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Impact and Critical Factors in Heijunka Implementation: An Action Research Study

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Abstract:

Purpose: Although Heijunka (production levelling or smoothing) is a lean tool designed to balance changing customer needs and production efficiency, this study aims to analyze the impact of Heijunka and identify various factors which can generally affect its successful implementation.

Design/methodology/approach: We adopted an action research (AR) approach to analyze the potential consequences of implementing Heijunka in a factory that faces demand that is not very predictable, and customers who require ever more individualized products at low prices with extremely demanding delivery times. An estimation of costs was carried out to compare three alternative production planning scenarios: (1) make to order (MTO) production, (2) weekly levelled production, and (3) production with minimal changeovers.

Findings: The analysis of the impact of implementing Heijunka in this factory demonstrated that MTO production planning without Heijunka is the most suitable option for the factory, bearing in mind that requested delivery times are the priority. We explore why Heijunka is unsuitable for this factory even though other lean principles and tools have been successfully implemented. In this way, we identify the main factors that might influence the successful implementation of Heijunka, such as changeover time, the number of different product types (and lot sizes), and the production lines' capacity.

Originality/value: Based on close collaboration between researchers and practitioners in the field of Operations Management, this AR study provides important information for decision-making regarding the application of Heijunka, and for advancing the current academic debate about successful lean transformation.

Keywords: lean management, Heijunka, make to order, action research, case study, costs estimates

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1. Introduction: Motivation, Aims, and Research Questions

Companies need to be able to react quickly to individual customers' changing needs. Fluctuation in demand means companies need to use management tools that allow them to respond to those fluctuations and achieve high levels of flexibility while maintaining efficiency without letting costs soar. Lean management, based on the Toyota Production System (TPS), facilitates the production of a variety of products, adapted to the needs of demand, with low costs, and acceptable pricing. It combines flexibility and efficiency, which are often thought to be incompatible with traditional production processes. Lean management is focused on making maximum use of resources and eliminating variation, and standardized methods and procedures must be closely adhered to, which is why lean production finds it difficult to cope with extreme fluctuations in demand. Tools such as Heijunka (production levelling) are designed to deal with precisely this variability caused by customer demand.

Heijunka involves the practice of smoothing production by evenly distributing the workload over time. Its goal is to minimize demand fluctuations by producing consistent quantities of various parts/products or variants at regular intervals. Instead of concentrating on large batches of a single product, Heijunka promotes a more balanced distribution of production volume. This approach enables greater flexibility and responsiveness to changes in demand while maintaining reasonable production costs.

However, Hampson (1999: page 369) believed that certain production concepts integral to the TPS theory and practice –such as Heijunka and muri (or waste resulting from overstressing machines and personnel)– impede "leanness".

According to Rewers and Diakun (2021), Heijunka –or production levelling– involves setting the size and sequence of product manufacture so that current demand can be met from the warehouse, avoiding sudden alterations to production plans. The concept of production levelling is based on using a repeatable and unchangeable production plan in which products are produced in the smallest batches possible. In this regard, they accept that Heijunka is not applicable in every company and process: Heijunka is pointless in companies using mass production systems and is not possible in unit production where all the components are unique.

Many companies operating in lean environments find that this technique is unknown and complex and does not always lead to the results they hope for. In a survey distributed in 2011 between Members of the Lean Division of the Institute of Industrial Engineers (IIE) and selected individuals from industry who are active in the field of lean, only 33% of the practitioners said Heijunka was successfully implemented within their organizations, versus the 85% and 62% that successfully implemented 5S and Kanban respectively (Cudney & Elrod, 2011).

Although decades of research have been dedicated to lean operations, Heijunka has received minimal attention in the academic literature, and recent studies on the topic are scarce. Coleman and Vaghefi (1994) and Hampson (1999) suggested that the concept of Heijunka has been underexplored in the academic and practitioner literature. In addition, Boutbagha and El Abbadi's (2024) recent systematic literature review confirmed the broad applicability of Heijunka in both manufacturing and service sectors. Still, they also noted that research on the implementation of Heijunka and its benefits remains an immature field of study that requires further exploration. They also concluded a need for further research into the costs of implementing Heijunka, as studying only positive impacts on system behavior is insufficient. They identified a need for cost estimation studies, as well as comparisons of current and target situations (before and after implementing Heijunka).

It would be extremely useful to better understand the suitability and impact of applying tools like Heijunka, which allow responses to fluctuations in demand while maximizing resource use (maximum efficiency or productivity) and minimizing inventory in lean environments. Considering the background described, this research was proposed with a dual objective: (1) solving a practical problem facing many companies today and (2) improving our understanding of the successful implementation of Heijunka and other lean practices in various contexts and different types of organizations. To that end, the following research questions (RQ) are proposed:

RQ1: What are the potential effects of applying Heijunka? And, more specifically, does the implementation of Heijunka always contribute to improved operational and financial results in lean companies?

RQ2: Are there any risks, negative effects, or disadvantages associated with implementing Heijunka? In other words, can Heijunka be an ineffective lean tool under certain circumstances?

RQ3: Is the successful implementation of Heijunka influenced by the characteristics of the production process and by the previous implementation of lean management tools? Do any lean tools affect the effectiveness of Heijunka?

RQ4: What conditions and characteristics of production processes and strategies would lead to the best implementation of Heijunka and lead to the greatest improvement in an organization's operational and financial results?

To answer these research questions, we focus our analysis on a particular factory that, from the moment it began its activity, achieved significant improvements in operating and financial performance following the implementation of lean philosophy and culture along with some of the key lean production tools. Success in implementing lean manufacturing (via SMED) allowed the company to reduce its changeover time, drastically shortening its delivery dates and improving quality standards and helped it to become a market leader. However, this factory faces fewer stable demands and customers who demand more individualized products at low prices with extremely demanding delivery timescales. A problem associated with the production method in this factory is the unbalanced workload, with intense production sometimes and light production at other times, including stopped production lines. The management needs to improve the utilization of worker capacity and time (achieving better productivity and efficiency) and control and minimize inventories, while at the same time maintaining production's ability to respond to more volatile customer demand. As the factory management is committed to the pursuit of kaizen or continuous improvement, they raised the question of whether implementing Heijunka might be useful in these new competitive conditions and thus help to overcome the problem they identified. The challenge facing this successful lean manufacturer is currently shared by an increasing number of factories.

This study had an action research (AR) approach. The management of the production plant had active and direct participation in the research, which aimed to answer a real, practical problem. In addition, despite the results of the study not necessarily being generalizable, we may be able to extrapolate the results to other production units with similar characteristics and backgrounds. In this sense, the study might advance the understanding of lean transformation and the chances of successfully implementing it in various types of organizations, industries, and environments. In this case, the business is a medium-sized production plant whose activity is unrelated to automobile production and is without assembly operations. It manufactures products in small batches, according to customer needs with fluctuating demand.

2. Theoretical Background

As previously noted, operations flexibility plays a fundamental role in today's dynamic, competitive environment, with customers demanding more and more products suited to their specific needs, with shorter and shorter lead times.

Demand fluctuations can be absorbed with an increased inventory level or by adding capacity flexibility in the production process (Liker, 2004). Increased inventory levels decouple the production process from demand allowing production to stabilize at a fixed level. Alternatively, demand fluctuations could be passed directly to the production process, which must then be flexible enough to meet customer requirements. Usually, it is very hard, or even impossible, to organize a production process that is completely flexible, as often this flexibility requires working overtime with additional workforce and machining equipment (Korytkowski, Grimaud & Dolgui, 2014). 'Zero lead time with no inventory literally means instantaneous production, which is physically impossible' (Hopp & Spearman, 1995: page 158). An intermediate solution is required (Rother, 2009): A trade-off between inventory levels and flexibility.

