Categorization of Lean Research and Development Tools and Techniques: A Process-Based Approach

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Abstract
Several categorizations of lean tools and techniques introduces are very specific requirement and yet there is no way systematically to link the Research and Development (R&D) based organization challenges. In this paper, we focus on the several categorizations of lean tools and techniques employed in manufacturing industry, discuss their weakness and related it with the R&D environment. A mass study done by prior researchers’ shows that most of the lean tools and techniques categorization focused on one side change initiative and not highlights the importance of every process in R&D thus affect the R&D based organization performance. Additionally, there is limited evidence to show that all LRDTT involved in R&D activity were categorized in a correct group function. Thus, this paper proposes a framework for categorizing the LRDTT that is applicable to R&D activity. The proposed framework is developed based on the activity of the R&D. As such, the proposed framework treats R&D activities individually. The framework allows reducing the misuse/misapplication of lean tools and techniques in R&D activities. It also allows observing existing gaps between the lean tools and techniques by considering every process in R&D environment.

Keywords: Categorization, Improvement Tools, Lean, Process-based, Research and Development, Tools and Techniques

1. Introduction
In recent years, there has been a shift in the manufacturing process to meet the demands of bringing new products to market. Companies across all industries typically develop one concept for a product and see it through much iteration to completion. This causes some companies to find themselves investing heavily in R&D for products to market; however, while the world’s economies are still uncertain, this is an expensive proposition. Hafer (2011) revealed that one of the proven approaches to enable better decision-making throughout R&D activities leads to reduced costs and lead times while improving quality is represented by a set of effective lean tools and techniques practices.

Most manufacturers confuse and diminish focus on the activities since more than 100 lean tools and techniques activities already exist. Some researchers categorized the lean tools and techniques according to the methodology, purpose, waste, performance, product characteristic, type of resource and outcome. Even so, categorization is not applicable to the R&D activities as there is a large difference when compared to manufacturing such as non-repetitive, non-sequential and unbounded activity.

R&D activities are progressively developed to create new or improved technology that can provide a competitive advantage in the competitive business environment that is risky in nature. The basic building blocks of competitive advantage are activities whereby every business success depends on what the company does and how it does it. The value added by activities allows a company to offer unique products or services, possessing significant value for customers, regardless of the price, within reasonable limits. Therefore, the aim of this paper is to categorize the lean tools and techniques based R&D activities.

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2. Literature Review

2.1. Research and Development Process

According to Yoon, Lee, Lee, & Yoon (2015), R&D activities are divided into three processes which are organizational process, support process and fulfillment process. Support process and fulfillment process are the primary activities in the R&D process while the organizational process is supportive activities\(^2\). Organizational processes include R&D planning, idea management, intellectual property management, human resources management, etc\(^2\). The support process in R&D include project planning, project monitoring, risk management, collaboration management, and gate assessment, while the fulfillment process in R&D process consist of Concept Modeling, Business Feasibility Analysis, Specification Definition, Design, Development, Prototype, and Market Test\(^9\). This can be illustrated as Figure 1 and 2.

However, this paper focuses on the fulfillment process since the purpose of organizational process and support process are use only to support it. This fulfillment process is also known as the core R&D activity because it is the best place to start assessing the eligibility of R&D activities\(^2\).

2.2. Lean Research and Development Tools and Techniques

Lean Tools and Techniques (LTT) is the systematic method introduce to supports the lean transformation in lean system to remove waste, variability, an overburden and deliver improvement in specific areas\(^12,13\). Prior research revealed that lean are less focused on R&D due to unawareness of how to implement lean practice in R&D activities within manufacturing industry\(^14-17\). Even so, every LTT in manufacturing still able to give its own benefit to R&D environment. Table 1 as listed below show

| Lean tools and techniques | R&D environmental benefits                                                                 | Sources     |
|---------------------------|------------------------------------------------------------------------------------------|-------------|
| 5S                        | More efficient workplace by eliminating waste and reducing non-value added activities   | [20 – 22]   |
| A3 - Report               | Provides a practice environment to explore and improve problem solving skills            | [23 – 24]   |
| One piece flow            | Creating fastest path to value whereby the first product is ready to be sold            | [23], [25]  |
| Kaizen                    | Reducing the project start-up delay and to improve and standardize the work methods      | [26 – 29]   |
| Pull system               | All activities in the development program are in sync with end-customer requirement      | [31 – 31]   |
| Lean six sigma            | Solving problems and improving processes is faster and more efficient                    | [32 – 35]   |
| Standardized work         | Shortening the cycle between initial concept and global market access                   | [36 – 39]   |
| TAKT time                 | Improving the lead time of development process                                          | [40 – 42]   |
| Value stream mapping      | Supports the necessary integration of different department or process into a collective value stream   | [43 – 45]   |
| Visual management         | Supports an organizations information processing capability                             | [46 – 47]   |
| Zero defects              | Preventing the transfer of errors to subsequent process steps or projects                | [48]        |
the most common LTT that gave the benefits to R&D environmental.

