficult to find these qualifications within an organization.

Another research recommendation would be to have an intensive study on the contribution of new technologies such as AI and machine learning towards Lean transformation. Additionally, case studies on recently implemented technologies such as IoT, Big Data, process mining, cloud computing and other technologies which have vast potentials to contribute towards Lean transformation would also be advantageous to trigger more exploration of IT capabilities to empower Lean initiatives. As Lean could provide better structure in developing these technologies, IT experts could also gain more benefits from these kinds of studies particularly in driving the development of the solutions.

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