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The Application of Efficency Improvement Methods in Manufacturing and Service Sectors Through Business Intelligence Systems – A Review

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Abstract – The paper presents the tools for improving efficiency, from its historical beginnings to modern business intelligence systems, furthermore includes good practices and case studies that illustrate both the potential and the benefits of lean methodology. We review the main characteristics of the lean methodology and the most basic components that can be applied by an organizational culture to improve processes. As the case studies show, these methodologies can contribute not only to optimising the operations of manufacturing firms, but also to improving different corporate cultures. The importance of the data analysis tools available through modern technology is also a key focus of the study, and these are increasingly being used in lean methodologies. These software tools are essential to help in collecting and analysing data generated by the application of efficiency improvement methods, as well as in plan-actual comparisons. The study emphasises the importance of continuous improvement of business processes, focusing on the synergies between modern technologies and proven efficiency improvement methodologies. The implementation of these methods is crucial for the operation and increasing the profitability of SMEs at the dawn of the 4th industrial revolution.

Keywords – Lean, Business intelligence, Efficiency, Management systems, Case studies

1 Introduction

The emergence of methods to measure and improve efficiency is not a new phenomenon, as such tools were already used in ancient Greek and Roman societies. During the period of the great geographical discoveries (15th-18th centuries), the competition for the possession of the world's wilderness forced the efficient serial production of galley ships. In the early

1800s, the emergence of manufacturing technologies, then considered revolutionary, gave a huge boost to production. These included mass production, rudimentary automation and the emergence of interchangeable parts (Koloszár and Pankotay, 2018).

The study aims to show how efficiency improvement methods and modern business intelligence systems are linked, and what good practices support the introduction and use of lean methods. The literature review will cover the key principles of what lean is and what it means. The main components of lean are described: JIT (Just-In-Time), Kaizen, VSM (Value Stream Mapping), MRP (Material Requirement Planning), Kanban, 5S. Nowadays, big data makes it a priority to manage these tools as efficiently as possible across different departments. Technological advances have enabled the tools for efficiency improvement to be extended to include business intelligence (BI) applications. These softwares are used for centralised data collection, which can be supported by a variety of custom-developed tools. The data to be analysed can be accessed by the relevant departments and management from the centralised database, making modern business intelligence systems an essential part of efficiency improvement. The paper includes good practices and case studies that illustrate both the potential and the benefits of lean methodology.

2 Research Methodology

The research is based on studies, articles and case studies on corporate efficiency improvement, including lean methodology. Google Scholar, Science Direct and Web of Science were used to collect the relevant literature. We applied the following keywords "Lean", "Lean manufacturing", "Lean management", "Efficiency improvement", "Business Intelligence" and "Business Intelligence Systems". Case studies were selected to cover the widest possible range of activities in both the manufacturing and service sectors. This also emphasises the universal applicability of efficiency improvement methodologies. A similar diversity can be observed in the geographical distribution of the case studies.

3 Overview: Methods for Improving Efficiency

It is not a surprise that the Japanese are at the forefront of revolutionising manufacturing processes, as Toyoda Sakichi is credited with inventing the first automatic loom, and at the same time created the so-called Jidoka concept. The idea is that if the loom detects any fault, it stops immediately to prevent further damage. This method was later incorporated into the Toyota Production System (TPS), a pioneer of modern efficiency improvement systems. The next very important milestone was the introduction of the Ford Model T in 1908. This was the first time that the manufacturing process used the assembly line, which required individually designed internal systems. This is one of the reasons why Highland Park is known as the birthplace of Lean production. Toyoda has constantly studied and analysed the industrial

processes in the USA, with particular emphasis on mass production and quality control. In the early 20th century, Gilberth and his wife studied work psychology and motion analysis to improve production efficiency, which was perfected during the Second World War in aircraft production (Brian, 1992).

