International Journal of Applied Optimization Studies
Year 2019 Volume 02 Issue 01 pp. 63-77.
www.ijaos.com

Employing lean concepts and tools in innovative and R&D based organizations

Tarannom Foruhi[a,*], Matineh Behzad[b], Zaynab Akhoundpour Amiri[c], Majid Felekari[d], and Hossein Havangi[e]

a Department of Industrial Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
b Department of Computer Science, University of Golestan, Golestan, Iran
c Department of Industrial Engineering, System Management and Productivity, University of Alghadir, Tabriz, Iran
d Department of Industrial Engineering, University of Kurdistan, kurdistan, Iran
e Department of Management, London Business & Engineering School, London, UK

*Corresponding author email address: T.foruhijp68@gmail.com

Abstract

One of the recent advances in the field of Lean concept is the use of its principles and tools in the field of research and development and innovation. Since R&D processes that lead to the creation of innovative products are not as standard as processes of classical production, or the supply chain in the industry, it is believed that lean principles and approaches in the field of research and development are not effective and even they can be an obstacle for the innovative and knowledge-based domain. But it should be borne in mind that the R&D activities also require a significant degree of standardization in the processes. Therefore, employing Lean thinking in research and development organizations and innovation can enhance their key capabilities. In this paper, after reviewing the differences between Lean R&D and Lean production and specific losses of R&D processes, the application of different Lean principles and tools will be discussed with an emphasis on the key capabilities of research and development organizations. By employing these principles and tools, organizations can increase the efficiency of their R&D process in different ways.

Original Article:

Received 2019-06-04
Revised 2019-08-28
Accepted 2019-08-30

Keywords:

Lean principles;
Lean tools;
Lean thinking;
R&D;
Lean production.

1. Introduction

Lean Thinking is a developed method for managing organizations to improve the productivity, efficiency and quality of their products and services. Lean production, which illustrates the application of this approach in the industry, derives from the successful management practices of the Toyota Auto Company, which was further introduced by James Womack and Dan Jones in the 1990s with the publication of the book "The Machine Changing the World" (Mitchell, 2004). Lean principles have evolved greatly since the inception of the 1980s, and today they have been used as a way to reduce costs, increase speed, and deliver superior quality to the builders. These principles have also been transformed into a standard part of the activities of successful and high-performing companies (Barnhart and PGRD, 2008). In this context, even successful approaches and methods in production were copied in other areas, and gradually, lean production and manufacturing have been expanded to service and administrative activities. With the expansion of global supply networks and international

supply chains, the issue of the lean supply chain has also been raised, in which improvements are mainly created in the physical flows and related information flows (Hohmann, 2012). Nowadays, the efficiency of the lean approach has been proven in all manufacturing and service companies seeking to improve their status, especially in improving their manufacturing functions. Lean concepts and tools help companies improve their productivity, cost, reliability and profitability. In addition, in promoting employee morale, long-term profitability growth and the fulfillment of many other goals play an important role (Cooper et al., 2006).

Although the principles and tools of lean concept are fundamentally based on the automotive industry, but as many scholars argue, its implications in other sectors, including the service sector and public sector organizations, have increased around the world especially in recent years (Hanna, 2007); Radnor and Bucci, 2011). Studies show that 12 percent of American financial institutions use lean principles. Institutions that have adopted a clear program in certain business areas have seen 40-20 percent lower operating costs over the next 12 to 18 months. In the health sector, there is also a decrease in waiting time (91%), an increase in access to services and manpower, namely physicians and health personnel (from 5 to 65%). In the public service sector, for example, the Florida Tax Administration has seen an increase of 93% in service satisfaction and a twofold increase in tax collection for three consecutive years (Dora et al., 2013). Carmichael et al. (2011) have recently shown the application of lean principles and concepts in order to reduce waste in the banking industry, especially with the aim of more resistance to the adverse effects of economic crises (George and George, 2003). Radnor and Bucci (2011) also reviewed the implementation of lean methodology at UK Business schools and universities. The results of this study have shown that the application of lean principles and tools, mainly as a result of government budget cuts in higher education, initially causes the outdated and old processes to be changed and subsequently improves the performance of this. Piercy and Rich (2009) have also shown a lean approach to improving performance and increasing final customer satisfaction at a telephone service center.