The concept of production levelling has been in existence for more than 50 years. It was developed by Toyota for the automotive industry. Sugimori, Kusunoki, Cho and Uchikawa (1977) stated that in the TPS, to make just in time production possible, levelling the production at the final assembly line is a prerequisite and the amount of levelling is determined by top managers. So, from the beginning, levelling has played a significant role in the just-in-time system and lean production (Schonberger, 1982; Monden, 1983; Womack, Jones & Ross, 1990; Chase, 1993; Hopp & Spearman, 1995; Fujimoto, 1999; Rewers, Hamrol, Żywicki, Bożek & Kulus, 2017). In the same sense, Coleman and Vaghefi (1994: page 31) noted that Heijunka "represents a not-so-new idea whose implementation forms the gist of JIT production" and they identified a dual objective for Heijunka: (1) reducing inventories thanks to small batch, mixed production and (2) the ability to balance the workloads for the production processes to each other and to capacity. Following on from the concept of factory physics by Hopp and Spearman (1995), de Treville and Antonakis (2006: page 102) suggested that 'it is the factory physics of lean production (reduction of capacity and inventory buffers, requiring reduction of system variability) that distinguishes it from other production processes such as traditional assembly line or batch manufacturing'. In other words, in lean production each operation must find a balance between maximizing utilization of capacity and minimizing inventory levels via elimination of variability from the system. The term Heijunka refers to the methodology or tools needed to allow the planning and levelling of the production program over a given time, both in terms of volume and mix of products. This allows production to adapt to the fluctuating demands of customers while minimizing how much WIP stock is kept. It is about producing small batches of many items in short periods with rapid changeovers, rather than large batches of one item after another (Liker, 2004). As shown in Figure 1, the main objective of Heijunka is to avoid peaks and troughs in the production schedule (Hüttmeir, de Treville, Van Ackere, Monnier & Prenninger, 2009) caused by fluctuations in customer demand.

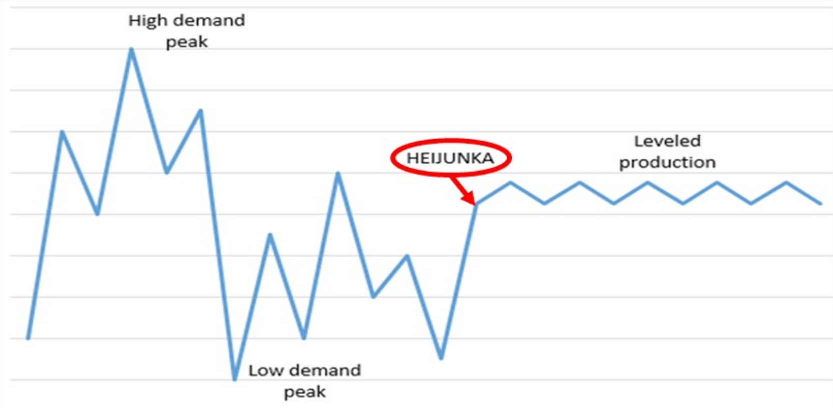

Figure 1. The aim of Heijunka

The possible benefits of implementing Heijunka or production levelling include:

- A reduction in stock (Coleman & Vaghefi, 1994; Rewers et al., 2017), both raw and auxiliary materials as well as finished products, compared to traditional batch production due to producing smaller lots of different products.
- Reduction of lead time to the customer and increased flexibility compared to traditional batch production by eliminating long waiting periods between production runs of a given item (Coleman & Vaghefi, 1994).
- Stability in the process which aids the supply chain (Monden, 1993; Rewers et al., 2017), reducing the bullwhip effect (Forrester, 1997; Matzka, Di Mascolo & Furmans, 2012).
- Peaks in production are eliminated along with overloading (Kochan, Lansbury & MacDuffie, 1997; Andel, 1999; Rewers et al., 2017), producing a more balanced use of equipment and resources.
- Improved production capacity (Yano & Rachamadugu, 1991) and maximized efficiency (Xiaobo, Zhou & Asres, 1999; Rewers et al., 2017).
- Improved competitiveness (Rewers et al., 2017; Teece, Pisano & Shuen, 1997).

Despite its benefits, Heijunka is one of the least intuitive and most complex lean tools. To achieve the benefits of Heijunka, the production process must be ready for implementation.

This is because lean implementation is focused on getting the right things to the right place at the right time in the right quantity to achieve perfect workflow while minimizing waste and being flexible and able to change. These concepts of flexibility and change are principally required to allow production levelling (Kim, 2015). That is why, before implementation, other tools need to be in place that allow continuous flow, a set production rate, and a standardized process working. These will allow optimization of the workforce, minimization of inventory, reduction in customer response times, and in short, flexibility in the system.

To achieve continuous flow, a flow of information on kanban cards and a stream of pull materials are needed in such a way that an 'upstream' operation does no more than the 'downstream' operation needs. Heijunka smooths out release of production kanban to provide a relatively level flow of production over all possible types of products, reducing the bullwhip effect (Korytkowski, Wisniewski & Rymaszewski, 2013). A layout based on flexible U-shaped cells facilitates this flow. Similarly, the fact of working with smaller batches means faster changeovers of machinery, which is why implementation of SMED is recommended (Liker, 2004; Korytkowski et al., 2014). Heijunka also needs a thorough understanding of customer demand.

Nevertheless, it is important to note that Heijunka also comes with some disadvantages that might discourage its use:

- It does not allow customer demand to be satisfied immediately but rather deals with overall demand in each timeframe. If the demand is extremely variable, the company runs the risk of being unable to cater to some customers.
- It reduces the ability to produce exactly what the customer wants at the time they want it, which is particularly important in cases where the delivery time is critical.
- During the period used as the basis for levelling, a stock of finished product is produced which then waits to be sent to the customer. This means that in addition to warehousing costs, this inventory also represents an opportunity cost, which could be significant to companies with limited warehouse space.

2.1. Empirical Research Background

As previously stated, although Heijunka (production levelling, smoothing or balancing) is one of the pillars of TPS and therefore of lean manufacturing, it has received little attention in the academic and practitioner literature. The recent systematic literature review (SLR), from 2012 to 2022, by Boutbagha and El Abbadi (2024), gives some insight into the most significant research areas related to this concept, as well as proposes an agenda for further research. The review, which covered 60 articles, confirms the limited research on this topic and reveals three main areas of focus: (1) the implementation of Heijunka and its benefits, (2) problem-solving related to Heijunka using optimization, and (3) the application of Industry 4.0 technologies.

Below we analyze the main results of the most recent empirical articles focused on the implementation of Heijunka in the manufacturing industry along with its benefits and disadvantages. They are presented in chronological order, and it is worth noting that most focused on analyzing and solving problems related to production levelling (or Heijunka) through quantitative modelling (optimization or simulation) based on single-case studies.

Hüttmeir et al. (2009) presented the results of a stylized simulation model combined with a case study in a BMW engine plant to analyze the trade-off between leanness and agility/responsiveness and to explore ways to combine Heijunka and Just in Sequence (JIS). The results suggest that the best option is to use Heijunka to smooth out the most extreme production numbers and carry out just in sequence (JIS) for the remainder. They conclude that the combination of Heijunka and JIS will create new incentives to improve process reliability, given the lack of tolerance for rework under JIS production.

Bohnen, Maschek and Deuse (2011) and Bohnen, Buhl and Deuse (2013) argued that application of conventional levelling approaches is limited to large-scale production, and they proposed a systematic procedure using optimization for levelling low-volume and high-mix production employing clustering techniques (Group Technology) to group product types into product families. They developed a software toolkit and presented a real-life application through a case study. They identified potential reductions in raw material stock, stabilization of inventory levels for finished products, and improvements in delivery reliability.

Matzka et al. (2012) examined a Kanban-controlled and Heijunka-levelled production system in which demands are controlled and limited by a Kanban loop. The production system (for a single kind of product) was modelled to find the optimal number of Kanbans and the optimal output buffer size to reach a given service level.