Sampling quality control was introduced by Deming in 1940, but was not successful in the USA. In 1951, he met Ohno, then head of production at the Toyota factory, who optimised the method and created the principles of the Toyota Production System (TPS). Taylor is considered the father of modern corporate efficiency, and his principles, formulated in his 1911 book, are known as "Taylorism". His work focused on increasing the productivity of physical workers. He placed great emphasis on measuring the time of processes and reducing them in an optimal way. He took unnecessary movements out of the process and arranged the rest in a logical sequence. He believed that if work processes were reorganised according to their principles, this would lead to higher productivity, which would have a positive effect on both managers and workers (Taylor, 1911). The dissemination of Taylor and Deming's methods is linked to Japan and the Toyota industrial company. It was TQM (Total Quality Management) and TPM (Total Productive Maintenance) that laid the foundations for the TPS system. It is important to mention the Deming cycle, which consists of 4 steps: Plan, Do, Check, Act. The author has always tried to draw attention to the circular nature of the process and the importance of its repetition. Deming emphasized that the repetitive application of the method leads to continuous improvement and higher quality level in production, in which the limited skills of workers can be developed. Womack and Jones (2009) in their study also emphasized the importance of circularity. The goal of the Toyota Production System (TPS) is "to create a production system that can respond flexibly to changes in cus-tomer needs. Costs are reduced by identifying and eliminating losses" (Kosztolyányi, 2015).

In fact, lean management has evolved from Toyota's production system. The word was first described in a paper by John F. Krafcik (1988), a former strategic developer at Ford Motor Company and now CEO of Waymo Inc. The increase in the competitiveness of the Japanese factory attracted the interest of researchers in Western countries, but it took quite a long time before they were able to implement it fully in their own systems (Hammerl et al., 2021). Two basic tenets of lean are respect for people and elimination of waste. Respect has a completely different meaning in Japanese culture, so the approach had to be adapted to Western production characteristics. One of the driving forces behind the philosophy is the power of the workers that fuels the lean. One of the critical points is to build on the ideas of the employees, as they are the ones who are closest to the various work processes. However, it is difficult to embed such a mindset in a society where brainstorming at the operator level is not common (Sayer and Williams, 2012).

The book by Womack and his colleagues (1990) was the real breakthrough in the adoption of the lean approach in Western organisational culture. It explored the differences between the US, European and Japanese car markets. It was also the time when the term "lean manufacturing" was introduced. The philosophy explores how to acquire the capacity for continu-

ous improvement and development. It shows how processes can be designed to best match real customer needs and how to create a quality-oriented, yet flexible organisational culture that focuses on real value creation by integrating supply chain actors. The application of lean principles in today's competitive world is crucial, but their effectiveness varies between organisations and sectors. According to Dora et al (2014), the size of the company, its structure, corporate culture, decision making processes and use of resources are all factors that influence the adoption of a lean approach (Koloszár and Pankotay, 2018).

Gupta et al (2013) have discussed in detail the key elements of lean that are used to eliminate losses. In the following, the tools that are essential for understanding this approach (JIT, VSM, MRP, Kanban, 5S, Waste elimination, Kaizen) are presented. Kaizen will be described in more detail later.

1. Just-In-Time (JIT)

JIT is a tool for lean manufacturing, based on the optimisation of process flow over time for successful design and end-product manufacture. Karlsson and Ahlstrom (1996) formulated the essence of JIT as the supply of each manufacturing process with the required parts, in the required quantities and at the right time. According to the JIT principle, the aim is to have parts available for each process exactly when they are needed. According to Shah and Ward (2003), JIT have a positive effect on efficiency.

2. Value Stream Mapping (VSM)

VSM is a graphical tool that can be used to scan and analyse workflows and isolate those activities that add or do not add value to the final product. Rother and Shook (1999) studied a VSM in which the current state of the value stream of a product was analysed. They concluded that the redesign process produces an improved version of the value stream, based mainly on reducing losses and lead times and improving material flow. Pattanaik and Sharma (2009) drew attention to the fact that the analysis of production processes is essential to identify and reduce non-value adding activities. This helps to minimise waiting time, queuing time, moving time and other similar losses.