But can lean tools help improve the research and development and innovation functions of an organization? Several studies have shown that in recent years the research and development as a non-industrial and non-productive area has been seen the application of the principles and concepts of a lean approach to increase efficiency and reduce cost and waste. For example, Hanna (2007) states that by using lean principles and concepts in the field of pharmacy, the time taken to record all the inventions and products from the research and development activities of the companies surveyed has been reduced by about three years. Also, a 46 percent reduction of the non-added-value activities (using value-stream maps) has been observed. Effective application of lean principles in Sandia National Laboratories in New Mexico has also led to increased quality, cost reduction, reduced project completion time and productivity (Dora et al., 2013). According to Tatham and Worrell (2010), the implementation of lean thinking in an indeterminate environment of research and development in the UK defense sector has created a high potential for reducing costs.

Despite the above studies of the positive impact of lean principles and tools in research and development and innovation, the implementation of lean thinking in innovation management has not yet been systematically implemented. For example, investigations by Schuh et al. show that out of the 143 companies active in the German manufacturing industry only a third are systematically involved in identifying waste in the product development process. The differences between the lean concept of producing and constructing a classic with a lean concept in research and development are largely the cause of this issue. For example,

the uncertainties that exist in processes or the limitation of the automation of research and development processes require specific requirements for the implementation of lean thinking in the field of research and development (Sehested and Sonnenberg, 2010).

One of the best approaches to overcoming the specific requirements of implementing lean thinking in the field of research and development and innovation is the exploitation of the key capabilities of organizations in this field. At the same time, research and development and innovation have their own specific waste areas, and the selection of appropriate tools to produce lean processes with respect to key organizational capabilities and their specific losses can be effective the most for the organization. As was seen in past reviews, most of the studies in this area have identified specific waste of research and development and a limited number of articles devoted to the use of lean tools to improve research and development and innovation.

In the meantime, the key capabilities of organizations for research and development and innovation are not being considered in providing lean innovation solutions. This paper attempts to emphasize the key capabilities of research and development and innovations organizations that distinguish them with other limited organizations of production and manufacturing, and by combining these capabilities with these two issues, namely, the specific waste of research and innovation, and the tools that are most relevant to this field, more effective and diversified solutions compared to previous studies for lean research and development and innovation. For this purpose, the principles and concepts of the pure approach will be reviewed in the second part of this article. The third part is devoted to research and development and lean innovations. In this section, waste areas in the research, development and innovation environment are investigated. After reviewing the lean tools for research and development and innovations, lean innovation strategies based on the key capabilities of innovative organizations are presented. In the end, the most important results and findings of this study will be reviewed.

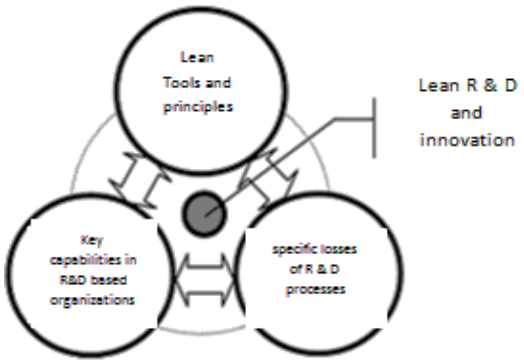


Fig. 1. Mutual interaction between lean tools and losses in R&D based organization.

2. Principles and Concepts of Lean Approach

According to Taiichi Ohno's idea, the founder of the Lean Approach, the focus of the Toyota automobile company was to "completely eliminate waste", and waste is said to be all that prevents the flow of material from raw material to finished product (Mitchell, 2004). In other words, the waste, which is called in the Japanese language of Muda, is a collection of activities that are not valued by the end-customer and the customer is reluctant to pay for those activities (Barnhart, 2016): waste caused by excess inventory; waste due to transportation; waste due to defective parts; process losses; waste due to waiting time and unemployment;

waste caused by excessive movements; waste due to excess production. Accordingly, lean thinking can be summarized in five principles.