Korytkowski et al. (2013) applied simulation modelling and multivariate analysis (MANOVA) to a manual and semi-automatic assembly line in a microelectronics factory producing four types of products with significant variability in order size. They showed the positive impact of Heijunka in improving throughput time and work-in-progress in job shop production. They argued that through a case-based approach they demonstrated how lean tools like Heijunka –when used appropriately– can help eliminate waste, maintain better inventory control, and achieve better operational control.

Korytkowski et al. (2014) discussed a multi-product lot-sizing problem for a job shop controlled with a Heijunka box using an alternative approach to levelling, called exponential smoothing. The simulation study assumed uncertain but stationary demand and it showed that by applying Heijunka, fluctuations in customer orders are not transferred directly to the manufacturing system, thus simplifying shop floor management and making production planning more predictable. It allows for smoother production and better utilization of production capacity, achieving a tradeoff between the variability in production line capacity requirements and inventory level.

ElMaragy and Deif (2014) believed that the cost of implementing Heijunka must be thoroughly studied and so proposed a dynamic systems approach to investigate the challenges of implementing production levelling. They developed a dynamic model analyzing the cost of production levelling policies in a lean cell. Results show that costly production capacity scaling can render lean production-levelling practices difficult to justify from a cost perspective. The lot-size selection was shown to be influential in choosing feasible lean production levelling tools. Lot-size choice requires a trade-off between cost and responsiveness.

Rewers et al. (2017) analyzed an example of the implementation of production levelling in a Polish surgical instruments manufacturer. They described the current production scheme and the reasons for implementing levelled production: no possibility of forecasting production output, the high number of orders, uneven personnel and machine loads, and long production pass-through time. They also identified the successive steps of their own method for implementing production levelling to achieve two objectives: reduce throughput time (or shorten pass-through time) and increase personnel efficiency (despite the staff's initial reluctance towards production levelling).

Gupta and Kumar (2019) illustrated the advantages of implementing Heijunka for an automotive spare parts supplier in India. The company's aim in implementing Heijunka was to address: (1) frequent customer follow-ups and frequent unplanned changeovers leading to loss of productivity, quality system stress and delivery constraints, (2) unplanned changeovers and loss of productivity, and (3) the supply chain not being consistent with the required rate or quality of parts delivery. The study showed substantial improvement in quality, staff productivity, machine productivity, delivery, and customer satisfaction. Standardization of work helps people work more efficiently, improving the efficiency of individual cells and therefore overall efficiency.

Sodikin, Yusuf, Hendrayana and Rusianto (2018) analyzed the implementation of Heijunka (and the elimination of mura, muri, and muda) in a manufacturer of work and sports gloves operating under a production-to-order system, characterized by continuous changes in demand and production planning. The company had no previous experience of implementing any lean principles or practices. This implementation allowed the company to balance the production rate (mura) and align the workload (muri) by using workload analysis based on the amount of daily production levelled. The workers freed up as a result were allocated to reduce the excessive workload in daily production.

Shetty, Abakari, Rodrigues, Oommen-Mathew and Motlagh (2019) used system dynamics to analyze the challenges of implementing production levelling in an electronic automotive parts manufacturing company producing a variety of component types that are stored in different buffers. A model was developed to stabilize the production units, and the results show that Heijunka contributed to reducing fluctuation in the upstream supply chain, with the primary objective being to hold minimal inventory.

Rewers and Diakun (2021) presented a methodology for implementing Heijunka or production levelling –considered a modern way of planning and controlling production. They used a simulation method with actual production data to determine the best variant of the production planning and control system to produce standard parts included in a customized finished product (manufactured according to an assemble-to-order system). They compared three variants in terms of the number of completed orders, number of orders completed on time, average waiting time for an order, and the degree of use of the available machine working time. The results show that the best variant was a mix of production levelling and production "for stock". In other words, the production of high-speed parts is planned based on production levelling, and the other parts are assigned a suitable stock level so that production for them is only triggered when parts are taken from the warehouse (pull system). However, it is worth noting that because the products are small, and because the company's strategy emphasized order timeliness over costs, the simulation model did not consider production costs and warehouse costs.

Alfaro-Pozo and Bautista-Valhondo (2023) analyzed the suitability and economic impact of applying Heijunka to production sequences at mixed-model assembly lines. This case referred to assembly of several product types, although these products are similar because they can be from the same product family. The analysis used two mixed integer linear programming models to measure the impact of regularity on production losses arising from work overload in relation to the production mix. Furthermore, it compared this lost production with the levelling of stocks in line. They concluded that preserving the production mix balances the workloads throughout the workday along with both levelling and considerably reducing in-line stock. In other words, the results indicate that the costs of achieving this regularity are compensated for by levelling intermediate stock and workload balancing.

Boysen, Schulze and Scholl (2022) reviewed the scientific literature on the assembly line balancing problem (understood as one of the most elementary optimization problems) and outline a possible research agenda for the next fifteen years. As they focused on modeling and solving real-world assembly line balancing problems, their approach is outside the scope of our research. However, it is worth noting their conclusions that Industry 4.0 technologies influence not only the appearance and capabilities of assembly lines, but also require adaptation of the assembly line balancing problems to be solved.

De Jesus-Pacheco and Schougaard (2023) performed an in-depth case study using an inductive approach to identify and address production levelling problems and challenges in assembly lines with an intensive manual workforce. More specifically, they analyzed the impact of production levelling on operational performance in a manual heating and cooling assembly line. The site was a factory in Denmark that needed higher productivity (and optimization of operator numbers) to efficiently meet just in time market demands. The authors identified significant waiting times for product lots and multiple bottlenecks in the assembly line and a need for interventions to improve production levelling. The results indicate that a lack of documentation and limited understanding of production and levelling processes can negatively impact operational performance. The scarce documentation of OEE, productivity, and the assembly line meant there was no case for optimization, as there was no solid foundation for making data-driven improvements. The study emphasizes the role of the workforce as an essential aspect of manufacturing to be managed. As ElMaragy and Deif (2014) stated, prior research indicates production levelling analysis that has focused more on policies and decisions to improve system design and operational performance, and less on associated costs. In addition, Rewers et al. (2017) noted the absence of analyzing indicators (or 'conditions') to consider during implementation of levelled production, along with descriptive instruments for measuring levelled production performance and efficiency.

Bearing all of that background in mind, we identified a research gap related to the absence of conceptual and empirical studies analyzing the factors that affect how effective and efficient a Heijunka –or production levelling, smoothing, or balancing– implementation is in different manufacturing contexts and production environments and for different market and customer demands.

There are also opportunities to advance empirical research on exploring alternative tools and approaches to Heijunka for responding to changing customer needs and achieving high levels of flexibility while maintaining efficiency.

To this end, there is a need for further empirical research in factories where management and decision-makers have ample understanding and sufficient documentation available about production, levelling processes, OEE, and productivity. It would be also interesting to explore processes with different levels of automation/digitization and therefore different workforce levels.

3. Methodology

This study begins from (a) a prior theoretical understanding of lean management and one of its specific tools (Heijunka), and (b) an observation of the experience of lean management implementation in one factory.

To carry out this study and answer the research questions, we adopted an action research (AR) approach, aiming to analyze the consequences of Heijunka for the factory being studied (contributing to practice), while at the same time advancing our scientific understanding of lean management and specifically of the adequacy of implementing Heijunka in different contexts (contributing to research).

AR is a research approach that came out of social psychology, in which the researcher acts as a change agent (Chein, 1948; Curle, 1949; Lewin, 1946). It is aimed at helping solve problems of a social nature, in such a way that both the researcher and those in the situations being studied (organizational agents) actively participate in the situation being analyzed. The research should produce relevant information to help solve practitioners' real-life problems. It produces an intervention or initiative based on agreement and foresees some type of decision for all agents involved, which is subject to evaluation, comment, and modification.

