Abstract—Lean management and innovation are two driving forces of today's business success. However, with fundamentally different concepts, some aspects of lean management may negatively affect a company's capability to be successful with certain types of innovations. This paper develops a framework to analyze such impacts. With comparisons between the lean culture, lean design, lean supply chain management and lean human resource management with the characteristics and contributing factors of different types of innovations, five propositions are presented. Each proposition can be tested through several hypothesis tests in future work. In addition, different strategies for a company to achieve the balance and maintain lean and innovation at the same time are also discussed. Advantages, disadvantages, and suitable situations for each strategy are analyzed.

I. INTRODUCTION

Consider a local engineering company that has just recently adapted the lean enterprise management throughout its system, from new product design to manufacturing and customer management. Company executives stress the importance of maintaining a high level of efficiency and quality throughout the entire process while removing any wastes that do not add value to the final product. A set of standardized rules have been placed upon the organization for the product design to prevent any forms of non-value-adding activities. This has, however, resulted confusions among a group of innovative engineers in the design department. Based on their experience, they know that some of their ideas will lead to radical innovations that create new market and bring huge success to the company in the long term, but many others may die after some testing. To test and realize the new ideas, significant resources including people, time, and capital investments are required. If being lean means removing any kind of activities that do not add value to the current customers, then should all activities that generate ideas that may lead to nothing be discouraged at all? What about ideas that do not add value to the current customers but may create value for a future market? Should these ideas be cut off from the current agenda? How can a lean organization promote product innovation and employee creativity while maintaining a good level of lean practices?

With different and sometimes conflicting objectives and fundamental concepts from innovation, some aspects of lean enterprise management are likely to cause discrepancies within an organization that is striving for product innovations. The goal of lean philosophy is to design and manufacture products of high quality and low cost in an efficient manner through eliminating all muda, the Japanese term for waste[1], which range from overproduction and unnecessary transportation to wastes of motion and correction [2]. Innovation is the commercialization of newly designed and implemented products or processes [3]. An important part of building innovative culture in an organization is to preserve uncertainty [3], encourage risk-taking experimentations on new ideas, and allow enough freedom to promote creativity among all individuals within an organization. As noted by Amabile, creativity is often crushed unintentionally in the work environments that are established to maximize business imperatives such as coordination, productivity, and control [4]. Many of the lean management practices reinforce such a mechanism that increases productivity and controls costs at the price of organizational creativity. This is especially true when the lean philosophy is applied to be the only way that organizations think and manage.

In this paper, we explore the effects of lean management on an organization's innovation capability and its employees' creativity. Techniques and strategies for an organization to achieve balance between successful lean practices and continuous product innovation will also be presented. The next section reviews the core concepts in lean and innovation.

II. LITERATURE REVIEW

A. Core Concepts of Lean

While the philosophy of lean was originated by Toyota in the 1950s, the term was first defined in the book, The Machine That Changed the World, which documents results of a study performed at the Massachusetts Institute of Technology (MIT) on the vehicle industry [1, 5]. Lean practices were implemented based on several ideologies that appeared prior to it, including total quality management [6, 7] and just-in-time (JIT) production [2]. These ideas sparked some of the key elements of lean thinking, including the focus of producing high quality products at relatively low cost only as items are needed [5]. Initiated by Taiichi Ohno at Toyota Motor Corporation, the techniques of eliminating waste and excess from the product flows were first introduced to automotive engine manufacturing, then to the automobile assembling, and later applied to the entire Toyota supply chain. A new group of lean principles were also formed to identify the value of customers, implement value stream mapping, develop flow production capabilities and a pull-based system, and identify and eliminate all forms of waste in the system [8].