2.1. Identify the value

The basic starting point for lean thinking is the value that the final consumer determines and the manufacturer must place in the product provided to the customer. By identifying the desired characteristics of the customer in the form of a definition of value, in fact, waste (Mudas), which is a collection of unnecessary actions or undesirable features from the customer, are also identified and their elimination of the production process and the realization of lean production is provided. Validating and revising a value is a continuous activity that should be done through continuous communication with customers.

2.2. Identification of the flow of value

Identifying the total value flow for each specific product, and sometimes for the family of each product, is the next step in lean thinking. The set value flow is a set of all necessary actions for a given product, this includes all the processes of product and service production, from the idea to the arrival of the product and services into the market. The most important technique for identifying the flow of value is the drawing of a flow chart, in which all the necessary actions for designing, ordering and building a particular product are shown. Generally, in the course of the flow of value, there are three types of activities: (1) activities that are clearly value-creating; (2) activities that are not value-creating but are inevitable due to technical knowledge and production assets. (First type Mudas); (3) Additional activities that do not create any value and can be immediately eliminated (second type Muda).

2.3. Creating an uninterrupted movement in the flow of value

When the value is determined precisely and the pure economic enterprise maps the flow of a given product and removes wasteful steps, then comes the next step of lean thinking, that is, in the sense of moving the value-creating steps. Movement is the fulfillment of progressive tasks during the flow of value so that a non-stop product, without waste, and without postponement, from design to market, from order to delivery, and from raw materials reaches the buyer's hands. In summary, the way to move the value is to: (1) determine and focus on a real goal, that is, focusing on a particular plan or a particular order or product itself from the beginning to the end; (2) ignoring the traditional boundaries of occupations, paths Job, functions and organizations; (3) reflection of work tasks in order to remove Mudas..

Where d_2 is a control chart constant and it depends on the number of samples used for calculating MR, and in the case of two observations, as in this work, d_2 =1.128.

2.4. Allowing the customer to extract the value from the producer

Extraction means that no company produces goods or services beyond the flow unless the customer wants it at the bottom of the flow. The best way to understand the logic behind extraction is to first go to an actual customer who wants an actual product, then go back and examine all the steps that need to be taken in order to get the product to reach the customer.

The use of a timely production technique (JIT) is one of the techniques that allows a customer at any stage of the value stream to extract the value from the producer

2.5. Pursuit of Perfection

After the organization correctly identified value and mapped out the flow of value and created an uninterrupted flow of value, and customers of each stage of the stream were able to extract value from the manufacturer, it is time to address the fifth principle of lean thinking, that is, the pursuit of perfection (Mirmohammadi et al., 2017). Perfection is the complete elimination of Muda so that all activities carried out during the flow of value are worthwhile.

3. Lean research, development and Innovation

In order to stay competitive, R&D has to cope with increasing level of dynamics in more and more complex product and project systems. In this regard, Innovative processes play a key role in achieving organizations' long-term goals. The necessity of strategic agility and need to create value compel companies to develop their innovative processes (Womack and Jones, 1997). Lean research, development and Innovation with the strengthening of customer values and the delivery of more innovative and high-quality products to the market at a speed of at least twice the speed of the rivals, has advantages as many other concepts and lean tools for companies (Cooper et al., 2006). The Lean Innovation System represents the systematic interpretation of Lean Thinking principles regarding product or process innovation and development. In fact, the goal of lean innovation is to create a noticeable distinction in products while reducing the deployment of resources by employing the principles of lean thinking for research, development management (Sehested and Sonnenberg, 2010). But it should be noted that the goals of research, development and production are fundamentally different. Manufacturing works by modifying or assembling physical objects (raw materials and components) and ultimately prepares an integrated and valuable product for sale or purchase. A successful manufacturing process is a process in which a product is produced frequently and periodically and sold at a certain profit. But research, development usually deals with the creation and testing of new ideas and the construction and integration of the results of experiments and ultimately provides an integrated and valuable collection of knowledge for other uses. This collection may be a new object or a prototype of a product that is being built and sold at a certain price and profit. It can also be a new process that should be developed or even a new technology used in production or knowledge that is used in other business functions (such as research and development, marketing, etc.) to meet business needs. In any case, the purpose of research and development is innovation (Frascati, 2002).