Within the field of Operations Management (OM), Westbrook (1995) presented AR as a research methodology that can overcome deficiencies associated with traditional research methods. He stated that academic OM research must be relevant to practitioners, applicable to unstructured or integrative issues, and must contribute to theory and that these three objectives could be achieved simultaneously through AR methodology. Similarly, Coughlan and Coghlan (2002) later define and explore the legitimacy of action-oriented research in OM and the logic and value of applying AR to the description and understanding of issues in OM.

Nevertheless, despite the undoubted benefits that using an AR strategy may bring to the progress of research in OM in general, and the practical implementation of lean management in various sectors and situations, there is little research looking at lean production (and related topics) from an AR perspective. It is worth highlighting work from Boardman and Clegg (2001), Jorgensen, Boer and Gertsen (2003), Lander and Liker (2007), Eriksson (2010), Baker and Jayaraman (2012), Bamford, Forrester and Leese (2015), Eltantawy, Paulraj, Giunipero, Näslund and Thute (2015), Liker and Morgan (2015), Darlington, Francis, Found and Thomas (2016), Perona, Saccani, Bonetti and Bachetti (2016), Gonzalez-Boubeta, Portela-Carames and Prado-Prado (2021) and Tébar-Rubio, Ramírez and Ruiz-Ortega (2023).

From an AR background, Alfaro-Tanco, Avella, Moscoso and Näslund (2021) developed an evaluation framework for the dual contribution of action research, distinguishing three types of research contributions –theory testing, theory building, and theory elaboration– and three types of contribution for practitioners –implementation of changes, recommendations for improvement, and diagnosis.

As already noted, we performed this AR study to address a practical problem (shared by many companies) but at the same time to advance knowledge about lean management in general and Heijunka implementation in particular.

In terms of practitioner contribution, we considered this study to be diagnostic AR as it involves researchers finding reasons for the target problem and suggesting actions for practitioners (Chein, 1948). Susman and Evered (1978) support the argument that the action research approach does not necessarily require direct implementation or intervention, but it can also involve (a) diagnosing the situation within an organization and/or (b) proposing improvement actions or resolving problems. Likewise, this approach is consistent with the eight characteristics that the application of the AR approach should meet in the field of management, according to Gummesson (2000).

Accordingly, AR allows researchers (academicians and practitioners) to solve a practical problem, collaborating from the “gemba” on a particular cycle of activities, including problem identification and analysis and reflective learning. The results of the study did not lead to implementation but did produce a final decision or diagnosis.

In terms of the AR contribution to research, our study fits a theory elaboration process (Spens & Kovács, 2006), emphasizing abductive reasoning which involves modifying a general theory to reconcile it with the specifics of a given context (Ketokivi & Choi, 2014).

Considering the benefits of an AR approach but the limited background, and according to Marín-García, Garcia-Sabater and Maheut (2022), below we describe how we executed AR in this study. As previously noted, an AR approach demands that the researcher plays an active role. In this case, two of the researchers were also agents or practitioners in the organization being studied and were part of the management team. One was the director of the production unit being studied, with prior experience in other continuous improvement projects using various lean tools and efficiency indicators. The other practitioner had direct participation in Heijunka implementation project. The third researcher was an academic, an expert in OM and lean tools, who participated in the project providing technical and academic support. Other workers in the business collaborated in the project as needed, providing and analyzing data from the section being studied. This structure ensured the adoption of a collaborative team-based approach as well as access to the information needed to carry out the research. The research team collaborated in all the AR cycles or phases identified by sharing ideas and reflections.

Although an AR project is largely based on researcher and practitioner experience (who are also not mere observers), to ensure research reliability and validity, steps taken to ensure rigor in the methodology and data collection process are described in detail. This makes the study repeatable in other sections of the same company or where appropriate, in other companies. It should also be noted that this study combines qualitative and quantitative analysis.

The study was carried out between January and May 2017. The AR project lasted, therefore, about five months and consisted of the following phases:

Phase 1. Approaching the problem and improvement opportunity: This first phase consisted of diagnosing the current situation in the company and operating problems or opportunities for improvement in the production process. In addition, we gathered information on lean management and the main tools that had or had not yet been implemented by the company up to that point. Based on that information, the researchers discussed potential alternatives for solving the problem or improvement area selected. In addition, the section of the business that would be the focus of the study was identified.

Phase 2. Data collection: We combined qualitative and quantitative methods for data collection, including observation, documentary evidence (historical or retrospective information), in-depth semi-structured interviews, and brainstorming/discussion among participants. Most of the quantitative data required was gathered from orders archived in the company ERP system. The employees in the section being studied provided additional qualitative information explaining and giving background to the data, which gave a better understanding of the problem posed. The inclusion of practitioners in the research team was crucial. The research team is not a mere observer but has deep knowledge of the organization in which they operate. This triangulation –the combination of multiple data sources and multiple researchers (academics and practitioners in this case)– improves the rigor of the research, something that is often questioned in studies based on AR and/or case studies.

Phase 3. Data analysis and process improvement choices: This phase comprised the analysis of data, proposing alternative scenarios, and identifying comparative graphs of the effects of the various proposed alternatives. It was a study of the effects of implementing Heijunka in different scenarios and production conditions.

It is worth noting that these three phases of the AR project were done through weekly follow-up and brainstorming meetings between the three researchers (academic and practitioner) along with other workers in the section being studied, and the leaders of other departments.

Phase 4. Discussion and recommendations: This phase included a discussion of the previous analysis to identify the proposed improvement alternative. There was a final meeting to close out the project in which the participants gave their conclusions. The researchers also gained an understanding of the topic and practical experience of applying their knowledge of Heijunka in a real working environment. In addition, the project produced a methodology that may be useful for application in other parts of the factory, and even in other companies.

4. Company Profile

Understanding the research context and purpose is the first phase for addressing an AR project. In this research, the unit being analyzed was a specific factory belonging to a leading multinational company in the packaging sector. The company has three lines of business: food, drinks, and special packaging. It has a presence in more than 30 countries in four continents with more than 100 production plants. The factory is dedicated to packaging for the food industry; it produces closures for cartons and containers.

The factory, which began operation in 2002, had a turnover of 80 million euros in 2017, and has approximately 220 workers, 20 of whom work in management, planning, engineering and finance, with the remaining 200 working directly in the plant. The location of the plant was strategic, as its nearness to the raw material supplier makes rapid, accurate delivery easier, and reduces the costs of raw material stocks. In addition, the product the company manufactures is packaged compactly, making transport costs a relatively small part of the total cost, allowing it to be exported all over the world.

Since opening its doors, this plant has worked according to the philosophy and principles of lean management and has been progressively implementing various lean tools. The factory management has promoted a culture of continuous improvement since the beginning with the aim of increasing the competitiveness of the factory and by extension the company. Through the reduction of waste, they have sought to increase productivity, responsiveness to customer needs and a reduction in lead times at a reasonable cost that would make them more attractive than their competitors and consolidate their position in the market.

In the same year as starting operations, the plant began to use Statistical Process Control (SPC) and the PDCA methodology to understand the production process better, to detect problems and to identify the best improvement solutions.

In 2004 the plant instituted a kanban system for intermediate products between each section of the factory. In 2005 they began implementing Total Productive Maintenance (TPM) and quick changeover systems (Single-Minute Exchange of Die, SMED), having consolidated and documented all of their work processes, technical specifications, machine manuals, job descriptions, and responsibilities for each post, as well as quality systems and environmental management systems (achieving certification to ISO 9001 and 14001). The rewards of implementing SMED were particularly noteworthy. They managed to achieve much faster changeovers (from over 10 hours to under one), which let them shorten lead times and increase productivity and the plant's capacity, thanks to the extra useable production time, which would have previously been used in changeovers, allowing them to deal with more orders. TPM also helped improve machine efficiency, as it drastically reduced the number of breakdowns, the principal cause of machine downtime.