3. Material Requirement Planning (MRP)

MRP is a tool that converts the specifications for the end products into a detailed schedule of raw materials. Inaccurate planning of raw material requirements can lead to a reduced productivity or, conversely, excessively high stock levels. As Rajeev (2008) has argued, MRP is a tool for estimating the demand for raw materials and finished goods as accurately as possible. In his study, Petroni (2002) concluded that the implementation of MRP systems poses a number of problems. He pointed out that management, integrability and data accuracy have a strong impact on the effectiveness of the use of such systems.

4. Kanban

Kanban is a logistics system in which the movement of materials between workstations is based on instruction cards. Only a given quantity of parts is allocated to the production line, so there is no excess storage of parts on the

production floor. This is a basic principle of the Kanban system. Alvarez and his colleagues (2008) conducted a case study to investigate the impact of the combination of VSM and Kanban on production. They concluded that although the joint implementation of the two methods is a major task and a lot of work is involved to coordinate them, the synergies in terms of process optimisation can lead to significant efficiency gains. Abdulmalek and Rajgopal (2007) developed a model to compare the pre- and postimplementation states of Kanban in a simulation environment. They concluded that the preimplementation state was characterised by a high inventory ratio and lower value added. The implementation of Kanban plays a key role in the development of better product and raw material flows.

5. 5S

   5S is a systematic methodology for a productive work environment originating from Japan (Gapp et al., 2008):

   1. Sorting out what is necessary and unnecessary in the workplace (Sort/Seiri).
   2. Optimal organisation, marking and clear arrangement of things in the work environment (Set in Order/Seiton).
   3. Keeping the workplace and its surroundings clean and tidy (Shine/Seiso).
   4. Standardize processes (Standardize/Seiketsu)
   5. Make the results achieved sustainable (Sustain/Shitsuke)

6. Kaizen

The Kaizen philosophy was first defined by Imai (1986, 1997). The word is of Japanese origin, meaning development. Many authors have dealt with this very popular subject and have tried to explain it from different perspectives. In business environment, it is about the continuous improvement of processes, involving both managers and employees. According to Newitt (1996), Kaizen is a compound Japanese word derived from two kanji (Japanese letters). The first three characters, Kai, mean change, and the second part, ZEN, means good. Overall, it represents a philosophy that embodies the principle of continuous improvement or development (Lillrank and Kano, 1989). The first definition of Kaizen is based on the fact that the method is used in enterprises to facilitate the involvement of employees in process improvement (Elgar and Smith, 1994). According to Bessant (2003), it is important to involve physical workers in various development processes. Since they are the most familiar with the different operations, this method can achieve much greater efficiency gains. This finding is further supported by the case study of Malloch (1997). Kaizen is also often seen as an ethical force that workers find in themselves to voluntarily solve the daily problems that arise. This contributes to their finding value in the work they do (Styhre, 2001). Kaizen can therefore be defined as a principle of cooperation and development, which has a positive impact on society (Suárez-Barraza et al., 2011).

Specific research in Japanese companies has revealed many things about the understanding and implementation of Kaizen, including the

fact that its interpretation and application depends on the characteristics of each company. In their study, Brunet and New (2003) defined Kaizen as a continuous series of activities in which stakeholders play a specific role in identifying and implementing improvements that contribute to the achievement of corporate goals. The implementation of Kaizen ranges across a very broad spectrum, from incremental improvements to radical innovation. Hamel (2009) summarises the essence of the methodology in the most complex way. As the author puts it, Kaizen is much more than an event, as it is a philosophy and a way of thinking. It is the most critical tool for achieving strategic requirements and implementing value stream/process improvement plans in terms of breakthrough performance. The performance of process innovation has been investigated through empirical studies and it has been concluded that there is a very strong link between TQM and innovation. The empirical results thus show a causal relationship between quality performance and innovation performance (Prajogo and Sohal, 2003). There are researchers who believe that Kaizen is a term that is still evolving and thus means different things depending on when and in which company it is applied (Tozawa and Bodek, 2002). As with lean, the Kaizen process can be divided into 4 main components, which are characterised by the acronym PDCA (Plan, Do, Check, Act).