According to the OECD Manual (2005), research, development refers to all activities that (a) contain innovations; and (b) completing those activities will lead to technical progress. Basically, research, development activities can be classified into three main categories: fundamental research, applied research and experimental development Sharma and Thomas (2008). Innovation also refers to the implementation of a product (product or service) or a new or fully upgraded process, a new marketing method, or a new organizational approach in business, organization of work or external communication. Activities related to innovation are all the scientific, technological, organizational, financial and commercial stages that are aimed to carry out innovation or yield innovation, directly.

Some of the innovation-related activities are innovative, but some of these activities are not innovative by themselves, but necessary for innovation. Activities related to innovation also include research and development activities that do not directly relate to the development of a particular innovation. According to the Oslo Manual, four main types of innovation can be cited: Product Innovation, Innovation in the Process, Marketing Innovation and Organizational Innovation (Johnstone et al., 2011).

The complexity of the innovation process and the barriers to communication or distance that are inclusive with globalization, make management of innovation projects more difficult (Khademolqorani, 2018). Therefore, the application of lean principles and concepts in this field can be considered an attractive subject for review. But what matters is the difference in the nature of research, development and innovation with classical production, which brings it closer to the field of services and away from manufacturing and production. Therefore, in applying lean principles and concepts to the field of research and development, more practical examples and experiences of the application of this approach in service areas should be considered.

Also, specific losses of research, development and innovation should be identified. Research and development organizations have good key capabilities that can be properly strengthened with the help of lean tools and can be used to manage and reduce waste and increase the efficiency of the research, development and innovation process. So simultaneous attention to waste, key capabilities and lean tools that are most effective in research, development organizations, provides a comprehensive approach to lean innovation (Figure 1).

3.1. Areas of waste in the research, development and innovation environment

3.1.1. Definition of value

As noted, value from the customer perspective is a basic element of lean thinking. Despite the many differences between research, development and classical production and manufacturing, the fundamental difference lies in the determination of "value" which will be the most important subject to consider in applying lean concepts and tools in the field of research and development.

Schuh et al. (2008) believes that the basic element of lean innovation is value system, which is the basis for designing the flow of value in innovative and developmental projects. The value system defines, organizes and prioritizes values in an innovative project. These values are defined by all stakeholders associated with an innovation or research and development process, such as domestic and foreign customers, according to the company's strategy and culture (Sehested and Sonnenberg, 2010).

3.1.2. Teamwork communication and work

Considering the nature of the research and development activities, which rely on studies by experts, effective communication flow within teams and among teams in different sectors is another issue, which if not dealt with properly, could render losses in research, development, and innovation activities (Schuh et al., 2011).

3.1.3. Bringing activities to conclusion

Research and development activities are likely to result in failure due to their risky nature. However, good processes that utilize high participation of people reduce the likelihood of failure in activities. On the contrary, weak processes are considered as obstacles to innovative activities. The failure of activities is a negative factor for creativity and innovation, thereby, improving the processes can be considered as a factor in reducing the impact of the opposing causes of innovation.

3.1.4. Time (and cost) of product delivery to the market

One of the challenges facing research, development is the ability to create new innovative products in the market at a cost and speed that can accelerate the growth of the organization. This is while individual moves in the form of unnecessary extra work, unnecessary loops, rework, travel between offices, holding unnecessary meetings, deploying product development teams at different locations, rather than collaborating in a place can increase the time of doing things. Also, people, systems and tools that are waiting or delaying in non-traffic processes, waiting for the approval or confirmation of one step to further develop or carry out the next stage of the innovation process, stopping projects, and waiting for data or modifying the results of upstream processes can increase the time and, consequently, the cost of research, development and innovation (Jafari et al., 2009).