There are three main objectives in the lean philosophy: (1) improving the flow of the system; (2) applying only value-adding time and steps into the organization; and (3) eliminating all muda, or waste [1]. To achieve these objectives, the basic identity of a system needs to be
Identified, value and waste need to be defined, and strategies need to be developed and implemented to enhance these definitions [2]. Through continuously reducing wastes in the system, a lean organization expects to develop and maintain production or service value for the customer [8]. Any tasks performed by the organization that consume resources but do not add value to the customer’s final product are considered as muda [2]. Seven general groups of muda are summarized in [9] and listed below:

- Overproducing more items than included in customer orders.
- Inventory due to increases of finished goods and work-in-process.
- Motion that does not add value to the final product.
- Waiting for any resource throughout the flow of design and production.
- Transportation or the additional movement that is not of value to the product.
- Over-processing or additional steps that do not increase the overall value of the product.
- Not being right the first time or the costs and time associated with repairing and correcting a product.

At the heart of lean philosophy, “value” is defined based on the customer’s perspectives in terms of cost, product functions, etc. The importance of customer value is displayed by the two levels of the lean approach: strategic and operational. The strategic level of lean thinking requires understanding the value of customers. The operational level achieves requirements set by customers through the practice of lean production techniques [8].

Among the lean techniques, standardization is a key component. It defines how the process is to be completed by sequencing all the tasks, and helps build new technologies or products on existing proven ones [10, 11]. Using standardization to simplify and formalize the work procedures, a lean organization expects its system to be less prone to variability and attain higher levels of process visibility [12]. Together with standardization, concurrent engineering, design for manufacturability (DFM) and value analysis form the lean design mechanism. The main purpose of lean design is to use existing components and make sure that the final designs are compatible with existing processes [13], so that the company’s resources can be leveraged as much as possible.

Other lean concepts include the pull-based system [2], just-in-time manufacturing [2], total quality management [6, 7], lean supply chain and customer management [14]. Applying them to the product design process means fast product design and development based mainly on customer orders.

B. Innovation and Creativity

The critical role of innovation to today’s business success has been documented and supported by numerous literatures [3, 15, 16]. Even in a recent interview with one of the US chief technology officer (CTO) candidates conducted by Technology Review, innovation was referred to be the single most important factor to boost the economy [17]. While a number of definitions exist for innovation, it generally refers to the implementation, institutionalization and commercialization of new and creative ideas [3, 18].

Based on the degree of changes an innovation brings to the technology and market, Abernathy and Clark categorized innovations into four groups: architectural, revolutionary, regular, and niche creation [19]. Architectural innovation includes the structural design and basic configurations of a product and process. It identifies the broad design of the products and sets the aim for competition in the industry. The major importance of architectural innovation is to disperse from prior industries to define the new configurations for an industry. In the event of such an innovation, both the current market and technology will be rendered as obsolete and new ones will be created. Different from architectural innovation, revolutionary innovation only disrupts the existing technology by introducing a new one, such as the steel closed body of automotives deemed all other automotive body designs obsolete. Besides changing the way products are designed, revolutionary innovation may also modify the way companies do business. However, this type of innovation serves the same market and the same groups of customers. Regular innovation is a form of incremental innovation that makes improvements on a pre-existing design or process. The innovation is applied to improve upon the established technical competence of a company in its current market. Finally, the innovation in market niche creation focuses on identifying new emerging needs from outside of the current market and meeting those needs through altering and improving existing technologies. As a result, new market opportunities are opened and the production and technical system are refined and strengthened [19].

All four types of innovation are critical to the success of an organization and the evolution of an industry. The timing of each type of these innovations, though, is based on the phase of the current system. Abernathy and Utterback defined three phases of industrial innovations to be fluid, transitional, and specific [20]. A fourth stage, the discontinuities phase, was added to this model by Roberts and Liu [21]. In the fluid phase of an industry, the rate of product innovation is at its peak and a variety of designs compete in terms of features, form and capabilities [20]. This phase has an emphasis on the overall performance of the product and the innovation is largely determined by customers’ needs and inputs. Innovation at this stage is characterized by frequent changes in the design. As the industry enters into the transitional phase, the process innovation rate starts to peak and the product innovation rate drops dramatically. A dominant design appears at the beginning of this phase to form the basic expectations of the market. After it is accepted by the majority, companies start to shift their R&D focus to incremental product improvements and rigid production...
process development. This stage emphasizes on the variation of products and expanding the overall technical capabilities of an organization. When the process innovation rate also starts to decrease, then the industry has entered the specific phase, which is characterized by cost reduction and quality improvement. Incremental innovations are usually applied here to improve the overall productivity and quality in the system [20]. The final stage defined in [21] as discontinuities stage begins when the introduction of a next generation innovation renders existing technologies or companies’ competitive ability obsolete. The pattern then cycles back to the beginning of the Abernathy/Utterback model where architectural innovation will be enforced [20].

