Identifying Influential Factors that Impact the Level of Organizational Improvement Resulting from the Use of Lean Practices on NPD Processes

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***Abstract*--The study of application of lean practices on new product development (NPD) processes could create fluctuation in the level of organizational improvement. However, some studies in the past shown that there are few studies that identified the influential factors impacting the level of organizational improvement. To further understand how the influential factors impact the level of organizational improvement, additional studies are needed. This research was designed to find the results for these understanding. The objectives of this research were (1) to identify the influential factors impacting the level of organizational improvement, (2) to determine the relationships between the influential factors and organizational improvement, and (3) to determine the relative importance of the influential factors impacting organizational improvement. The findings of this research can provide valuable insights for organizations seeking to improve NPD process and organization management. Also, the organizations implementing lean gain the important information from the study of the relationships among lean factors. The rankings of the relative importance of influential factors also provide the better outcome for allocating resources for lean implementation.**

I. INTRODUCTION

New product development (NPD) is an important strategic function in many organizations. A new product means products that has never produced by a company and will be sold for new targeted customers [1]. New products can result from breakthrough innovation, product repositioning, or cost reduction activities [1]. Organizations launch new products to markets to grow and sustain their revenue and position in the market [2]. Without new products, organizations may fail to penetrate new markets and may ultimately lose market share. Thus, NPD is an important activity from a competitive perspective. Cooper [3] found that U.S. firms generated 50% of sales revenues and 40% of total profits from new products. Although organizations gained more profits on new products, research by Barczak, Griffin, and Kahn [4] found that just over half (59%) of new products introduced by U.S. organizations are actually successful. This success rate has remained unchanged since the mid-1990s. The continued failure of many new products implies that there are still opportunities to improve NPD processes.

Researchers and practitioners have studied and published success factors for organizations to consider in improving NPD. NPD processes, as summarized by previous researchers, consist of four phases: idea generation, concept selection, development, and launch [1, 5]. NPD processes begin with generating ideas, followed by initial screening, and so on until products launch. Before beginning activities in one phase, the previous phase must be initiated.

This research studied improvement in NPD processes by applying an Industrial Engineering perspective. Industrial Engineering (IE) is focused on deploying concepts, tools, and techniques to increase effectiveness and efficiency of production processes and organizational operations. Lean, one set of IE tools and techniques, has been widely applied to production processes and in other organizational functions, including new product development. Based on previous research on lean, the application of lean to NPD processes has the potential to improve NPD process performance.

Lean, used first in Japanese manufacturing organizations, has been well-known since the publication of The Machine that Changed the World [6]. The fundamental objectives of lean production are to minimize wastes and to maximize flows [7]. Lean has been deployed and implemented in many different manufacturing organizations. More recently, lean practices have spread to other industrial sectors, including health care and information technology. Lean practices have also spread to other functional processes in manufacturing organizations, including NPD. Researchers and practitioners have suggested that organizations can improve NPD processes by applying lean practices [8-10]. The application of lean practices to NPD processes can streamline NPD by shortening time to market, by reducing NPD costs, and improving new product quality. Before discussing the application of lean to NPD processes, two terms must be defined, "lean principles" and "lean practices." Lean principles refer to the five lean concepts developed by Womack and Jones [11] and include customer specification, value stream identification, flow improvement, pull creation, and continuous improvement. The five lean principles are fundamental rules to guide organizations in selecting and using lean practices. "Lean practices," on the other hand, refer to tools and techniques used to enable the application of lean principles to a particular activity or process.

Researchers and practitioners use the term "lean product development" to refer to the application of lean in NPD. Researchers and practitioners have studied "lean" in NPD processes using a variety of approaches. There are three main approaches used to apply lean in NPD: design for lean production, the Toyota Product Development System (TPDS), and lean principles in product development (2007). Design for lean production is focused on designing new products to support a lean production environment [12]. TPDS is focused on the approach that Toyota has used to develop quality new products, as well as making the product development process faster and cheaper [12]. Lean principles in product development are focused on applying lean thinking, including the five lean principles, to NPD processes.

Researchers and practitioners have proposed frameworks that organizations can use in applying lean to NPD processes. One framework, proposed by Haque and James-Moore [8] , suggests that organizations improve NPD processes by using the five lean principles to identify issues found in NPD processes and to select proper practices to solve those issues. Another framework was proposed by Oppenheim [13] and is called the Lean Product Development Flow. The framework defines deliverables, success factors, and performance measures for applying lean principles.