Various lean tools and techniques are introduced to support the R&D activities in order to remove waste, variability and burdens, and deliver improvements in R&D activities; but, they still cause confusion and diminishing focus on the R&D activities. Therefore, it is very important to categorize the LRDTT in a systematic way that links the R&D problem on how best to avoid challenges faced by the responding manufacturer.

2.3. A Methodology-based Categorization

According to Larteb, Haddout, & Benhadou (2015), lean R&D tools and techniques can be categorized into soft LRDTT practices and hard LRDTT practices. Soft LRDTT are practices that place emphasis on organizational and human aspects in operations, quality and performance management. These are practices that relate to principles, managerial concepts, people, and relations. On the other hand, lean R&D tools and techniques for hard practices are more concerned with the methodological and technical side of lean R&D. However, this system of classification is simplistic and arbitrary as the principles in lean R&D activities are to create more value for customers with fewer resources. This paper focuses on lean R&D hard practices which consist of 5S, A3—report, standardized work, TAKT time, Visual management, Kaizen, Lean six sigma, One piece flow, Pull system, Value stream mapping, and Zero defects.

2.4. A Purpose-based Categorization

The focus of prior research related to R&D activities are on reducing waste, enhancing efficiency, reducing variability, preventing quality problem, detecting problems and analyzing them for the purpose of continuous improvement. The study by Amin & Karim (2012) offers probably the most comprehensive lean tools and techniques categorization based on purpose, which is quality improvement, process and support system as shown in Table 2.

However, this may not be applicable to all companies in the same manner as companies may have a different mission and vision. Therefore, the purpose-based categorization is inappropriate to use and somehow a temporary solution might be needed in order to against the actual root cause of problem.

2.5. A Waste-based Categorization

Over the past decade, most research in manufacturing has emphasized the application of lean by picking out of which resource is used and possibly how much of it is waste; this is done by quantifying waste or non-value added activity, and eradicating or reducing waste or any non-value added activity. Pavnaskar, Gershenson, & Jambekar (2003) have categorized the lean manufacturing into three applications. These are identification of waste, measurement of waste and elimination of waste, as shown in Table 3.

According to Soković, Jovanović, Krivokapić, & Vujović (2009), certain lean tools and techniques are used to improve the process as well. However, this waste-based categorization is too focused on the reduction of waste even though it was improving the quality of products or services.

| Table 2. A Purpose-based Categorization [15] |
|--------------------------------------------|
| **LTT** | **Quality Improvement** | **Process Improvement** | **Support System Improvement** |
| Standardized work | √ | | |
| Value stream mapping | | √ | |
| Andon system | | | √ |
| A3 (One page report) | | | √ |
| 5S | | | √ |
| Pull systems | | | √ |
| Kanban systems | | √ | |
| Quick changeover | | | √ |
| Kaizen | | | √ |

| Table 3. A Waste-based Categorization [4] |
|------------------------------------------|
| **LTT** | **Identification of Waste** | **Measurement of Waste** | **Elimination of Waste** |
| Cellular layout | √ | | |
| Facility layout diagrams | | √ | |
| Load leveling | | | √ |
| Six sigma | | | √ |
| Value stream mapping | √ | √ | |
2.6. A Performance-based Categorization

During any process or activities in manufacturing that consists of R&D activities, resources such as information, time, money, space, people, machines, materials, and manufacturing tools will be consumed and perhaps wasted\(^4\). The performance of resource scan be evaluated using four parameters, whether independently or in combination, of poor morale, incapability, inefficiency, and unreliability (Table 4).

However, the poor morale applies only to people while inefficiency applies to time, money and space. Furthermore, the severity of this performance characteristic depends on user perception\(^1\). Some of the performance is not compatible with the R&D environment as the R&D environment focuses on the innovation capability, customer satisfaction, etc.