Using a different mechanism, Henderson and Clark categorized innovations based on the changes to the core concepts and the linkages between them. Four types of innovations, namely the incremental, radical, modular, and architectural, were defined [22]. Key problems associated with the architectural innovation were discussed as a result of the path dependencies of technological progress. Since this type of innovation requires rethinking and redesigning the linkages among a product’s core concepts and components, the traditional architectural knowledge embedded in the structure and information-processing procedure of established firms may actually impede the progress of its architectural innovations. In dealing with it, an organization will need to build and apply new architectural knowledge, and thus new infrastructure. Therefore, resources and new types of learning must be invested to comprehend innovation that is deemed architectural. Knowledge must be obtained to identify innovation that enhances the business and is detrimental to the competence within it through new organizational learning.

Innovations that sustain or disrupt a company’s existing competitive advantages was investigated by Christensen [23]. A sustaining innovation improves existing products along the dimensions of performance that the main stream customers value of. A disruptive innovation, on the other hand, underperforms in area(s) most desired by the mainstream customers, at least in short terms, but offers other valuable features. Due to its great potential, this type of innovation will eventually better more established technologies and dominate the market. The value network structured around mainstream customers was identified to be the reason why many established firms have stumbled over disruptive innovations. Focusing only on existing mainstream customers is likely to lead a company to develop sustaining technologies that overshoot the demand and lose the market to disruptive technologies that had been initially denied by the same group of customers.

No matter what kind of innovation a company is striving for, supervisory and organizational support should assist in strengthening the employees’ creativity in order for innovations to flourish in the organization [4]. The three main components: expertise, creative-thinking skills, and motivation, that build up an individual’s creativity need to be understood and supported [4]. Expertise is the knowledge that an individual possesses. Creative-thinking skills define an individual’s approach to solving problems and understanding certain situations. Motivation is the intrinsic value an individual places on solving these problems [4]. It is found that when individuals are free of extraneous concerns and are encouraged to explore ideas and take risks, they are more motivated and creative [24]. Complex and challenging jobs characterized by high levels of autonomy and skill variety better promote employee creativity than simple or routine jobs.

The overall tension and conflict between creativity and the organization structure was discussed in [25]. The authors suggested that the two concepts, how an organization generates knowledge in practice, and how the organization implements ideas through process, could not be isolated in an organization. To encourage creativity and ensure growth, business processes and innovative practices need to be established at the same time. If practice is absent, there will be a lack of creativity resulting in less innovative ideas. However, without process, the system can become unmanageable and ideas may flow outside to other organizations. Only after a balance between practice and process is achieved will an organization be able to produce creativity and growth.

C. Lean and Innovation

Lewis evaluated the effect of lean practices on an organization’s competitiveness through three case studies [26]. In the three companies investigated, two of them supported the hypothesis that lean practices will result in an overall decrease in organization’s innovativeness. The study reveals that the more successful lean principles are applied in an organization, the more focused the organization tends to be on incremental production changes, and the less innovative activities are involved. Since the process of innovation requires greater lengths of experimentation and higher levels of risk, they are usually eliminated from the task list at an early stage. One of the companies studied, though, maintained an innovative process while applying some lean concepts. The reason behind this is due to the trade-offs that this third company achieved between lean practices and general innovation in order to sustain a competitive advantage on its products design. It determined that going “too lean” would be harmful to its system, and therefore, developed a plan to standardize its processes without sacrificing creativity.