In addition to Haque and James-Moore and Oppenheim [8, 13], other researchers and practitioners have proposed similar frameworks, including Anand and Kodali, Reinertsen and Mascitelli [14, 15]. These researchers and practitioners also recommend that organizations use the five lean principles and lean practices, as well as practices from project management and marketing, to create lean NPD processes.

In particular, lean practices associated with minimizing waste and maximizing flow are frequently mentioned in the literature [7, 11]. Previous research has shown that lean can improve NPD processes. However, only a few empirical studies have tested the usefulness of practices when applied to NPD processes and in NPD process performance improvement. Additionally, few studies have looked at identifying the challenges faced by organizations and the extent to which challenges become barriers to lean implementation. Haque and James-Moore [8] and Anand and Kodali [14], for example, used case studies to validate the impact of lean on NPD processes. To further understand how the application of lean on NPD processes can improve an organization, additional studies are needed. This research was designed to find the results for these understanding. The objectives of this research were (1) to identify the influential factors of lean in NPD processes impacting the level of organizational improvement, (2) to determine the relationships between the influential factors of lean in NPD processes and organizational improvement, and (3) to determine the relative importance of the influential factors of lean in NPD processes impacting organizational improvement.

II. LITERATURE REVIEW

After The Machine that Changed the World was published in 1990, organizations around the world realized how Toyota was able to ascend to the top tier in the automobile market [6]. This encouraged organizations, especially within the automotive industry, to improve production processes and product development processes to be more competitive. Since that time, many organizations have used Toyota Production System (TPS) methods to try to improve performance. TPS is also known as lean production and has been studied and applied in a variety of industries. Many authors have tried to clarify the key concepts of TPS. In Lean Thinking, Womack and Jones [11] simplify the lean principles used by Toyota and formulate them as five guidelines from which organizations can select and apply to improve themselves. Cusumano and Noeoka define the term of “lean” as a thinking system that can help organizations improve processes to save costs, time, and resources. While researchers and practitioners use different terms and definitions, the core principles of TPS or lean production remain the same and are focused on eliminating wastes and improving the flow of materials through processes. Womack and Jones [11] defined five lean principles: customer specification, value stream identification, flow improvement, pull creation, and continuous improvement.

Organizations should use the five lean principles to guide lean implementations. Previous studies have found that most organizations failed in implementing lean because organizations focused on using lean practices without understanding lean principles or because the organization implemented only one or two lean principles [16, 17]. The successful organizations in implementing lean applied all principles and used different practices to respond to each principle [18]. Researchers and practitioners have tried to expand lean to other functional areas, including NPD processes.

Lean has been implemented in NPD in some organizations over the past 10 – 20 years. There are many different terms used to refer to the implementation of lean in NPD processes. Some researchers and practitioners use the term “lean product development.” There are three main approaches used to apply lean in NPD: design for lean production, the Toyota Product Development System, and lean principles in product development [12]. The first approach is designed for lean production. Design for lean production is focused on designing new products to support a production environment [12]. New products are expected to have lower production costs and be easier to assemble. Under this approach, new products should not require major changes to existing production processes and would not include components that existing suppliers cannot produce [12].

The second approach is the Toyota Product Development System (TPDS). TPDS captures the way that Toyota has approached developing quality new products, as well as improving product development processes to be faster and cheaper. The Machine that Changed the World provided an overview of the product development system used by Toyota [6]. Organizations have tried to duplicate processes used by Toyota. Morgan and Liker (2006) were the first researchers to deeply study and document the details of NPD processes at Toyota. Morgan [19] spent 1,000 hours interviewing Toyota employees, as well as Toyota stakeholders in Japan, to determine the practices underlying Toyota’s achievements. From the study, Morgan and Liker [19] summarized 13 principles of TPDS:

1) Establish customer-defined value to separate value added from waste.
2) Front-load the product development process to thoroughly explore alternative solutions, while there is maximum design space.
3) Create a level product development process flow.
4) Utilize rigorous standardization to reduce variation and create flexibility and predictable outcomes.
5) Develop a chief engineer system, which assigns a leader to manage a new product development team from project start to finish.
6) Organize to balance functional expertise and cross-functional integration.
7) Develop technical competences for all engineers.
8) Fully integrate suppliers into the product development system.
9) Build in learning and continuous improvement.
10) Build a culture to support excellence and relentless improvement.
11) Adapt technologies to fit your people and process.
12) Align your organization through simple visual communication.
13) Use powerful practices for standardization and organizational learning.