3.1.5. Surplus or extra production

The exact matching of customer needs with the functions included in the product is one of the most important challenges. Shaw et al. (2008) showed that, according to 141 research, development department managers, their customers use only 70% of the functionalities and performance characteristics of the product. Therefore, 30% of the functions that are not used by customers, based on the producer's mindset, are included in the product. This 30% additional function, which shows the difference between actual customer requirements and the functions presented in the product, is called over-engineering or extra production. Therefore, it seems that accurate determination of values from the customer perspective and subsequent implementation of them in the process of product development is one of the fundamental principles of successful research and development. Additional technical functions and characteristics, usually leads to increased time and cost of research and development. Extra or additional production involves collecting, storing and maintaining too much information, processing data on a routine schedule regardless of current demand and working on innovative projects that are not part of the production cycle of a product, building prototypes or designing preliminary studies to a higher detail than necessary to make decisions is another example of surplus or extra production.

3.1.6. Data and information

Data and information are an important part of the research, development and innovation process and in different ways can be a factor in generating waste in this process. Over processing, gathering unnecessary information, incomplete or inaccurate information, building

prototypes or beginning a test without the necessary data accuracy are waste samples in the process of research, development and innovation due to weakness in data and information (Jafari et al., 2009).

3.2. Lean Tools and Techniques for research, development and Innovation

3.2.1. Knowledge maps

Knowledge is one of the key elements in research, development, and innovation organizations. Therefore, knowledge management in such organizations is very important. Knowledge map is one of the tools for knowledge management. A knowledge map is in fact the graphical representation of inter-organizational information exchanged between individuals. The process of knowledge mapping can be defined as a process of drawing, evaluating and communicating information, knowledge, potentials and capabilities of the individuals and groups of an organization. There are various techniques available for this purpose, including information flow analysis, social network analysis, process knowledge drawing and functional knowledge mapping (Cañas et al., 2009). The most important advantages of knowledge maps are: Identification and attention to knowledge assets, discussion and negotiation over their importance; encouragement to re-use the knowledge already available within the organization and prevention of re-invention; identification of islands of expertise and discovery of effective and emergent groups; reduction of the communication obstacles for experts; improvements of customer responses, decision making and problem solving; preparation of an inventory and evaluation of intellectual assets; preparation of information for designing knowledge architecture; discovery of key resources, opportunities and constraints. A complete comparison of the characteristics, tools and approaches related to each one and the framework for selection of the appropriate technique for an organization is presented by Cañas et al. (2009).

3.2.2. Designing experiments

One of the lean manufacturing tools, and in particular Six Sigma, is the design of experiments that have been shown to be used to improve research and development activities (Zhan, 2005). For example, Jan shows that the use of designing experiments reduced the simulation activity time and, as a result, improved the activity (Crow and Bozeman, 1998). The design of experiments is used to control, predict and optimize complex processes to examine the role of experimental factors on any output impacts of a process. Therefore, this tool plays an important role in the development of complex manufacturing processes, new products, and process improvement (Rother and Shook, 2003).

3.2.3. Modeling and simulation

The necessity of reducing time and cost by modeling and simulation has increased the attractiveness of the development of predictive models before making the prototype. These models, which can be used in the areas of design, quality and construction, have helped to increase the accountability of companies (Rother and Shook, 2003).

3.2.4. Research work cells

Another way to implement lean principles in research and development units is to use research work cells to draw workflow in a laboratory or research center. By facilitating the flow of knowledge, experiences, personnel, materials and warehouse, while the lost space is reduced, high performance is also achieved at the workplace. With this approach, the time taken to search for parts or tools is reduced and safety increases. Research work cells employ the same traditional concepts of pure cell work as the 5s (organization, order, discipline, purification, and standardization) (Rother and Shook, 2003).

3.2.5. Value flow plot

Value Stream Mapping (VSM) is one of the tools that can be used in research, development and innovation processes, because it simplifies and refines complex systems. The value stream refers to all actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product. This process involves: 1) the production flow from raw material into the arms of customers; 2) the design flow from concept (idea) to the introduction of the product. In other words, the flow of value is both the flow of materials and the flow of information, both of which are equally important. This technique tries to capture all processes using standard signs and signals. After plotting the current flow in the form of the "present state map", we can provide the desired flow picture by deleting the non-valuable steps in the form of a "future state map", and thereby move towards getting the processes and the system lean (Rother et al., 2003).