Based on observations in the Toyota Production System, Mehri illustrated some of the negative effects of lean design process on product innovation [11]. First, since the focus of lean is on eliminating all forms of waste, Toyota is forced to outsource a large part of new product designs from other companies rather than supporting technological innovations within the company. The system also promotes the idea of “benchmarking” products and using the current information to improve only upon pre-existing product designs at a
III. IMPACT OF LEAN ON INNOVATION

The key concepts in lean culture, lean design, lean supply chain management, and lean human resource management are compared with the key contributors or hindering factors to innovation culture, different types of innovations, and creativity. These comparisons lead to five propositions, each of which can be tested through a series of hypothesis tests in future work.

Characterized by early routinization and uncertainty reduction, lean management represents a typical technical process [3]. Being rigid, standardized, and constrained to productivity, it places goals and guidelines, leaving less room for creative thinking and innovation [3]. The fundamental objective of waste elimination is usually translated into a lean culture that reduces any forms of slack [29], risks [9], and variability [5, 6, 30], all of which are important to facilitate innovations [29, 31-33]. While the continuous improvement initiative in lean is likely to have a positive impact on incremental process innovations, the lean culture to reduce slack, risks, and variability is expected to have a negative impact on a company’s culture to foster innovations. This leads to the first proposition and the summary of comparisons, as shown in Table 1.

TABLE 1. LEAN CULTURE VS. INNOVATION CULTURE

| Reduction of slack: The lean concepts promote the reduction of any slack, or underutilized design resources, within the environment to eliminate waste. | Extra time and design resources are needed to facilitate innovation [32]. |
| Reduction of risk: The lean concepts promote the reduction of any risks or potential failures that can result in necessary corrections [9]. | Identifying any forms of risk as a negative can prevent innovation from being achieved [29, 31]. |
| Reduction of variability: The lean concepts promote the reduction of variability to achieve product quality at relatively low costs [5, 6, 30]. | Variability is necessary to account for uncertainty in the system. |
| Proposition 1: The lean culture of reducing slack, risk, and variability has a negative effect on a company’s innovation culture. | Uncertainty is a major source of creativity. Preserving variability fosters innovation [3, 29, 33]. |

Next, the concepts in lean design are compared to the contributing factors of different types of innovations. Closely related, standardization and DFM are two main practices in lean design that aim at simplifying product design, minimizing parts count, and standardizing parts and process [13]. On one hand, with the goal to closely match product design with existing manufacturing capability, DFM is expected to increase efficiency and asset utilization. On the other hand, however, it limits the design space and thus hinders dramatic changes to the design. Standardization can be part of DFM, but also stands alone as a lean design practice. It defines the way product design is to be completed every time with standard procedures, standard materials and standard parts. Such design approach that uses existing components and matches new products with existing manufacturing methods is expected to keep innovations that require new technical skills, changes to the components, or changes to the architectural linkages out of the door.

Value analysis is another key component in lean design [13]. In order to identify non-value-adding activities, value should be clearly understood and defined. The lean thinking emphasizes that value can only be defined by the end users [34]. Customers’ needs and wants should be closely followed in product design and manufacturing. Any products or features that the current customers do not want will be considered muda since they do not generate revenues in the current market. This approach is expected to continuously and incrementally improve products and increase customer satisfaction, especially in a market pull situation. However, it may hinder radical innovations that create technology push opportunities and cause companies to stumble over disruptive innovations [23]. Therefore, exclusively following customers’ definition of value and the elimination of all “non-value” adding activities can lead a lean company to failures because customers can be wrong, or at least shortsighted.

Similar to disruptive innovations, when a radical innovation starts a new technology s-curve, it is very likely to be worse in some areas than existing technologies [32]. However, given enough space to be developed, the new technology s-curve will take off and surpass the existing ones. But if a company focuses only on (short-term) customer values and renders anything that does not improve the current products as wastes, there is little chance that this company will be successful with radical innovations.