The third approach for applying lean to NPD is lean principles in product development. The lean principles in product development approach is focused on how to apply lean thinking, which includes the five lean principles, to the NPD processes [12]. This approach originated from the success of the implementation of lean principles in the production process. A key element of this approach is to eliminate wastes and to improve flow in NPD processes. Previous studies of this approach have focused on developing frameworks for organizations to use in applying the five lean principles to NPD processes.

Haque and Moore proposed a framework for applying the five lean principles to the NPD process. The product or outcomes of the NPD processes are defined as knowledge or information. Haque and Moore defined each lean principle to use in NPD processes as follows:

1) Value specification: NPD teams must know who the internal customers and external end users are, as well as the expectations of the customer. Thus, NPD teams should have good relationships with their customers and suppliers.
2) Value stream identification: NPD teams must identify the value stream of current NPD processes and eliminate non-value added activities from processes associated with NPD. The value stream map should include information across the entire organization. The value stream map for a new product should also include information flows across NPD processes or information that can be used to create standards for each process.
3) Flow improvement: NPD teams must improve the flow of information in the NPD process and develop flow by paying attention to the workload rate needed for upstream and downstream activities. NPD teams should also focus on reducing delays in NPD processes, as well as improving knowledge and information flow.
4) Pull creation: NPD teams must control and manage information flow to support downstream activities and customer needs.
5) Pursue perfection or continuous improvement: NPD teams must continuously identify and eliminate waste from NPD processes. To enable continuous improvement, top management and managers should motivate NPD teams to keep pursuing the application of lean in NPD processes.

Haque and James-Moore [8] suggest that when improving NPD processes by applying lean, organizations use the five lean principles, including customer specification, value stream identification, flow improvement, pull creation, and continuous improvement, to identify issues found in NPD processes and select proper practices to solve those issues. Lean practices associated with minimizing waste and maximizing flow are most frequently mentioned in the literature. A variety of practices have been identified as being useful in improving NPD processes. Oppenheim [13], for example, proposed using value stream quality and Kanbans to eliminate waste and improve flow in NPD processes. Reinertsen [15] proposed using queue management and stand-up meetings to improve flow in NPD processes. Mascitelli [10] proposed Kaizen events and gap analysis to eliminate waste and improve flow in NPD processes. For this research, two types of practices were studied: traditional lean practices and other improvement practices. Traditional lean practices are tools and techniques that were originally developed and used within the Toyota Production System framework or “lean.” Other improvement practices, such as those used in project management and marketing, were also included in the study. Previous researchers and practitioners have suggested that such practices can be used to implement lean principles in NPD processes.

Oppenheim proposed a framework called Lean Product Development Flow. This Lean Product Development Flow framework is similar to the framework proposed by Haque and Moore [8], but includes deliverables, success factors, and some measures used to evaluate the lean implementation in NPD processes.

1) Value specification: NPD teams identify all customers and stakeholders and develop new products that satisfy all customers’ and stakeholders’ requirements. NPD teams eliminate wastes from the NPD process and deliver new products in shorter times and with lower costs. After implementing value specification, NPD teams can use the throughout time of NPD processes to evaluate success in the implementation of the value specification principle.
2) Value stream identification: NPD teams use value stream mapping to define the current state of NPD processes and suggest a more effective future state. The future state should have shorter times. To measure performance

improvement, savings from waste in terms of both money and time values, can be used.

3) Flow improvement: Organizations allocate all resources to support the desired future state and to meet targeted times. NPD teams also identify and eliminate uncertainties that can cause activity delays. After completely implementing the proposed future state. NPD teams can use the completion time of the value stream to evaluate the improvement of NPD processes.
4) Pull creation: NPD teams and people who work on activities associated with NPD processes should know who will receive the output of each activity, understand the needs of downstream activities or processes and understand when downstream activities or processes need specific outputs.
5) Pursue perfection or continuous improvement: The implementation of lean principles to NPD processes requires effort. Effective leadership is important. Training NPD teams and people who are involved in the NPD processes can help support lean implementation.