In 2006 the plant began continuous improvement projects following the Six Sigma methodology, which encourages process control and reduces process variability to eliminate out-of-specification products and reduce raw material consumption and customer complaints. In December 2017 the company had completed more than a dozen 6 Sigma projects. Furthermore, the use of 6 Sigma tools, such as design of experiments (DOE), and Ishikawa and Pareto analysis, has helped the plant understand their process better, which has led to improved productivity through the communication of this understanding in manuals and worker training. The sum of these effects has visibly improved the factory's competitiveness.

In 2007 the company applied 5S methodology in all factory areas to make the most of the benefits of the previous implementations. The results were very satisfactory: they allowed visual control of the production system and maintenance, faster set-ups with SMED, a reduction in breakdowns with TPM, and a reduction in the number of non-conforming products and spoilage. The factory was cleaner and tidier (particularly important in this sector), the risk of accidents was reduced, and the workplace was more comfortable. Thanks to 5S, the plant succeeded in generating a culture and level of tidiness and cleanliness, which allowed them to achieve certification to the BRC Food Safety and Hygiene standard in only 6 months.

In 2008 the plant introduced Failure Modes and Effects Analysis (FMEA) methodology, to identify improvements to the process which would help them to continue pursuing continuous improvement.

All of this makes it clear that this factory is no lean amateur (Liker, 2004), as the philosophy and management system affect all plant activities. The progressive implementation of various lean tools has contributed to the improvement of operating and financial results over and above other plants in the same company. This has led to projects for the implementation of lean tools in other factories in the group, with the plant in our study being used as a benchmark and a source of trainers. The continuous improvement produced by working to this philosophy and the continual, progressive implementation of various lean tools have meant that Overall Equipment Effectiveness (OEE) has trended upward continuously since 2002.

4.1. Characteristics of the Production Process

There are three stages in the process of producing closures in this factory: cutting, coating, and stamping. The machinery used in these stages is heavy and non-configurable; in other words, the layout of the plant is fixed and cannot be modified for changes in production.

Customer orders generate one order for cutting material, one for coating, and another for closure manufacturing. Typical lead times between order placement and delivery dates are 2 to 3 weeks, though it can be as short as one week in case of urgent customer need (this is extremely short compared to competitors). The raw material supplier is close by and has no problems with supply. It is important to highlight that nowadays, many of the products require custom designs for each customer, so they are 'made to order', without a stock build-up, and it is not possible to share raw materials in process or semi-finished products between the different customers. Nevertheless, it is possible to classify the products in families according to the cap diameter which is the main parameter driving format changes in the production lines.

In this sector, delivery times are critical and reducing them can be a significant competitive advantage for the factory. This is because the factory produces closures for food packaging, principally fruits and vegetables (which could be harvested early or late depending on the weather). This reduction in delivery times and production exclusively to order was made possible by the drastic reduction in changeover times from more than 10 hours to less than one, thanks to the SMED system. These shorter delivery times have let the company grow and increase its customer base in a market where the rapid packaging of fresh products represents benefit.

Currently, this factory is in the middle of a new stage of its journey towards excellence and intending to maintain and improve its competitiveness, it needs to progressively reduce production costs while maintaining or even improving product quality and its capacity to produce to order, maintaining or reducing delivery times. There is pressure from the competition in this aspect, which is why the company decided to examine what would be the impact of Heijunka and whether it could be one way to respond to the ever more demanding market requirements in terms of price, quality, flexibility, and delivery times.

To that end a study of Heijunka implementation was performed in the final closure stamping phase, the final part of the production process. This section of the process was chosen for analysis because it has the most variable demand and is most affected by significant workload variations making planning difficult, both in terms of organizing production and workforce, and therefore presents a challenge to efficient use of resources. Furthermore, it is the only part of the process in which the customer is the final customer and investigating any improvement that might reduce delivery times here is important. Lastly, successful production levelling here might make life easier for other 'upstream' sections in the same factory.

5. Analysis and Results

To examine the financial impact of implementing Heijunka, a detailed analysis of the working methods in the plant was performed and the influence of the number of changeovers on two of the most important costs was analyzed.

Those are the cost of changeovers themselves and the cost of stock, neither of which add value to the product and which the company therefore wishes to reduce.

As stated previously, the factory in this study produces to order. It cannot be considered a pure just in time system (JIT) as the different orders, along with their respective delivery times, are received in the factory each day. Planning is based on competitive criteria for manufacturing, with priority given to the requested delivery times. Once orders are completed, the stock is sent out, so there is no finished product stock, only raw material stock. It is difficult to plan consistent production, and so it is common for production shifts set at the beginning of the week to be changed midweek, which can cause significant problems. It is pure production to order, minimizing stock costs but causing inconsistent work, making production planning difficult and requiring a considerable number of changeovers, with the associated costs and downtime.

This analysis aims to examine whether it would be more beneficial for the factory to keep the current production system or to use two potential alternative production systems that would allow more stable working and fewer changeovers: (a) applying Heijunka with a weekly time base or (b) producing all units of the same format in such a way that changeovers are minimum. Therefore, three alternative systems were compared:

1. Make to order (MTO) production: The system currently in use in the factory, in which different products are produced according to orders from customers and their delivery dates. Production is planned to produce what customers want when they want it. Consequently, there are a high number of changeovers.
2. Weekly levelled production: Starting from the monthly demand, levelled production is carried out applying Heijunka with a weekly time base; each week, the same number of units of each product format are produced in one go. This time base was chosen as orders in the factory usually have a lead time of about 1 week or 10 days, which means that this time base achieves levelled production appropriate for customer demand while minimizing costly changeovers.
3. Production with minimal changeovers: All units of the same format are produced before changing over machinery for the next lot. This is mass production of each format in which changeovers are minimized.

An estimation of costs was carried out to compare the three systems, using various assumptions:

- Changeover cost (CO cost): This is the cost of the time operators take to adjust and prepare machinery for producing a different format. Two situations were identified which give different costs:
    - ✔ Factory at less than 100% production: In this case, the cost is determined by (a) labor on the line which is stopped while doing the changeover rather than working on production, and (b) labor of the SMED mechanics who work on preparation and pre-assembly to make changeovers as fast as possible. Considering the personnel assigned to the line, the hourly cost of the workforce, and the average duration of the changeover, the cost of a changeover in this situation is €252.7.

$$CO\ labor\ stopped\ cost = No.workers\ stopped\ during\ changeover\ period * Average\ changeover\ duration * Hourly\ labor\ cost$$

$$CO\ SMED\ cost = No.SMED\ workshop\ workers * Working\ hours * Hourly\ labor\ cost * \frac{1}{Average\ number\ of\ changeovers\ during\ working\ hours}$$

$$CO\ cost_{<100\%} = CO\ labor\ stopped\ cost + CO\ SMED\ cost = 252.7€$$

    - ✔ Factory at 100% production: In this case, in addition to the costs noted above, there is an opportunity cost of time lost in the changeover, which could have been used for production. This opportunity cost is calculated from the profits that might have been made from the product potentially manufactured during the changeover time, which is estimated at €233.3. The total cost of a changeover in this situation rises to €486.

$$CO\ opportunity\ cost = Average\ changeover\ duration * Rated\ machine\ speed * OEE(\%) * Profit\ per\ product = 233.3€$$

$$CO\ cost_{100\%} = CO\ cost_{<100\%} + CO\ opportunity\ cost = 486€$$

- ✔ Stock cost: Two types of stock generate costs for the factory: raw material (RM) and finished product (FP). Both were considered together, but they have different effects depending on the type of planning system used. We assume that all RM is provisioned at the beginning of the month for the three scenarios. Under MTO production, there is no FP stock, as finished products are sent to the customer immediately once produced. In balanced or Heijunka production and minimal changeover production, there is both FP and RM stock.