In summary, Table 2 compares the fundamental ideas of DFM, standardization, and value analysis in lean design to the nature of radical, revolutionary, architectural, and disruptive innovations. Two propositions are presented accordingly.
In summary, the lean human resource management characterized by stressful busy schedules and multi-functionality requirement is expected to have a negative impact on the employees’ creativity. Table 4 summarizes the above analysis and presents the fifth proposition.

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<th>TABLE 2. LEAN DESIGN VS. INNOVATION CAPABILITY</th>
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<td><strong>Standardization:</strong> Use standard process, standard materials, and standard parts in designing new products. Match new designs with existing components and manufacturing methods [12, 13].</td>
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<td><strong>Radical innovation:</strong> Requires different approaches from the existing ones [15, 33]. Causes increased uncertainty in the work setting; design may not depend on existing technologies [29].</td>
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<td><strong>Design for manufacturability (DFM):</strong> Simplify the product design, minimize the parts count, and standardize parts and processes. Designs need to be compatible with existing manufacturing procedures and processes [13].</td>
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<td><strong>Revolutionary innovation:</strong> Requires dramatically different design, new machinery, and new skills to render existing technologies obsolete [19].</td>
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<td><strong>Proposition 2:</strong> Standardization and DFM in lean design has a negative effect on a company’s radical innovation capability, revolutionary innovation capability, and architectural innovation capability.</td>
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<td><strong>Architectural innovation:</strong> Requires changes to the interactions and linkages between the core concepts and components. Using existing architectural knowledge may hinder this form of innovation [22].</td>
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<td><strong>Value Analysis:</strong> Current customers’ requirements are exclusively followed to assess value in product design [8, 13]. Non-value adding activities are eliminated.</td>
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<td><strong>Radical innovation:</strong> May be initially worse in some areas than the existing technology (when a new s-curve starts) [32].</td>
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<td><strong>Disruptive innovation:</strong> Blindly following the requirement of existing customers will lead a company to stumble over disruptive innovations [23].</td>
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<td><strong>Proposition 3:</strong> The lean value analysis has a negative effect on a company’s capability to successfully deal with radical innovations and disruptive innovations.</td>
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TABLE 3. LEAN SUPPLY CHAIN MANAGEMENT VS. INNOVATION CAPABILITY

| Lean supply chain management: minimizes buffers in the system and limit number of vendors to eliminate waste [35]. |
| Revolutionary innovation: Requires changes to the interactions and linkages between the core concepts and components. Using existing architectural knowledge may hinder this form of innovation [22]. |
| **Proposition 4:** Lean supply chain management has a negative effect on a company’s responsiveness to radical innovations and revolutionary innovations. |

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<th>TABLE 4. LEAN HUMAN RESOURCE MANAGEMENT VS. EMPLOYEE CREATIVITY</th>
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<td><strong>The lean job setting leads to increased stress, reduced job autonomy and skill utilization [36], and less informal communications.</strong></td>
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<td><strong>Expertise and motivation are two key contributors to an individual’s creativity [4]. Too much stress will decrease employees’ motivation. Low level of job autonomy leads to low level of motivation [24]. Informal communication may inspire creative thinking [31].</strong></td>
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<td><strong>The multi-functionality and high productivity requirements on employees leads to the loss of specialized expertise [11, 12].</strong></td>
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<td><strong>Proposition 5:</strong> Lean human resource management has a negative effect on employee creativity.</td>
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The lean concept of eliminating waste, while being applied to supplier management, means eliminating buffers and limiting the number of suppliers. Working exclusively with a few vendors may improve the efficiency of a company’s supply chain during normal time. However, when dramatic changes to the product components are required, this strategy may slow down a company’s speed in response. Table 3 lists the fourth proposition and the comparisons.