Plan

- The first step in the process is to analyse the current problems and conditions.
- The objectives for change must be defined.
- Define the processes that will lead to a solution.

Do

- The second step is to implement the plan.
- Small changes need to be tested.
- Data on the effectiveness of the changes should be collected.

Check

- The data collected need to be evaluated, with the help of the business intelligence systems mentioned earlier. In large companies, these tasks are performed by business intelligence experts, data analysts or data scientists.
- One of the core elements of the process is the identification of discrepancies between results and targets.

Act

- The solution must be standardised in order to be integrated into basic processes.
- Identify and define the next problem.

Then the cycle starts again. As the basic motive of the Kaizen philosophy is to become better/efficient in small steps, it is practically an iterative process.

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4 Business Intelligence Systems for Measuring Efficiency

The interpretation of BI that is still in use today can be linked to Howard Dresner, who says that business intelligence is "a set of methods and concepts that improve the decision-making process by using the so-called fact-based systems" (Cser et al., 2010, p. 39). Their application aims to support operational and strategic decision making as effectively as possible by using BI software to transform the raw data collected into useful information (Evelson and Nicolson, 2008). In a study, Loshin (2012) pointed out that BI can help transform information into important knowledge. According to Drótos (2015), the following components can be distinguished within business intelligence systems: source systems, data preparation methods, data storage implementation - data warehouse, data mining techniques, visualization tools and interfaces. The author sees the essence of BI systems as a tool that creates the possibility of "converting data from ERP (OLTP) and other source systems, arranging them in a new way, and then retrieving and analysing them in a goal oriented and user-friendly way" (Drótos, 2015, p. 15). This insight is also supported by the results of a study by Görcsi and co-authors (2019), in which they examined the Hungarian large enterprise sector and concluded that the main motivation for the introduction of BI systems is to replace reports that are prepared from different sources and in different formats, often manually. This facilitates and accelerates management decision support, which is nowadays very much needed in today's highly competitive market. The benefits of business intelligence systems have also been articulated by Popovič and colleagues (2012). These include faster access to information, easier query and analysis, interactivity, and easier process integration and data consistency.

Increased competition in the market requires continuous technological innovation by businesses. More and more firms are coming to the realisation that they need to keep pace with technological developments (Móricz and Drótos, 2019). In the 1990s, enterprise resource planning (ERP) systems were one of the most important technological innovations. They replaced solutions that performed only limited functions and enabled integrated data management across the entire spectrum of organisational structures (Drótos and Szabó, 2001). In the last decade, a new trend has started to emerge and business intelligence systems beyond the limits of traditional ERP solutions have appeared. In 2011, the introduction of BI software was already the top priority among Hungarian medium and large enterprises in terms of IT development (Drótos et al., 2012).

The literature identifies the primary benefit of business intelligence as supporting the achievement of various organisational goals by improving the quality of decision support (Visinescu et al., 2017). Effective decision support is a fundamental prerequisite for establishing and maintaining competitiveness. Business intelligence systems present relevant information to managers quickly and in a well-structured form. A number of studies have highlighted their positive impact on business performance (Aleš Popovič et al.,

2019), as well as on organisational competitive advantage (Wixom et al., 2008).

Business intelligence systems therefore provide the link between organisational efficiency tools (lean, Kaizen, etc.) and business management, by using the extracted data to produce dashboards (visual representations of key data for analysis on a page or screen) to support decision making.