To calculate the cost of stock one must consider (a) financial expenditure derived from stock maintenance, and (b) warehousing expenditure. To estimate the financial costs of maintaining stock it is necessary to evaluate the opportunity cost of having the stock, applying interest to the capital invested in said stock that the factory could have earned if it had invested that capital in a long-term bank account. The warehousing expenditure includes the costs of warehouse functioning, such as salaries, heating and lighting, and insurance, as well as the building rental, plant and equipment needed for moving and transporting the stock. Nonetheless, these costs of warehousing were not considered in our study as the three different scenarios (MTO, balanced production, minimal changeover production) would have the same costs because the warehouse in this case belongs to the factory, so there is no rent to pay, and no variation in costs based on the amount stored. The only significant variation in stock costs due to a non-MTO production system would be that of storing the finished product before sending it to the customer. To quantify that, we will take a financial cost of 3% annual interest on the value of the stored material, as the stored material represents this lost income.

$$Stock\ cost_{3\%\ annual} = No.units\ in\ warehouse * Unit\ value \left(\frac{€}{units}\right) * \frac{3\%}{year} * \frac{1\ year}{365\ days}$$

- Other costs of keeping stock and using alternative production systems to MTO must be considered:
  - ✔ Cost of late delivery to the customer: When using a non-MTO production system some products may be produced before the customer orders them, which must then be stored, while other products, which are needed, wait to be produced. In the case of the factory in this study, there is a penalty of 5% of the sale price for each day of late delivery. Given that the average profit from sales is 20%, a delivery that is four days late will mean the loss of all of the profit from that operation.

$$Stock\ cost_{late\ delivery} = No.units\ pending\ delivery * Unit\ value \left(\frac{€}{units}\right) * Penalty\ 5\%$$

  - ✔ Opportunity cost of using the warehouse which could be rented out: The warehouse belongs to the factory. Having it full of finished product stock means losing the chance to rent that space to other businesses. To quantify that opportunity cost, we suppose that 25,000 finished products take up 4m2 and the same area would be filled by 1,800 units of raw materials. Finally, we suppose that the rental price of warehouse space would be €3/m^2, in line with other warehouses in the area.

$$Stock\ cost_{oportunity\ warehouse\ rent} = No.units\ in\ warehouse * Occupied\ space \left(\frac{m^2}{units}\right) * Estimated\ warehouse\ rental\ price \left\{\left(\frac{3€}{m^2 * month}\right) * \left(\frac{1\ month}{30\ days}\right)\right\}$$

Figure 2 shows the ... cumulation and the costs of changeov... on to be the most profitable productic... ver and stock costs in the situation with the intermediate number of changeovers between MTO system and production with minimal changeover.

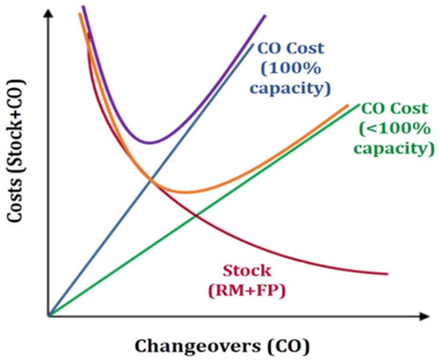

Figure 2. Expected costs variation depending on the number of changeovers

Below, we present the economic impact study of the implementation of Heijunka in the production plant based on one month's production data. Initially for a single production line, and then for the three existing lines in the plant. We used production data from May 2015, a normal production month, in which 11,825,827 units were produced in 22 different batches.

5.1. Single Production Line Study

Firstly, costs were estimated for the scenario of pure MTO production, in which the sequencing of production is determined by the customer orders received. This produces, a higher number of changeovers and the highest associated costs. To simplify matters, raw materials were assumed to be delivered at the beginning of the month and stored until use. In contrast, finished product stocks are zero, as orders are sent as soon as they are finished, without being stored, and without incurring late delivery penalties or opportunity costs of filling the warehouse with FP.

Table 1 shows the estimated costs for production under pure-MTO, with a total of 21 changeovers needed to meet customer demand. This gives the initial data for the cost chart.

Line	Product	Quantity	Co	Changeover (Co) Cost (100% Capacity)	Changeover (Co) Cost (<100% Capacity)	Stock (S) Costs	Total Costs S+Co (100%)	Total Costs S+Co (<100%)
1	A	3,466,169	21	10,206.00	5,307.12	356.81	10,562.81	5,663.93
1	B	2,525,372						
1	C	2,331,444						
1	D	1,829,460						
1	E	1,597,677						
1	F	75,705						

Table 1. Estimated costs for MTO production planning

To continue getting the chart, the costs were estimated for a production system with production levelling. To do that, levelling was performed following the basic greatest common divisor (GCD) series calculations described by Cuatrecases (2013) with a weekly time base. Based on that levelling, 15 changeovers were needed for the weekly production to be consistent for a month.

After levelling, the stock and changeover costs associated with that production plan were examined following the same procedure as in MTO system, getting the second point needed for the chart, corresponding to the intermediate point in terms of numbers of changeovers needed.

Finally, the minimum number of changeovers possible was examined. To achieve that, each product was produced in turn to minimize changeover costs. The associated costs of keeping stock, warehouse costs, and opportunity cost of lost warehouse rental income, as well as late delivery penalties, were all considered. This gives the final point in the cost chart and is the edge case with the fewest changeovers possible.

With the three points of stock and changeover costs calculated for the three planning situations, we arrive at the cost chart shown in Figure 3.

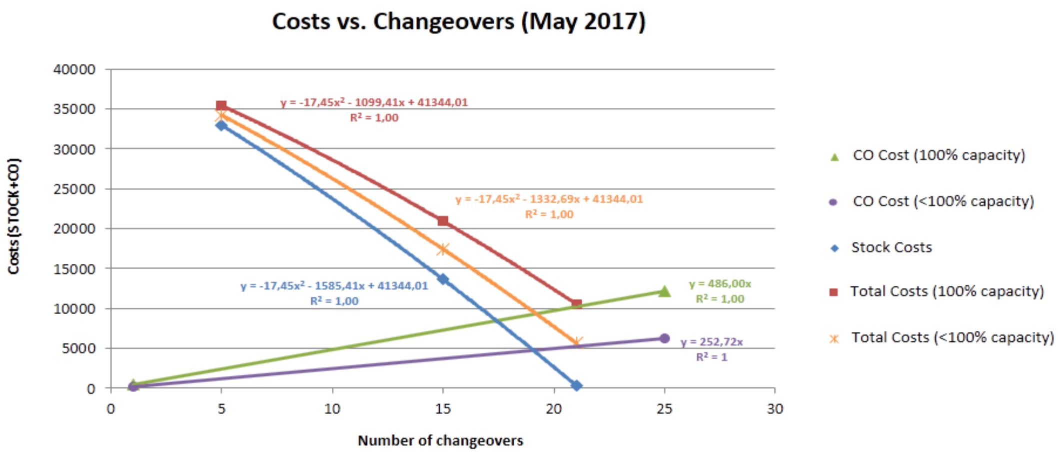

Figure 3. Total costs vs. Changeovers for one production line

It shows that the total costs, both at full production capacity and less than full capacity, are reduced as the number of changeovers rises. In other words, the closer the organization gets to a pure MTO system, the lower the total cost of stock and changeovers. This is because the tools the factory implemented previously to increase changeover efficiency (SMED, 5S and TPM) have meant that changeover costs in the plant, especially when it is not running at 100% capacity, are relatively low. Therefore, the costs of stock, and especially the high costs to the factory of late delivery, are more significant in overall costs, and penalize any production system, which is not pure MTO. The conclusion of this analysis is, therefore, that the best option for the factory would be to keep their current MTO planning system.

5.2. Study for Three Production Lines

After looking at the impact of implementing Heijunka on a single production line, the same study was performed examining the three production lines in the factory. In this case, in addition to seeking the most balanced production possible, the process involved attempting to balance the workload of the three lines, aiming for each line to have as similar a workload as possible to aid maintenance and avoid breakdowns.

To that end, the monthly workloads of the production lines were balanced so that each line was in use for approximately the same duration by sharing the work across the different lines. To achieve the best balance with the least changeovers, it was decided that each line would specialize in different products, with production times that would allow the possible workloads to be balanced and aiming to avoid the same product being produced at the same time on different lines.