Extensive amounts of lean can also be harmful to the employees’ creativity. Standardized systems and monotonous job routines may lead to decreased levels of commitment and less motivation, a key factor contributing to one’s creativity as identified in [4]. This is shown in a three-year study conducted by Parker to test long-term effects of lean productions. The work characteristics, job autonomy and skill utilization of employees across all levels of the lean production were found to be decreased [36]. To represent the different levels of lean production, the lean teams, assembly lines, and workflow formalization and standardization groups were involved in this study. In each case, as worker groups got more standardized, employees’ overall participation in the decision making processes, as well as their commitment to the organization both decreased.

In a lean organization, increasing worker utilization and reducing the size of the workforce usually lead to reduced manufacturing costs. However, stress is also created in the work environment from busy schedules and multiple responsibilities expected from the lean workers [14]. In certain situations, stress may drive “creative tensions” that stimulate employees’ creativity [24]. However, too much stress is more likely to stifle employees’ creative thinking. As noted in [37], most people cannot function effectively in a time crunch for long periods without burning out, even if they have a sense of being on an important mission and being challenged. Therefore, even though the jobs in a mature lean system are supposed to make employees feel important and challenged and thus greatly respected by the company, workers will not be able to innovate when they have been under too much stress for too long.

The multi-responsibility and multi-functionality requirement on the lean workers also leads to decreased expertise in the workers’ specialized areas. This is consistent with the findings from [11] which shows that in order to keep up with the high efficiencies in productivity, the design engineers at Toyota seldom get a chance to enhance their technical skills. Since expertise is another key contributing factor to creativity [4], decreased creativity is expected as a result.

In summary, the lean human resource management characterized by stressful busy schedules and multi-functionality requirement is expected to have a negative impact on the employees’ creativity. Table 4 summarizes the above analysis and presents the fifth proposition.
Next, we discuss a few solutions suggested in literature to achieve the balance between lean and innovation.

IV. SOLUTIONS

Organizations should realize that lean practice is not the sole answer to building their overall competitiveness. As two forces that are driving today’s business for better performance, lean and innovation cannot be separated. Figure 1 demonstrates a simple example. As it shows, if lean and innovation are effectively combined, a company’s total profit will be increased much more as a result of reduced cost, enlarged market size and enhanced customer willingness to pay higher prices for a certain type of products. Just like creativity and structure cannot be separated to create value and ensure growth [25], a good balance between innovation and lean should be achieved. Special attentions need to be paid to the specific types of innovations that are more likely to be hindered by lean management, as discussed in the previous section.

Several strategies that have been proposed in literature are discussed in the following sections to help a company remain lean while keeping continuous product innovation.

A. Outsourcing Innovation

For an organization that enforces lean practices, depends on the nature of such organization, it is not necessarily a must to perform product innovation all by its own. One strategy is to simply outsource innovations [11, 38], especially when there are high risks and development costs associated with the new product design. This strategy can help an organization avoid committing significant levels of in-house resources, such as facility and inventory space, and employee time and commitment. It also helps lower the risks and costs of new product introduction [38].

The strategy of outsourcing innovation is most effective for companies in an industry where the technology progress speed is high and innovations have a significant impact. By outsourcing, more time and resources can be placed on the development of core competencies and maintaining the lean practices. The way Toyota Corporation designs and develops its products gives a good example of outsourcing product innovation [11]. The name “Toyota” is often synonymous with the lean practices. At the same time, Toyota is also identified as an innovative organization. Since the rigid lean approach and the expensive tooling equipment prevent significant levels of changes in the design and development of a new product, Toyota has realized the difficulties to create radical innovations from within the company. It outsources a significant part of its product from its suppliers, and relies on their knowledge and expertise to define new technologies. For Toyota to maintain its high efficiency and productivity, outsourcing innovation has been an essential part for it to keep up with technological innovations.

There are some potential downfalls with this approach. First, this strategy does not benefit or inspire creativity within the organization. Without the need and opportunities to practice, employees, especially those ones on the product development team, will lose their creativeness in the long term, which leads to a decrease to the company’s innovation capability. Second, too much outsourcing can be detrimental to a company’s core strengths and competencies. When the product innovation is outsourced, a company may lose the knowledge and expertise in product design. Since many technologies are path dependent, the company may not be able to design competitive new products when needed. Besides, when incremental changes to modules/parts no longer lead to overall product improvement, the relationships among the product components and core concepts need to be reconfigured and architectural innovation needs to take place [22]. In such a situation, a company that depends significantly on its suppliers’ component innovation will be having difficulties in keeping up with the technological progress.