3.2.6. Cause and effect graph

A cause and effect graph or fishbone diagram, also known as the Ishikawa chart, was devised in 1960 by Professor Ishikawa of the University of Tokyo. This chart helps identify the causes of a problem. Only by identifying the underlying causes of a problem can the problem be fixed forever. Drawing the cause and effect graph helps people involved with a problem to get the same understanding of the problem, develop the possible solutions, and apply the knowledge of all the team members. In the first step, it must be determined what the problem is, what it involves, when and in what place it occurs.

In the second step, the main potential causes that cause this problem are identified, such as individual, environmental factors, process and method factors, material and equipment factors, and management factors. In the third step, the underlying causes of occurrence of the root causes through the brainstorming and gaining opinions and views of all people involved with the problem are identified. In the fourth step, the obtained chart is analyzed and decision or revision on the accuracy or importance of the identified causes is made. Fishbone charts or cause and effect diagrams should be developed by the team of people involved with the problem and updated if needed. It is better to subordinate each underlying cause to a root cause, but overlapping of the underlying causes may also occur.

3.3. Lean innovations based on key capabilities of innovative organizations

Research, development and innovation organizations have the capabilities that the application of the fundamentals and tools to those capabilities can have far more impact on efficiency gains. In other words, choosing innovative solutions and their appropriate tools in research and development organizations can be more successful with these capabilities.

3.3.1. Selection of the most important problems to solve

In complex environments, there are many problems to solve, and choosing the most important ones to resolve will have many benefits. One of the most important capabilities of research and development and innovation compared to the classic production is that in the research, development phase, you can select a subject or issue that is more valuable from the customer's point of view to solve. Choosing issues and, consequently, ideas for solving problems provides a greater potential for improvement or value creation for the organization, while choosing solutions to improve the production process or delivering the product to the market is not as effective. In other words, more lean tools in the early stages, namely the finding of problems (customer demand) and the formation of ideas and solutions (research, development and innovation), will create the potential for greater improvement for the organization (Womack and Jones, 1997).

Targeting the root causes of problems using lean tools, such as a cause and effect graph or fishbone diagram, provides a deep insight into the issues to avoid choosing artificial solutions or cramming them (Schuh et al., 2011). The preparation of a value system also makes the requirements clear and tailors them to specific needs in the form of a hierarchy of objectives. The benefits and goals associated with the product are also prioritized and can be presented at any time for all stakeholders (Sehested and Sonnenberg, 2010).

3.3.2. Interaction opportunities

Quantitative innovations are made by individuals who work alone, and many innovative solutions come to mind by looking at possible improvements in previous solutions. Therefore, interactions, networks and teamwork should be encouraged for more innovation. Many of the lean solutions result from teamwork, joint education, and non-personal thinking (Schuh et al., 2011). Among the lean tools that can help to strengthen this key feature in innovative organizations, research work cells can be mentioned. By using research work cells, a more fluid flow of work, higher performance, and easier flow of knowledge and personnel experiences are possible. Knowledge maps also help improve the communication of people working in the same field and promote their collaboration (Rother and Shook, 2003).

3.3.3. Capacities or resources available for new experiences

Many ideas need to be strengthened and developed before their value can be evaluated. There are several ways to do this. To allocate a part of the time for employees to search and discover new issues or to allocate funds for this purpose, is one of the capabilities of innovative organizations based on research and development (Schuh et al., 2011). This feature can be strengthened by design of experiments (DOE). Design of experiments to examine the role of

multiple empirical factors on each of the output impacts of a process and plays an important role in the development of complex processes, new products, and process improvements. This tool is used to control, predict and optimize complex processes in labs and has shown its effectiveness. Knowledge maps that increase understanding of the complexity inherent in scientific research can be useful in strengthening new ideas (Rother and Shook, 2003).

3.3.4. Simplifying processes

Simplifying the review and testing processes, implementing single-part flows rather than doing batches and using related technologies to monitor pieces and components in order to minimize latency are the most basic steps that are taken to streamline the research, development and innovation processes, through reducing the time and cost of delivery. Information from the process of developing a knowledge map can be useful for eliminating time waste by avoiding duplication. (Source) The necessity of reducing time and cost has increased the use of modeling and simulation so that the development of predictive models for design, quality and construction before the production of prototypes are considered and using this tool will increase the company's accountability. Research work cells also help reduce workplace waste, reduce search time to find pieces and tools (Rother and Shook, 2003).