Reinertsen emphasized improving flow in NPD processes to make them more efficient. Because the flow of information in the NPD process is critical, improving information flow can shorten NPD time. Although the application of lean to NPD processes is different from manufacturing, some lean practices can be used in NPD. For example, organizations can reduce batch sizes to improve the flow of information in NPD processes. Organizations have to manage information between upstream and downstream activities by increasing communications among people who work in NPD processes. Organizations can ask engineers who work on drawings to constantly communicate to production department or suppliers. When finished with the design of parts for a new product, engineers should propose that design to the production department or suppliers. Production staff and suppliers can provide feedback to engineers part by part. A feedback loop between production staff, suppliers, and engineers is shorter and faster. Engineers can redesign a problem part right after production staff and supplier reviews instead of waiting until completing the entire new product design. Such a process will reduce major changes to new product designs, at the end of development process.

Since lean principles originated from Toyota, TPDS and lean principles in product development are similar. Three recently published studies have proposed frameworks for implementing lean in NPD processes. Those studies were conducted by Ward, Welo, and Mascitelli [10, 20, 21]. Each framework focuses on eliminating wastes and improving flow in NPD processes and on adopting lean manufacturing concepts, such as Toyota Seven Wastes, to NPD processes.

Ward [20] identified four elements for applying lean to NPD. The first element is knowing the customer and identifying NPD value streams. The second element is using set-based concurrent engineering to create new product alternatives at the beginning of the NPD process. The third element is promoting an entrepreneur design system to determine NPD project leaders who know the entire NPD process and NPD value streams. The fourth element includes: cadence, flow, and pull. Cadence is used to create standardized NPD processes that specify resource loads and reduce chaos in NPD processes. Flow is focused on making knowledge available when needed. Pull is focused on engaging people involved in NPD processes to respond directly to the needs of customers.

Welo [21] proposed a model for implementing lean in the NPD process. The model consists of six components: define customer values; promote lean as the organization’s culture; integrate resource planning and management, portfolio management, and organizational management; implement standardization; add knowledge from organizational learning to the NPD value stream; and continually improve across all functions in an organization.

Mascitelli [10] proposed a framework that incorporates Toyota’s methods, five lean principles, and project management practices to approach the product development process. This work suggests different practices to implement in different NPD activities, such as using QFD to translate customer requirements to design requirements. In addition to lean, Mascitelli proposed the use of project management practices, decision-making practices, and other practices that can help improve flow in development projects and make development projects successful by delivering new products on time and within budget. Previous studies have shown the possibility of applying lean to NPD processes.

Organizations use performance measurement to evaluate outcomes of processes and to determine opportunities for process improvement [22]. In the performance measurement process, indicators are used to assess the efficiency and effectiveness of a process [23]. The performance measurement literature recommends that multiple performance indicators should be used and that performance indicators consider different perspectives [23, 24]. A balanced scorecard, for example, is a performance measurement framework that focuses on four perspectives: financial, customer, internal business process, and innovation and learning [24]. In another framework, Neely, Gregory, and Platts [23] proposed four core performance indicators to apply in organizations: quality, time, flexibility, and cost. Performance measurement frameworks are not necessarily applicable to all organizations. Rather, organizations must modify or adapt performance indicators for the unique aspects of the organization, and businesses must use performance indicators that fit with the organization’s needs [25].

The application of lean to NPD has been studied by researchers and practitioners for two decades. Most practitioners suggest that organizations will benefit from applying lean to NPD processes. The impact of lean on NPD process performance improvement is important to justifying the efforts required to implement lean. In the improvement cycle, organizations set targets to motivate employees and use performance indicators to assess businesses and processes after improvement [26]. Some examples of the potential impact and effect of lean on NPD processes have been identified in the practitioner and research literature. Improvements documented in the literature include shortened total time for NPD processes and reduced product development costs [8, 14, 15, 27]. There are limited empirical studies that have focused on the impact of lean on NPD process performance. However, the studies that have been undertaken provide evidence for a positive impact of lean on NPD process performance [8, 14]. One purpose of this research was to identify performance indicators used by organizations to measure the impact of lean on NPD processes. From the literature, there are three main performance perspectives that organizations can use to measure NPD process performance improvement: time, cost, and quality.

Organizations implement lean to improve process performance [28]. Performance measurement concepts are applied to understand improvement resulting from the application of lean to NPD processes. Researchers and practitioners have claimed that applying lean to the NPD process can result in shorter NPD process times and reduced costs [13, 20]. However, there are few studies that define performance indicators to assess improvement in NPD processes after organizations apply lean. In the new product development literature, organizations use performance measurement to evaluate the effectiveness of NPD processes [29]. There are three main dimensions of performance indicators commonly used to assess the success of NPD processes and projects: time, cost, and quality [30-32]. Time, cost, and quality are multiple dimension indicators and consistent within the frameworks created by Kaplan and Norton [24] and Newly, Gregory, and Plattes [23]. Thus, performance indicators, used to assess NPD process performance can be divided into indicators related to time, indicators related to cost, and indicators related to quality.