2.7. A Strategy-Based Categorization

A number of researchers have categorized LTT in a variety of strategy which are characteristic-based, outcome-based and resource-based. Prior researcher believed that LTT could be categorized based on different characteristics of the process industry which are product characteristics, process characteristics and when product eventually becomes discrete in the process\(^2\). However, this categorization scheme is limited by the use of process industry and may not be applicable to R&D environment.

A few years later, Van, Bocquet, Eynard, Jankovic, & Vosgien (2011), have proposes the LTT to be categorized based on type of resource which are time, information/knowledge, opportunity/potential, money/investment and motivation. These six elements are strongly linked to the project targets (Van et al., 2011). Difficulties arise, however, when an attempt is made to implement the LTT based on resources due to some of the resource itself not valuable thus unable to sustained competitive advantage especially to the product development as well as R&D.

More recent years, other researcher suggests that the LTT need to classify according to outcomes of Design Science which are concepts, models, methods and instantiations\(^4\). However, this categorization scheme is developed special for visual management in order to improve transparency in planning and control in construction site. Table 5 shown the strategy-based categorization framework proposes the types of LTT for various company strategies.

According to a mass study done by prior researchers, it appears that the current literatures on LTT categorization are focusing on the whole of manufacturing environment, also known as product development, which is purpose-based, tool-based, performance-based, characteristic-based, resource-based and outcome-based. In general, therefore, it seems that all LTT categorization scheme able to avoid most manufacturer from confuse during LTT utilization. However, all the previously mentioned categorization schemes suffer from some serious weaknesses. Each of categorization methods only focused on one side change initiative and not highlight the importance of every process in R&D thus the outcome of company performance are less efficiency in term of financial, quality, time and customer satisfaction. Additionally, the selection of appropriate LTT for R&D environment cannot be implement in the R&D activities due to R&D characteristics gave big difference compare to manufacturing characteristics such as non-repetitive, non-sequential, unbounded activity\(^6\). As a result, the current LTT classification frameworks developed by prior researchers do not present a LTT selection guideline that supports R&D processes, thus the lean benefit are unattainable.

Table 4. A Performance Characteristic-Based Categorization [4]

| LTT Characteristic | Capability | Efficiency | Reliability |
|-------------------|------------|------------|-------------|
| Cellular layout   | √          | √          |             |
| Facility layout diagrams |          | √          |             |
| Load leveling     | √          |            |             |
| Six sigma         | √          | √          |             |
| Value stream mapping | √        | √          | √           |

Table 5. A Strategy-Based Categorization

| Strategy | LTT | Sources |
|----------|-----|---------|
| Characteristic-based | Products Process, Product discretization | [52] |
| Resource-based | Time Information/ Knowledge, Opportunity/Potential, Money/Investment, Motivation | [53] |
| Outcome-based | Concepts, Models, Methods, Instantiations | [46] |
3. Conceptual Framework

R&D is a unique environment; the work performed across projects is similar and can benefit from some of the same optimization LTT applied to manufacturing. It is important to know the extent of a process, to ensure that business responsibilities are met. Classifications of LTT proposed by prior researchers tend to focus on traditional classifications based on organizational structures or subjects which are often subject to change through amalgamation, devolution and decentralization.

Basically, every company, from SME to multinational must have detail understanding of the product or service, the industry to be competing in, the nature of the market and the amount of capital needed to kick-start the venture which is they have to consider product safety, market gap, keep R&D time short, keep R&D simple, dependence on other products, customer usage, pressure from the competition, industry growth and stability, expected product or service lifecycle, etc. LRDTT classification based on processes provides a more stable framework since the process and R&D organization that are carried out usually remain much the same over time. As such, this paper proposes a conceptual framework of LRDTT based on the R&D processes, namely Lean R&D Process-based categorization framework. LRDTT are categorized based on R&D activities which consist of Concept Modeling, Business Feasibility Analysis, Specification Definition, Design, Development, Prototype, and Market Test. (Figure 3).

4. Conclusion

The categorization framework for LTT has been developed via various approaches by prior researchers. However, within the scope literature review, none of the prior studies make an attempt to categorize LTT based on the organization activities/processes. The Lean R&D Process-based Categorization Framework proposed is this paper closes the literature gap by re-categorizing LTT in such a way that it is in line with the R&D processes. The categorization of lean R&D tools and techniques in this paper can reduce the misuse of lean R&D tools and techniques or the misapplication of tools at improper activities or for improper purposes. Therefore, a continuation of this paper can focus on the field work activities and test the relevance and validity of the proposed framework.

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