3.3.5. Avoiding production and engineering surplus

Avoiding extra production and engineering with the help of tools such as value stream mapping (VSM) (Sehested and Sonnenberg, 2010), and product development structures (Jafari et al., 2009) that differentiate the steps and activities of value from non-valuable steps and activities.

3.3.6. Data and information management

Research, development and innovation organizations usually have a high level of familiarity with information and communication technologies. Therefore, standardization of different data modeling methods as well as standardization of the data exchange process can help to reduce the losses caused by data and information problems.

Finally, proposed framework for implementation of lean principles in innovative and R&D based organizations are summarized in Table 1.

Table 1. Proposed framework for implementation of lean fundamentals and tools in research and innovation organizations.

Losses areas in the R&D and innovation environment	Organization's key features which are based on research and innovation	Lean principles and tools
Definition of value	Choosing the most important problems to solve (Schuh et al., 2011)	Cause and effect chart (Schuh et al., 2011)
Communication and Teamwork	Existence of opportunities for interaction between individuals and departments (Schuh et al., 2011)	Research Cells (Rother and Shook, 2003) Knowledge maps (Rother and Shook, 2003)

Activities with no results	Capacities and resources available to experience new opportunities (Schuh et al., 2011)	Experiment Design (Rother and Shook, 2003) Knowledge maps (Rother and Shook, 2003)
Time (and cost) of product delivery to the market (Jafari et al., 2009)	Simplifying processes (Rother and Shook, 2003)	Knowledge maps (Rother and Shook, 2003) Modelling and simulation (Rother and Shook, 2003) Research Cells (Rother and Shook, 2003)
Surplus or extra production (Jafari et al., 2009)	Avoiding from excessive engineering	Drawing the value flow (Sehested and Sonnenberg, 2010) Product development structure (Jafari et al., 2009)
Weakness or Inaccuracy of Information (Jafari et al., 2009)	Managing data and information	Standardization of data modeling (Jafari et al., 2009) Standardization of the data exchange process (Jafari et al., 2009)

4. Conclusion

Although research and development activities such as production and manufacturing activities are not standardized, but recent studies have shown that a pure approach can also help improve the performance of research and development organizations. In this paper, a framework for the implementation of lean thinking in the field of research, development and innovation was presented, in which the identification of specific losses of research and development and the exploitation of key capabilities of research and development organizations in combination with principles and Lean tools, give a comprehensive approach to lean innovation. The most important areas of waste in the research and development environment are the definition of value, communication and teamwork, the failure of the activities, time (and cost) of delivery to the market, surplus or additional production, data and information used. On the other hand, some of the most important lean tools and techniques that fit well with research and development environments include knowledge maps, designing experiments, modeling and simulation, research work cells, value flow plots, and causing graphs. These tools, combined with the key capabilities of innovative organizations, are as follows to help eliminate waste and thus mitigate the research and development process:

- Choosing the most important problems to solve: By using the cause and effect graph, you can largely eliminate the losses in the value definition.

- Interaction Opportunities: With the help of research working cells and knowledge maps, we can limit the losses of communication and teamwork.

- Capacities and resources available for new experiences: Research and development organizations and innovation have the capacity and resources to explore and discover new things. If these capabilities are combined with tools such as experiment design and knowledge mapping, it can control wastes rendered by inconclusive activities in such organizations.

- Simplifying processes: Research, development and innovation processes are inevitably complicated, which is a factor in increasing the time (and cost) of delivering products to the market. At the same time, there is the possibility of simplifying processes with the help of tools such as knowledge maps, modeling and simulation, and research work cells in innovative organizations.

- Avoiding over-Engineering: With the help of tools such as value flow plots and product development structure, it is possible to avoid loss of extra or additional production.

- Data and information management: Data and information are one of the most important requirements for Research, development and innovation activities. Innovative organizations have the ability to eliminate data loss or data defects by standardizing data modeling or the process of data exchange.