A comparison was carried out using this model of shared production between the current MTO production plan, a balanced production plan with a weekly time base, and a production plan that minimized changeovers (producing all a particular format at one time). The aim, as in the study of a single line, was to produce a cost chart that would allow to compare the three production possibilities.

Firstly, the maximum changeover case was examined, the context of MTO production in which production is determined by customer demand, and no stock of finished product is kept. Table 2 shows the costs associated with this system of production, getting the first point of the plot.

Line	Product	Quantity	Co	Changeover (Co) Cost (100% Capacity)	Changeover (Co) Cost (<100% Capacity)	Stock (S) Costs	Total Costs S+Co (100%)	Total Costs S+Co (<100%)
1	A	11,750,122	20	9,720.00	5,054.40	285.42	10,005.42	5,339.82
	B							
	C							
	D							
	E							
2	F	11,339,531	12	5,832.00	3,032.64	345.82	6,177.82	3,378.46
	G							
	H							
	I							
	K							
3	J	7,405,761	17	8,262.00	4,296.24	409.71	8,671.71	4,705.95
	L							
	M							
	N							
	O							

Table 2. Summary of costs for MTO planning

Next, production levelling, or Heijunka, was examined, with a weekly time base. To do that, monthly production was balanced following the GCD method with a time base of a week, so that a moderate number of changeovers was needed. On doing the balancing, a total of 40 changeovers were needed (14 on line 1, 12 on line 2, and 14 on line 3). Total cost was estimated with the same procedure as in MTO system.

Finally, proceeding the same way, the scenario with the least number of changeovers was analyzed, with each product being produced in one run, getting the final point of the chart. These data allow us to produce the cost curve shown in Figure 4.

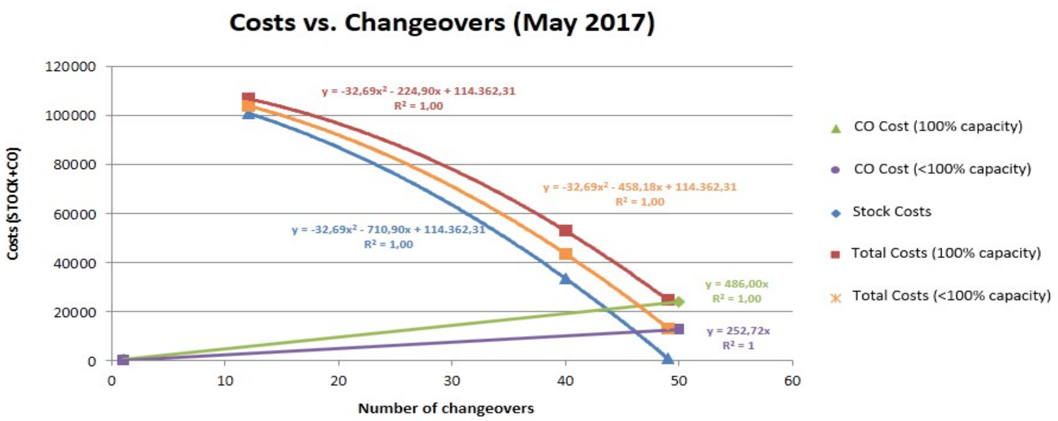

Figure 4. Total costs vs. Changeovers for the cap production plant

As in the previous case, the overall costs are reduced with more changeovers, in other words, as production approaches an MTO system. This is because the overall costs are significantly affected by the stock costs, which are considerable, principally due to the cost of late deliveries to the customer, while the costs of changeovers are relatively small. Therefore, the best recommendation for the factory is to minimize stock costs, with the best option being to continue using a pure MTO production system.

To complete the study, we analyzed what would have happened in this production plant if they had not implemented SMED (or had not completed one or more of its stages), and consequently, not reduced the time taken and costs of changeovers; in this situation, changeover costs would have been high compared to stock costs. Figure 5 shows a comparative analysis of the costs in three possible situations:

- Changeovers taking 10h, equivalent to not having implemented SMED in the plant.
- Changeovers taking 3h, equivalent to only implementing the first stage of SMED.
- Changeovers taking 1h, the current situation following six stages of SMED. implementation with progressively quicker changeover times.

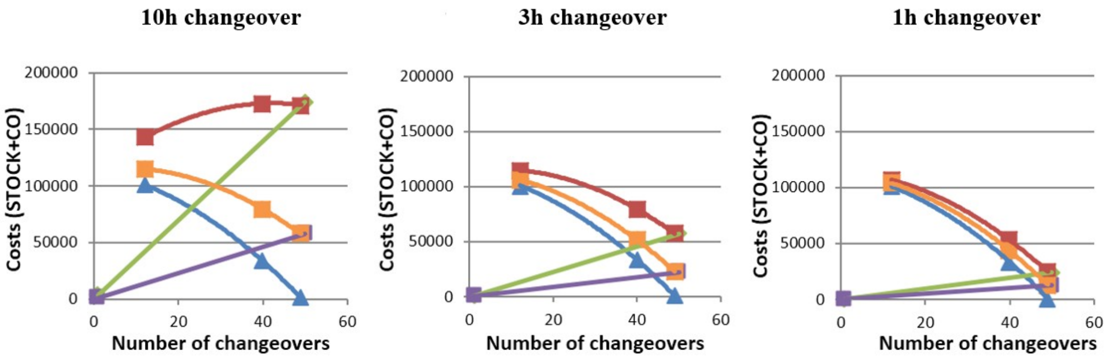

Figure 5. Comparison of total costs of different changeover times

Looking at the situation of the factory operating at less than 100% capacity, in every case the total costs are reduced when there are fewer changeovers. This is because the changeover costs in this situation are not affected by the opportunity costs of adjusting and making setups when other products could be produced instead which would provide income to the factory (shallow slope). Therefore, we may state that, when the factory is not operating at maximum capacity (production below 100%), MTO planning is the most efficient alternative for this plant.

However, the cost analysis when the factory is operating at maximum capacity, shows that when changeover times are long (10h), then minimizing the number of changeovers needed to manufacture each product format is beneficial. This is because the changeover costs in this situation are significant as they represent the loss of a lot of production time, greatly reducing the plant's productivity. Therefore, in this case, it would be better to accept the stock costs associated with a non-MTO system rather than be subject to the costs of changeovers. When changeovers are faster (3h or 1h) it is clear that, although the factory is operating at 100% capacity, it is better to perform more changeovers, as these are cheaper, and they lead to lower stock costs.

Thanks to the implementation of SMED, this production plant has achieved significant reductions in changeover times and has removed the influence of factory workload (that is, whether it is operating at 100% capacity or not) on the suitability of its production system. Thus, MTO is the most appropriate system for organizing production, compared to Heijunka (weekly levelled production) or mass production of each product format (production with minimal changeovers), regardless of whether the plant is operating at maximum capacity or not.

6. Discussion and Conclusions

The study has two principal contributions: (a) it facilitates decision making within the production unit being studied and lets us draw conclusions and make recommendations that are useful for managers and practitioners in general in other businesses and (b) it allows general conclusions to be drawn about the practical implementation of lean management in organizations, contributing to scientific understanding on this topic.

6.1. Practical Contribution and Recommendations for Managers

The impact analysis of implementing Heijunka in this factory demonstrated that the current MTO production line planning, without Heijunka, is the most efficient option for the factory. The analysis identified three factors, which influence the suitability and effectiveness of production balancing through Heijunka: changeover time, the number of different product types (and lot sizes), and the capacity that the production lines are running at. In this way, the study identified various reasons why the implementation of Heijunka would not be ideal for this factory.