5 Efficiency improvements based on case studies

The primary aim of lean thinking is therefore to identify losses and waste and to eliminate activities that do not add value to the final product. The tools provided by the lean philosophy are designed to permanently improve the processes used to create products or services. Lean was originally applied in industrial production (maintenance, quality control, logistics and design), but it has been discovered that it can also provide solutions for the service sector (hospitals, banks, universities). This chapter presents a review of empirical studies dealing with the economic impact of lean methods. Basically, the case studies are presented according to two main areas of activity. The first category includes manufacturing companies and the second includes examples from the service sector.

5.1 Case studies on manufacturers

Costa and colleagues (2018) investigated the implementation of 5S at the Manitowoc Crane Group Portugal, a metalworking company. They concluded that the production area became much more orderly and safe. Previously, incorrect tool transport could result in up to 15 minutes of downtime in some production phases, which the successful implementation of 5S has completely eliminated.

In another study of the cartonboard industry, the introduction of tools such as the 5S and its tooling reduced setup time by an average of 47%, saving EUR 10 114 per month. As an additional result, staff were able to be more involved in process optimisation, allowing employees to make their own suggestions for improvement measures (Roriz et al. 2017).

A study in an aluminium foundry found that the introduction of visual management, kaizen and TPM enabled an increase in the performance of production areas and facilitated information flow and communication (Vilarinho et al. 2017).

Monteiro and colleagues (2017) studied the internal logistics processes of a manufacturing company. Following the application of lean tools, they made the following findings: standardisation and clear definition of the responsibilities of the participants in the processes allowed the work team to set priorities, which resulted in more optimal time allocation. This contributed to a significant reduction in the lead time of the processes. The improvements resulted in annual savings of EUR 6 245 for the company.

Pombal and colleagues (2019) studied the impact of implementing 5S and visualisation in a manufacturing company. They concluded that the time needed to find materials was reduced by 70% (from 45 seconds to about 10-15 seconds). In addition, the efficiency of stock control has improved for 71 of the 252 kanban events used, thanks to the redefinition of minimum stock levels.

Singh et al (2018) investigated the applicability of lean methodologies in an Indian bicycle parts manufacturing company. The results showed that the firm was able to achieve an annual cost reduction of Rs. 242 208.

Amrani and Ducq (2020) conducted a study in the aerospace industry. The efficiency improvement measures introduced reduced the scrap rate by 66%, cycle time by 43%, and the inventory present in the production process was also reduced. Furthermore, the logistics department showed a 50% saving in transport and trucking costs. In total, the changes implemented have provided the company with savings of EUR 123 555.

An excellent basis for the study by Rosa and colleagues (2017) was provided by an automotive company that manufactures steel cables for car window lifts. They concluded that the application of a lean philosophy allowed to improve the efficiency of the manufacturing process. The number of pieces produced per hour increased from 350 to 493, which represents a productivity increase of about 41% for the assembly line.

Another study also looked at an automotive assembly process, where a new loop layout was introduced in workstations to improve production results. They concluded that productivity improved by 10% (Gna-navel et al. 2015).

Ruben and colleagues (2017) conducted studies on the application of lean methodologies in an Indian automotive parts manufacturer. Results showed a reduction of USD 2 000 in scrap costs, an improvement of 86%. Cycle times were reduced by 18%, lead times by 21%, raw material consumption by 25%, energy consumption by 19.12% and water consumption by 14%.

Kennedy and colleagues (2013) studied a food processing company in the UK, where the main focus was on reducing losses. Their results showed that the company achieved annual cost savings of GBP 45 000.

Similarly, another study analysed a food processing company in Ecuador, where the time taken to convert raw materials was reduced from 164 to 140 minutes by implementing lean methodologies. This represents an annual saving of USD 9 200 (Moya 2016).

In a study published in 2012, Gautam and Kumar examined an Indian manufacturing company before and after efficiency improvements. The analysis shows that the company's production output per shift increased from 210 to 300 axles with fewer operators.