Organizations likely face challenges when implementing lean in NPD processes. Many of the challenges result from the need for transformational change. There are many changes and adaptations required in a transition to lean. Many organizations have been unable to successfully navigate this transformational change. Lean implementation also requires collaboration and effort from all stakeholders, employees, and departments [33]. Collaboration between many employees and departments can make a lean transition more challenging. Knowing challenges that may occur during a lean transformation can be helpful by enabling top management to develop contingency plans prior to the implementation.

Organizations are more likely to successfully implement lean if they apply all five lean principles and if they use different practices to address each principle [18]. In a lean implementation, organizations should select proper lean practices to match with situations or issues found in processes [34]. Most practices used in a lean implementation are related to a particular lean principle. At the beginning of a lean implementation, organizations use a few practices. Moving forward in a lean implementation, organizations are more likely to adopt additional practices to realize additional improvement [28]. Research suggests that organizations should not apply only a couple of principles to processes [27]. Organizations should apply all five lean principles, as a lean system, to achieve improvement. Thus, if organizations use more practices, it is implied that more lean principles are applied, and organizations are more likely to see performance improvement.

Studies of Total Quality Management (TQM) by Powell and Taylor and Wright [35, 36], showed that TQM adoption time affects the level of performance improvement. Organizations require sufficient time to adapt and integrate new approaches in their processes. Organizations that have implemented TQM for a longer time can adapt and adjust the TQM implementation to better suit their processes and to achieve greater process performance improvement. Similar to TQM, lean is an improvement method. Thus, it is possible that the number of years of experience with lean may be associated with the level of NPD process performance improvement. Researchers suggest that in the implementation of lean, organizations will see a positive impact from lean, but may not see major changes initially after implementing lean [28]. However, in the long term, organizations can potentially see significant changes in processes and process performance improvement.

Based on the literature review, the influential factors of lean in NPD processes impacting the level of organizational improvement used in this research included practice use frequency, perceived usefulness of practices, performance indicator use frequency, perceived NPD process performance improvement, challenge frequency, perceived lean barriers, number of practices used, and years of experience with lean. The definitions of these factors are summarized next.

Practice use frequency was defined as the total number of organizations that used a particular practice.

Perceived usefulness of practices was defined as the average usefulness rating for a particular practice, used by organizations to apply lean to NPD processes.

Performance indicator use frequency was defined as the total number of organizations that used a particular performance indicator to evaluate the impact of lean on NPD process performance.

Perceived NPD process performance improvement was defined as the average extent to which NPD process performance improved in organizations after applying lean.

Challenge frequency was defined as the total number of organizations that faced a particular challenge, during efforts to implement lean in NPD processes.

Perceived lean barriers was defined as the average rating of the extent to which a particular challenge was a barrier to lean implementation efforts.

Number of practices used was defined as the total number of practices used by an organization to apply lean to NPD processes.

Years of experience with lean was defined as the number of years that an organization had applied lean to NPD processes.

III. RESEARCH METHODOLOGY

The aim of this research is to determine the relationships between the influential factors and organizational improvement, and to determine the relative importance of the influential factors impacting organizational improvement. The methodology that we used in this research is Interpretive Structural Modelling (ISM). ISM is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. ISM was first proposed by J. Warfield in 1973 to analyze the complex socioeconomic systems [37]. It is primarily intended as a group learning process, but can also be used individually. It transforms unclear, poorly articulated mental models of systems into visible, well-defined models useful for many purposes [38]. It develops a diagram, which shows the complicated interrelationships between various elements of the system in a complex situation. A multilevel ISM model is developed by decomposing the system into several sub systems or elements, in consultation with experts from industries and academia. ISM is interpretive as the judgment of the group decides whether and how the variables are related. It is structural as on the basis of relationship, an overall structure is extracted from the complex set of variables [39]. Thus, ISM develops insights into collective understandings of these relationships.