The proposed framework in this paper can be developed by identifying a wider range of losses in R&D processes and strengthening the capabilities of innovative organizations in combination with the expanding tools of the lean concept.

References

Barnhart, T., and PGRD, G. R. D. (2008). Lean in R&D: the surprising fit. Future State Spring, 1-3.

Barnhart, T. M. (2016). Creating a Lean R&D System: Lean Principles and Approaches for Pharmaceutical and Research-Based Organizations. Productivity Press.

Cañas, A. J., Carff, R., Hill, G., Carvalho, M., Arguedas, M., Eskridge, T. C., and Carvajal, R. (2005). Concept maps: Integrating knowledge and information visualization. In Knowledge and information visualization (pp. 205-219). Springer, Berlin, Heidelberg.

Carmichael, Ch., Mullen, S., & Mante, E.J. (2011). Banking Industry Leverages Lean Principles to Eliminate Waste, a White Paper. USA: North Highland consulting.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2006). Portfolio Management for New Product Development.

Crow, M., & Bozeman, B. (1998). Limited by design: R&D laboratories in the US national innovation system. Columbia University Press.

Dora, M., Kumar, M., Van Goubergen, D., Molnar, A., & Gellynck, X. (2013). Operational performance and critical success factors of lean manufacturing in European food processing SMEs. Trends in Food Science & Technology, 31(2), 156-164.

Frascati, M. (2002). Proposed standard practice for surveys on research and experimental development. Paris: OCDE.

George, M. L., & George, M. (2003). Lean six sigma for service (p. 273). New York, NY: McGraw-Hill.

Hanna, J. (2007). Bringing' Lean' Principles to Service Industries. HBS Working Knowledge.

Hohmann, C. (2012). Lean management (Doctoral dissertation, Ed. D'Organisation Eyrolles).

Jafari, M., Akhavan, P., Bourouni, A., & Roozbeh, H. (2009). A Framework for the selection of knowledge mapping techniques. Journal of Knowledge Management Practice, 10 (1).

Johnstone, C., Pairaudeau, G., & Pettersson, J. A. (2011). Creativity, innovation and lean sigma: a controversial combination. Drug discovery today, 16(1-2), 50-57.

Khademolqorani, S. (2018). A hybrid model for the prioritization of municipal projects in Iran. IJOAS, 1(12), 1-10.

Mirmohammadi, S. H., Babaee Tirkolaee, E., Goli, A., & Dehnavi-Arani, S. (2017). The periodic green vehicle routing problem with considering of time-dependent urban traffic and time windows. Iran University of Science & Technology, 7(1), 143-156.

Mitchell, T. P. (2004). Principles of Lean Thinking: Tools & Techniques for Advanced Manufacturing. National Research Council Canada.

Organization of Economic Cooperation and Development (OECD). (2005). Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual, 3rd edition. Paris.

Piercy, N., & Rich, N. (2009). Lean transformation in the pure service environment: the case of the call service centre. International journal of operations & production management, 29(1), 54-76.

Radnor, Z., & Bucci, G. (2011). Analysis of lean implementation in UK business schools and universities. Association of Business Schools, London.

Rother, M., & Shook, J. (2003). Learning to see: value stream mapping to add value and eliminate muda. Lean Enterprise Institute.

Schuh, G., Lenders, M., & Hieber, S. (2011). Lean Innovation–Introducing value systems to product development. International Journal of Innovation and Technology Management, 8(01), 41-54.

Sehested, C., & Sonnenberg, H. (2010). Lean innovation: a fast path from knowledge to value. Springer Science & Business Media.

Tatham, P., & Worrell, D. (2010). Lean Thinking in an Uncertain Environment: The Implications for UK Defence Acquisition. International Journal of Defense Acquisition Management, 3.

Sharma, S., & Thomas, V. (2008). Inter-country R&D efficiency analysis: An application of data envelopment analysis. Scientometrics, 76(3), 483-501.

Womack, J. P., & Jones, D. T. (1997). Lean thinking—banish waste and create wealth in your corporation. Journal of the Operational Research Society, 48(11), 1148-1148.

Zhan, W. (2011). Reducing simulation time using design of experiments. International Journal of Lean Six Sigma, 2(1), 75-92.