Chandrasekaran and colleagues (2008) applied lean manufacturing techniques to an automotive assembly line. The positive effects observed after the implementation of lean manufacturing included the elimination of functional problems, reduction of quality complaints, elimination of rework and cost savings.

In a study by Kumar and colleagues (2006), an Indian tool manufacturing company was analysed. The efficiency improvement methods used resulted in annual savings of about US$ 140 000.

Vinodh et al (2014) also studied an Indian company. After applying the lean methodologies, the following results were obtained: a 10% increase in machine efficiency and a reduction of 230 seconds in the time to manufacture a product were observed.

5.2 Case studies on the service industry

A study in the field of maintenance found that the use of lean tools contributed to minimising human errors, identifying unnecessary maintenance activities and reducing total monthly maintenance time by 1020 minutes (Jasiulewicz-Kaczmarek and Saniuk 2017).

Hasibul et al (2018) analysed value stream activities (VSM) in a Swedish vehicle dismantling company. They concluded that 70% of the tasks were counted as value-creating activities, 21% of them did not create value but were necessary to maintain production continuity. However, the remaining 9% were considered pure waste.

A case study by Duran and colleagues (2017) uses the example of a thermal power plant to illustrate the impact of implementing lean methodologies on a company's costs. Two case studies were examined. In the first, the 5S methodology was applied in the repair shop and the parts warehouse. The results show that in the spare parts warehousing system, the plant was able to achieve cost savings of around USD 300 000 per year. The second study was based on a value-price mapping exercise to control the coal pulverisers. They found that they were able to save 1.44 hours per day in the maintenance of the pulverizer, which reduced annual costs by USD 287 088.

Another study was conducted to improve the clinical and pharmaceutical material supply system at São João Hospital in Portugal. The use of Kanban and 5S methodologies has simplified the commissary system. The new system has enabled the optimisation of drug stocks, resulting in an annual cost reduction of around €2 million. The improvement has led to a 70% reduction in the space needed to store medicines in the warehouse (Imai, 2012).

6 Summary

The paper reviews the brief history of efficiency improvement and its encounter with business intelligence systems. Following a review of the literature, it can be seen that efficiency improvement tools are most prevalent in manufacturing, although there are also examples from the service sector. The various efficiency improvement tools (JIT, Kaizen, VSM, MRP, Kanban, 5S) and business intelligence are almost exclusively found together in large-scale companies.

The social, societal and cultural patterns of Japanese people are very different from those of European people, and therefore the corporate cultures are also very different. For this reason, the adaptation of efficiency improve-

ment techniques is not a simple process, and requires a major change of mindset, especially at managerial level. This problem is exacerbated when looking at the SME segment, where these techniques are are spreading very slowly. Another breaking point could be the East-West fault line. The economic migration from Central and Eastern Europe to the West will further increase the shortage of skilled workers, which could be another barrier to the co-operation of management and physical workers.

An alternative direction for improving efficiency is automation and robotisation, which, although rapidly developing, in many cases cannot perform the fine mechanical movements and perform the work of the workers themselves. Furthermore, it is more cost-effective - certainly for SMEs - to review their own operating routines and thus increase their efficiency and profitability.

As the case studies show, these methodologies can contribute not only to optimising the operations of manufacturing firms, but also to improving different corporate cultures.

The study emphasises the importance of continuous improvement of business processes, focusing on the synergies between modern technologies and proven efficiency improvement methodologies. The practical application of these methods is crucial for competitiveness of SMEs at the dawn of the 4th industrial revolution. Business intelligence systems provide connectivity between ERP (Enterprise Resource Planning), quality, invoicing, management and other softwares, facilitating complex data analysis, data visualisation that contributes to optimal decision making. Of course, business leaders and practitioners need to be open to change and recognise that they not only have the potencial to improve profitability, but also make a significant contribution to meet with sustainability criteria.

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