The steps to be followed in ISM methodology are as follows:

1. *Identification of elements*: Identification of elements related to the problem issue for the system, is the first step of ISM method. For this the group problem-solving approaches like brain storming, Delphi method and judgment/opinion/feedback of industry practitioners and academic experts are used. The outcome of this step should be a complete and adequate list of elements/factors. Through a detailed literature review of the articles on lean NPD processes, various influential factors impacting the level of organizational improvement were identified. Out of which only 8 factors were finalized in consultation with experts for this study. The eight factors are practice use frequency, perceived usefulness of practices, performance indicator use frequency, perceived NPD process performance improvement, challenge frequency, perceived lean barriers, number of practices used, and years of experience with lean.
2. *Contextual relationship*: Contextual relationship between the elements with respect to pairs of elements to be studied is identified, which are mentioned in step 1. After the identification of elements and their contextual relationship a structural self-interaction matrix (SSIM) is developed by using the pair-wise comparison of elements.
3. *Rechability matrix*: This matrix is developed from SSIM and its transitivity is checked. This transitivity of the contextual relation is a fundamental assumption in ISM. It suggests that if factor A is related to B and B is related to C, then it is mandatory that A is related to C.
4. *Canonical matrix*: This matrix is derived from the matrix obtained in step 3 and it is converted into canonical matrix format by arranging elements as per their level.
5. *Digraph*: This canonical matrix form of the reachability matrix is used to draw the digraph with vertices or nodes and lines of edges, also the transitive links are removed based on the relationships given in the reachability matrix. The drawn digraph is transformed into an ISM by replacing factor nodes with statements.

Characteristics of ISM: This methodology is interpretive as the judgment of the group decides whether and how the different elements are related. It is structural on the basis of mutual relationship; an overall structure is extracted from the complex set of elements. It is a modeling technique, as the specific relationships and overall structure are portrayed in a digraph model. It helps to impose order and direction on the complexity of relationships among various elements of a system. It is primarily intended as a group learning process, but individuals can also use it.

Advantages of ISM approach: ISM offers a variety of advantages like: i) The process is systematic; the computer is programmed to consider all possible pair wise relations of system elements, either directly from the responses of the participants or by transitive inference. ii). The process is efficient; depending on the context, the use of transitive inference may reduce the number of the required relational queries by from 50-80 percent. iii). No knowledge of the underlying process is required of the participants; they simply must possess enough understanding of the object system to be able to respond to the series of relational queries generated by the computer. iv). It guides and records the results of group deliberations on complex issues in an efficient and systematic manner. v). It produces a structured model or graphical representation of the original problem situation that can be communicated more effectively to others. vi). It enhances the quality of interdisciplinary and interpersonal communication within the context of the problem situation by focusing the attention of the participants on one specific question at a time. vii). It encourages issue analysis by allowing participants to explore the adequacy of a proposed list of systems elements or issue statements for illuminating a specified situation. viii). It serves as a learning tool by forcing participants to develop a deeper understanding of the meaning and significance of a specified element list and relation. ix). It permits action or policy analysis by assisting participants in identifying particular areas for policy action which offer advantages or leverage in pursuing specified objectives.

Limitations of ISM approach: There may be many variable to a problem or issue. Increase in the number of variables to a problem or issue increases the complexity of the ISM methodology. So we can only consider limited number of variables in the development of ISM model. Other variables which are least affecting a problem or issue may not be taken in the development of ISM model. Further experts help are taken in analyzing the driving and dependence power of the variable of a problem or issue. These models are not statistically validated. Structural equation modeling (SEM), also commonly known as linear structural relationship approach has the capability of testing the validity of such hypothetical model.

Applications of ISM approach: ISM can be used at a high level of abstraction such as needed for long range planning. It can also be used at a more concrete level to process and structure details related to a problem or activity such as process design, career planning, strategic planning, engineering problems, product design, process re-engineering, complex technical problems, financial decision making, human resources, competitive analysis and electronic commerce.

MICMAC analysis: Matrice d'Impacts croises-multiplication appliqúe an classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The purpose of MICMAC analysis is to analyze the drive power and dependence power of factors. MICMAC principle is based on multiplication properties of matrices. It is done to identify the key factors that drive the system in various categories. Based on their drive power and dependence power, the factors, have been classified into four categories i.e. autonomous factors, linkage factors, dependent and independent factors.

Autonomous factors: These factors have weak drive power and weak dependence power. They are relatively disconnected from the system, with which they have few links, which may be very strong.

Linkage factors: These factors have strong drive power as well as strong dependence power. These factors are unstable in the fact that any action on these factors will have an effect on others and also a feedback effect on themselves.

Dependent factors: These factors have weak drive power but strong dependence power.