Generally speaking, for an organization to decide whether to adopt this strategy, three conditions need to be satisfied, which are: (1) demand is increasing at a dramatic rate, resulting in new specialist organizations for innovative processes; (2) there has been a significant increase in the supply of knowledge workers in the industry; (3) the company has enough technological capabilities to interact with various organizations [38]. For companies in an industry where suppliers have high-impact and swift levels of innovation, outsourcing is a suitable strategy [38]. However, for companies with sufficient knowledge and capacity to perform product innovation in-house, some other strategies and techniques would be more beneficial.

B. Establishing an Independent Innovation Center

Lindeke, et al introduced the concept of Temporal Think Tank™ (T3™) as an innovation tool for lean organizations [27]. To run a T3™ center, employees who are efficient with cultural change and full of ideas are identified from different departments, and teamed up temporarily in an independent
organization. Being led by professional managers, they interact with each other and generate creative ideas for product innovation. They incorporate entrepreneurial thinking to recognize opportunities in the industry, plan how to seize it, and take the appropriate action. Ideas generated from the T3™ center will be assessed, selected, and suggested to the parent organization on its technology roadmap. After completion of the time in the T3™ center, which is usually one to two years, these idea champions will return to their original work positions to implement the ideas they worked with in the T3™. Upon returning, they are also expected to bring back the culture and atmosphere of creativities to their home departments. In this way, the parent organization can remain lean without sacrifice innovations that require a lot of “non-value adding” trials and risk-taking experiments. As presented in [27], this strategy has helped several organizations to maintain their innovation capability.

Setting up such an independent organization also facilitates innovations at different levels and in different categories. Since companies usually try to minimize internal conflict and maximize consensus, conformity is usually emphasized more; thus employee efforts and attention are focused toward prescribed directions. Using the T3™ center will help make up for the structural environments that discourage innovation. In addition, organizationally independent groups have been suggested to enhance architectural innovations and radical innovations to which the core concepts and the linkages between core concepts and components need to be changed [22]. In addition, as noted in [23], for a company to harness disruptive innovations, one way is to create an independent organization with a cost structure not honed to achieve high profit margin from the existing market. A T3™ center is such an independent organization that can help companies deal with disruptive innovations.

To adopt this strategy, it should be emphasize that the resources used to create and maintain the T3™ are beneficial to the long-term prosperity of the company, and thus not to be deemed as waste. One potential disadvantage is related to the size of the workforce. Since key leaders will be taken from their natural work environment for a period of time and sent to the T3™, this strategy only works when a company is able to remove part of its staff without affecting the rest of the system. The workforce must be capable of maintaining its status without certain individuals. If the number of employees is relatively low, or if the demand of production is exceeding the supply of the workforce, this option may be harmful to the productivity of the organization.

C. Lean Innovation System

Another approach that can be used to reduce the negative effects of lean on innovation is introduced in [39] as the “lean innovation system.” This approach defines the methodical interpretation of the lean principles with regards to product innovation. The lean innovation value system is a mapping system that defines values for an innovation project based on external and internal customers. It applies the lean concepts to the R&D facilities to generate product differentiation with reduced resources and waste. In the “lean innovation system,” there are ten principles and three specific steps. The first step, “structure early,” defines the innovation team, constructs the hierarchy of value in the system, and defines the architecture of the product. The second step, “synchronize easily,” applies value stream mapping and capacity planning to identify the most effective and efficient forms of innovation. The third step, “adapt securely,” defines the continuous innovation of product design to meet the values and requirements of customers. This approach has not yet been implemented systematically in any companies. But the few companies that have identified customer value in the development stages have experienced beneficial results in maintaining innovation in their organizations [39].