We see that if the factory were operating at maximum capacity, applying Heijunka would be more beneficial if changeover times were long, or in other words, before implementing the SMED system. However, once the SMED system was in place, reducing changeover times to a minimum, implementing Heijunka would not produce any improvements in efficiently adapting to specific customer needs. At the same time, in the case of the factory not operating at maximum capacity, Heijunka would not contribute to better results, regardless of changeover times. In this case we see that there is no benefit to Heijunka except when lines are running at 100% capacity and order sizes are very small (or there are many different product lines).

It is important to note that the factory had already implemented TQM tools and that levels of quality would not change in the three production planning scenarios examined in this study.

The results of this study allow us to consider what type of interventions and action plans the management of this factory may put in place in the future to improve efficiency while maintaining high flexibility/customer adaptation, high quality, and rapid delivery times. As de Treville and Antonakis (2006) stated, lean production job design may engender intrinsic worker motivation; but there are likely to be substantial differences in intrinsic motivation under differing lean production configurations. Discounting the suitability of Heijunka, and to improve plant efficiency, continuous improvement, and seeking operational excellence, the management could try to improve worker motivation, involvement, and multi-skilling through implementing shojinka and 'respect for people'. These tools help minimize wasted movements of workers, ensure their safety, and give them greater responsibility by allowing them to participate in running and improving their jobs (Lander and Liker, 2007). Furthermore, Monden (1993) argued that shojinka –adjusting and rescheduling human resources– was an essential support for the TPS and therefore of lean manufacturing.

The factory we studied did not have U-shaped cells, and seru (Yin, Stecke, Swink & Kaky, 2017) is not applicable yet, in so far as its production lines are not reconfigurable. Nevertheless, another avenue to explore in this factory would be to increase the amount of automation or introduce Industry 4.0 enabling tools as the next step on the path of continuous improvement and operational excellence. More specifically, that would entail examining whether the introduction of automation and I4.0 technologies in some activities (mainly repetitive tasks and defect checking in production) would improve quality and process assurance and in turn reduce costs and improve efficiency.

It is also important to highlight the fact that the decision methods and efficiency calculation methods used in this Heijunka viability study are relatively simple, and applicable to other production lines, both in this facility and other companies. So, any organization could easily identify (through the calculation methods used here) whether it would be worth adopting Heijunka and thus balancing production or using a strict MTO planning approach. The analysis in this study may be reproduced in other businesses, modifying the assumptions used here to the idiosyncrasies of each factory.

As a result of this AR project, the company decided not to implement Heijunka (as it would not be profitable or provide other benefits) but rather to explore other alternatives to improve the four manufacturing capabilities (cost, quality, flexibility, and delivery times): improve SMED, automate the area or section under study, or apply Shojinka. In short, this study (based on the AR approach) allows us, at least, to discount Heijunka as a means of improving competitiveness in this factory. It has not resulted in implementation, but rather consists of diagnosis and improvement proposals or solutions and at the same time generates topics for future research, building on the knowledge gained through this first study.

6.2. Contribution to the Advance of Scientific Research

Although our analysis is focused on the situation in a specific factory, our study does allow us to respond to the research questions raised in the introduction.

Responding to RQ1, we concluded that despite the potential benefits of Heijunka –in terms of gaining stability and maximizing the use of resources, increasing efficiency, process capability, and, ultimately, competitiveness–, implementing it does not always contribute to improved operational results. In this sense, and also responding to RQ2, Heijunka may be an ineffective tool in certain circumstances, and we may conclude from this study some of the factors leading to Heijunka possibly not being beneficial in terms of costs. For example, in industries with variable customer demand and where the delivery time can be critical (such as in this study), reducing production flexibility and increasing delivery times can be significantly disadvantageous for the company. In addition, there are operational factors that limit successful Heijunka application, such as (short) changeover times to produce different products, especially in facilities with non-reconfigurable machinery. As in the factory in our study, the successful implementation of SMED allowed the changeover times to be reduced so much that MTO production is better than the application of Heijunka, especially when the lines are at full capacity and there are opportunity costs of stopped lines.

Furthermore, and considering RQ3 and RQ4 together, the study has allowed us to identify some general factors that may affect the successful application of Heijunka:

a) Prior implementation of other lean tools –such as kanban, quality control tools, and particularly SMED, to reduce changeover times and costs– which contribute to improved capacity to respond to customer needs with made-to-order products, efficiency, quality, and short delivery times.
b) The stability of demand, or the possibility of predicting it.
c) The possibility of classifying products into groups or families.
d) Lot sizes or the number of different product lines.
e) Equipment usage rates, whether production lines are running at 100% capacity or not.
f) The level of customer priority requests for very short delivery times.
g) Physical availability of warehousing, to be able to work with a small stock of raw materials and finished goods for levelling.
h) The opportunity cost of full warehousing and lines not running.
i) The cost of unbalanced or irregular working.
j) The availability of multiskilled, flexible workers.

As previously noted, it would be useful in the future to examine the impact that shojinka, empowerment, and respect for people, and the introduction of automation and I4.0 technologies to the production lines would have on the effectiveness of Heijunka.

Our study analyzed different what-if scenarios and showed that there are trade-offs between the benefits and costs of Heijunka implementation. In line with ElMaragy and Deif (2014), our research showed that the benefits from implementing lean manufacturing tools depend on various internal and external factors. Despite the implementation of lean manufacturing practices providing potential advantages, it should not be achieved at any cost.

We may conclude that a company operating in a lean management environment should only select and implement those principles and tools which are appropriate for the specific characteristics of the business and its market. In other words, a successful lean implementation can be carried out gradually and progressively, and some tools may even be discarded. In this regard, ElMaragy and Deif (2014: page 393) also concluded that the choice between the "best lean" and "no lean" practices for achieving production levelling does not have to be completely binary but is instead a continuum between these two poles.

Our research continues the open debate in the scientific arena about what is and is not lean, accepting that a company doesn't need to put all of the principles and tools from the original TPS into practice for it to be considered a lean company. Our results are more in line with a contingent than a universalist approach and can provide additional support to lean decision-makers or practitioners.

6.3. Limitations and Future Lines of Research

Despite the results and conclusions of our study, it is not without limitations. As previously mentioned, the efficiency calculation methods are relatively simple. Although this allows our analysis to be easily reproduced in other factories or companies, we are aware of the limitations that this entails. In this sense, in the future it would be suitable to explore more sophisticated methods for calculating stock and changeover costs, to study in more detail, the suitability of implementing Heijunka in different production environments. Besides, our cost analysis only focuses on changeovers and stocks, whereas the true gains of production levelling are in proper workforce and machine workload, which is not included in the analysis. In this regard, future research will continue within the framework of the AR project which the company in this study began and it will investigate the potential consequences for the company of both shojinka (increasing workers training and widening their skill set) and increased process automation and digitization for improved business effectiveness in line with continuous improvement and the search for operational excellence. Nowadays, many companies in various sectors are simultaneously implementing lean management and Industry 4.0 technologies and lean 4.0 is an emerging topic of research. More specifically, Bouthbagha and El Abbaddi (2024) recently noted that additional research is required about I4.0 technologies that can facilitate implementation of Heijunka and the workforce's adaptation to it. Furthermore, they identified a lack of literature interested in analyzing the effect of Heijunka implementation on people, and "their productivity in addition to the reluctance they show during the transition to a lean system" (Bouthbagha and El Abbaddi, 2024: page 37).

In addition, although this study was positioned as part of an AR research project, it did not produce any specific changes or actions in the "gemba" other than analysis, reflection and diagnosis. In this regard, some steps of the AR iterative cycle are not contemplated as the study did not involve immediate intervention. This could be considered a limitation of our AR study, and it could be addressed with further research examining the effects of implementing Shojinka and automation and I4.0 technologies in line with the continuous improvement process.

Finally, it would be interesting to look more deeply into the research questions and conclusions raised by this study and examine the propositions it produced in a large sample of companies implementing lean management with different levels of effectiveness. Thus, further research is required to evaluate the generalizability of our findings, and this future research will have to conduct multi-case studies or more single-case studies to allow us to reach more generalizable conclusions.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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