Independent factors: These factors have strong drive power but weak dependence power. A factor with a very strong drive power, called the 'key factor' falls into the category of independent or linkage factors.

IV. RESULTS

The structural model is built by connecting the level of factors (practice use frequency, perceived usefulness of practices, performance indicator use frequency, perceived NPD process performance improvement, challenge frequency, perceived lean barriers, number of practices used, years of experience with lean) from level I through level V. The relationship of each factors are shown by an arrow pointing from factors at level I to factors at level II, III, IV, and V, respectively. The connecting different level of factors then become the ISM model as shown in Figure 1.

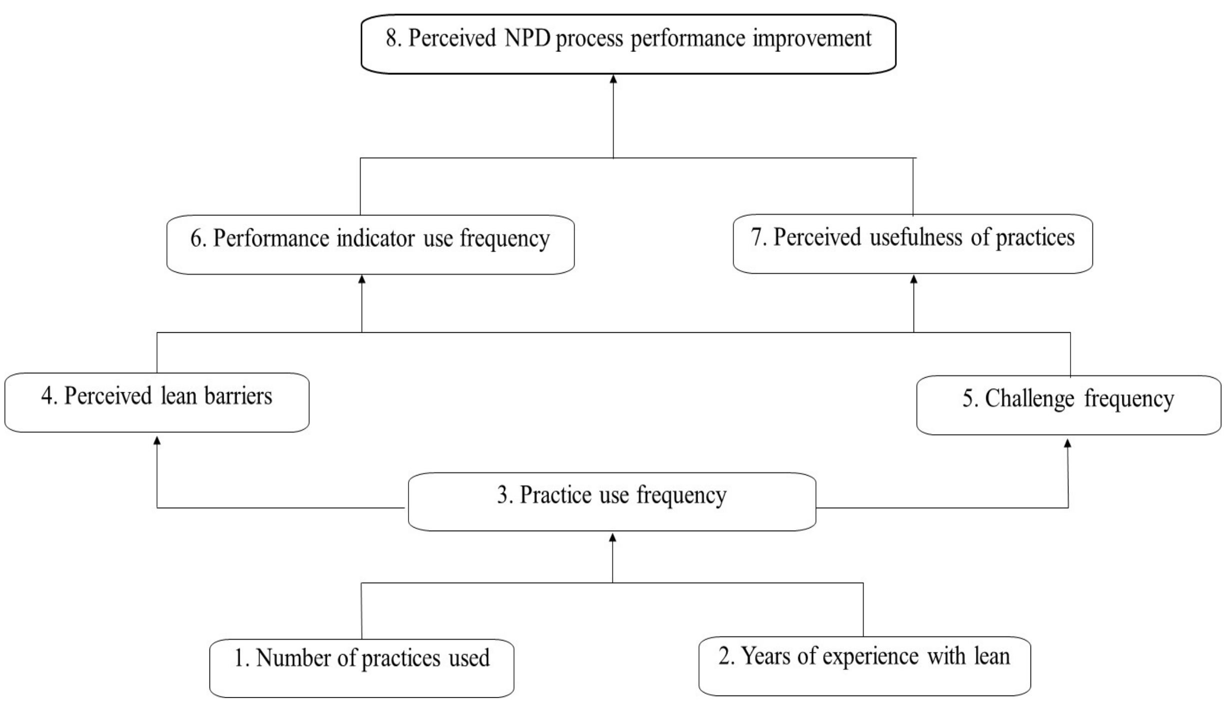

Fig 1: the structural model

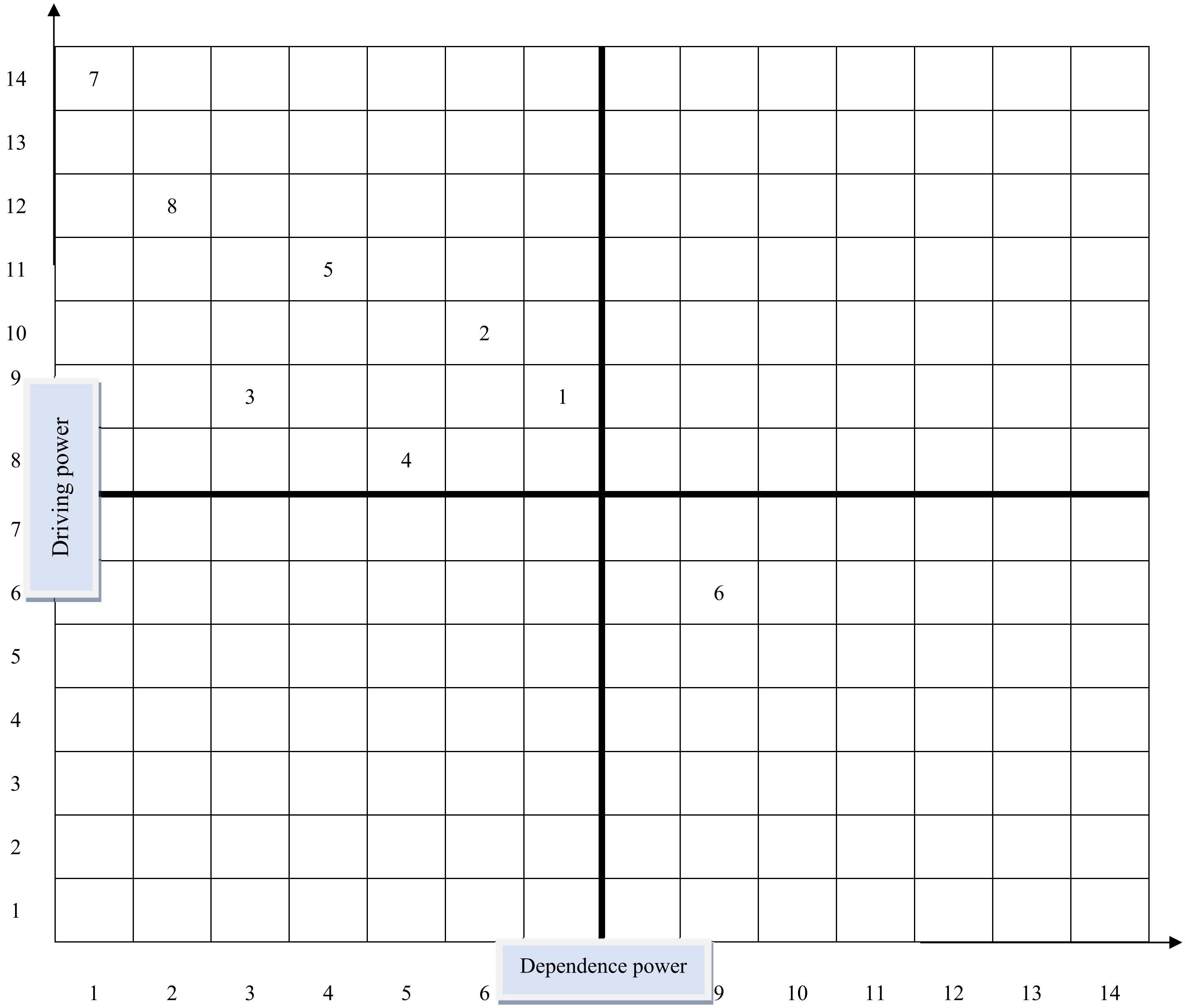

Fig 2: Driver power and dependence power diagram

The model shown in Fig 1 is subject to identify which factors are "driving factors" or "dependence factors." MICMAC analysis is used to characterize the driver power and the dependence power of the factors shown in Fig 2. The factors are classified into four clusters based on the driving power as a vertical axis and the dependence power as a horizontal axis.

In practical view, the MICMAC analysis provides valuable insights regarding the relative importance and inter-dependency of the factors. The practicing managers can use the analysis to identify the variables that need to be managed in their projects. Suppose, there is an factor, which turns out to be an "autonomous factor." Autonomous factors are located in the bottom-left quadrant in the driver power dependence diagram. The autonomous factors contains weak drivers, weak dependents, and do not have much influence on the model. Thus, the "autonomous factor" does not have much influence and continuously adds value to deliver projects. Management should not therefore pay much attention to the autonomous factor.

V. DISCUSSION AND CONCLUSION

The findings of this research can provide valuable insights for organizations seeking to improve NPD process and organization management. Also, the organizations implementing lean gain the important information from the study of the relationships among lean factors. The rankings of the relative importance of influential factors also provide the better outcome for allocating resources for lean implementation.

This work is undoubtedly on-going research. The future study will be focused more on developing a robust implication from the results. The diagraph model representing the relationships among factors will become a conceptual framework for testing further hypotheses in the study. The qualitative techniques such as an interview, coding, and pattern matching will be the tools for elaborating more on explanation of each factors using in the study. The multi-variate statistics will also be tested for confirming the relationships of those factors.

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