With this strategy, the lean approach could be embedded into the R&D stages. The creation of new ideas in the design stages are no longer deemed as waste, but viewed as value-adding to the potential products. It is determined that to meet the needs and requirements of the customer, innovations must be involved. To implement this strategy, a company must change its organizational thinking. Rather than only to identify and eliminate waste and standardize the system, the culture must now promote the need for constant changes. The new value system can then be used to provide a more transparent view of the needs and value of all customers (external and internal). This approach would be beneficial for an organization with the expertise to be innovative, but do not have the resources available to implement a process similar to the T3™.

D. Innovative Product Development Process

A technique called “Innovative Product Development Process (IPDP)” [40] can also be adopted by lean organizations to increase its product innovation capability. It is a technique that integrates concepts from Quality Function Development (QFD) and the Theory of Inventive Problem Solving (TRIZ) for companies to introduce innovation to their product design process. QFD, commonly denoted as the House of Quality, identifies the customer value of products based on customer requirements and a product’s quality characteristics. TRIZ is a system used to determine innovative solutions to product development. The TRIZ approach has similarities to that of lean, including the optimization of the operations of the system and elimination of items that do not add value. In combining QFD and TRIZ, Yamashina, et al. developed the IPDP method to systematically construct innovation into the product planning stage through the product design stage [40]. Applying the technique, QFD is first used to determine the areas where innovation is needed based on customer requirements. TRIZ is then implemented to define the solutions necessary to improve these areas. The solutions are then used to construct innovative product designs. Though being designed for the use by general organizations, the IPDP technique can be
adopted by lean organizations to maintain their product design innovation. The use of TRIZ is beneficial towards the lean practice because it efficiently utilizes resources in the system to eliminate wastes. The QFD process is used to analyze the hierarchy of a product and determine the needs for product innovation based on customer needs. The requirements for innovation can then be defined by introducing the TRIZ problem-solving approach. This strategy is helpful for a lean environment because it promotes efficient levels of innovation. The analysis through QFD is used to determine when a new product innovation is necessary, so excess resources are not consumed for innovation that may not be beneficial to the product.

Similar to the “lean innovation system,” this strategy would be ideal for a company that has the expertise for innovation but not the capacity for deployment of a new research center like the T3™. A major benefit to this approach is that it integrates concepts from TRIZ and QFD, two approaches that have been proven to be beneficial. A downfall is that it is still in its conceptual stages; very few studies have been performed to test its capabilities. But we identify this IPDP method as a possible strategy that lean organizations can explore to sustain its creativity and innovation.

E. Summary
Based on the analysis, advantages and disadvantages for the different solutions suggested by literature to help lean organizations to maintain its innovation capability are presented. Which strategy(ies) a lean company should choose is based primarily on the company’s characteristics and its products. We summarize the suitable strategies for different types of companies in Table 5.

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<tr>
<td>A need for rapid product introduction</td>
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<td>Creative knowledge base</td>
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<td>Established concepts / innovation-</td>
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<td>driving infrastructure</td>
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<td>Limited workforce and established</td>
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<td>organizational structure</td>
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V. CONCLUSION

In this paper, we identified and discussed potential negative effects of lean management on an organization’s innovation capability and employees’ creativity. A framework that includes several propositions is proposed to guide future studies. Strategies for lean organizations to instill creativity and improve innovation capability are also presented. Even though there are widespread differences in the objectives of lean philosophy and innovation theory, they can be alleviated by applying effective approaches including those ones discussed above. While lean thinking focuses on reducing costs, innovations create new business value by transforming original ideas to products or services that satisfy customers’ certain needs, and thus enlarge the market size and strengthen a company’s overall competitiveness. An organization that effectively accommodates both lean and innovation will benefit the most and be competitive in the long term.

Future study includes in-depth investigations and hypothesis tests to validate the propositions put forward in this paper. The effectiveness of the strategies in moderating the negative impacts will be tested in different industry and company settings. More solutions to better achieve the balance between lean and innovation will also be studied and developed.

REFERENCES