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Heijunka-Levelling customer orders: a systematic literature review

Meryem Boutbagha [a1*], **Laila El Abbadi** [a2]

[a] Laboratory of Engineering Sciences, National School of Applied Sciecnes, Ibn Tofail University, PO Box 241, University Campus, Kenitra14000, Morocco.

[a1] *meryem.boutbagha@uit.ac.ma*; [a2] *laila.elabbadi@uit.ac.ma*

Abstract:

Heijunka is the central concept of the Toyota Production System which aims to maintain both flexibility and stability of the production system by producing the same quantity of products every time interval (a day, a shift, an hour, etc.). This study is a systematic literature review whose objective is to give an idea about the most important research areas regarding this concept and to propose an agenda for further research. A total of 60 articles were reviewed using specified inclusion and exclusion criteria. The review showed that heijunka received little attention in the academic literature and disclosed the existence of three main research topics, namely: Implementation of heijunka and its benefits, Heijunka-related problem-solving using optimization, and Heijunka and Industry 4.0 technologies. This review could have some limitations related to the number of reviewed articles. It is possible that, unintentionally, some important articles haven't been included.

Key words:

Heijunka, Production leveling, Toyota Production System, Lean Production, Systematic literature review.

1. Introduction

Goods were once produced by craft method and were too expensive for people to buy (Womack et al., 2007). The hand-crafted production was based on well qualified and experimented workforce (El Abbadi et al., 2020; Ma, 2014). Then came the Mass Production System or the American Production System (APS) (Hu, 2013) as an alternative, at the beginning of the twentieth century (Womack et al., 2007), basing on division of labor, moving assembly lines, parts interchangeability in addition to economy of scale in order to reduce costs (El Abbadi et al., 2020). Nevertheless, the low costs were at the expense of variety of products which were all the same (Womack et al., 2007). Afterwards emerged a new production system in Japan: Toyota Production System (TPS) (Later named Lean Production System) which, at the same time, merges the advantages of the previous production systems and avoids their disadvantages (Womack et al., 2007). What's more, the implementation of lean tools has been proven to have a positive impact on the global performance of companies, whether it's economic, environmental or social (Elrhanimi et al., 2016; 2019).

The best way to explain TPS philosophy is the old proverb saying "Haste makes waste", meaning that doing things in a speedy and hasty way will certainly results on wasting time, money and energy. As per with this idea, Taiichi Ohno explained that the core of TPS philosophy is to eliminate waste in all its forms (Elrhanimi & EL Abbadi, 2020) and that "can be realized only when all the workers become tortoises" (Ohno, 1988). Tortoises refer to slowness but also to consistence.

In that sense, TPS «takes the total volume of orders in a period and levels them out so approximately the same amount and mix are made each day for a period of time» (Liker, 2004). This concept of levelling customer orders is what Toyota called heijunka, the production system wherein a sequence of a mix of products is produced on the same assembly

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line (Coleman & Vaghefi, 1994), which insinuates that both volume and type of products are levelled (Boutbagha & El Abbadi, 2022).

Per contra, the APS does the opposite. The production is done according to the order of customer demand, and that has turned out to create problems and to deliver poor quality products (Liker, 2004): Extra work may be done one week to ensure delivering the exact quantity to the customer but in the following, employees may have small amount of work to perform (Liker, 2004). In some cases, and in order to deal with unexpected demands, extra items are produced and stocked (make-to-stock), which leads to extra charges due to the inventory management. What's more, all the pile of products in the inventory become obsolete if a defect has been detected or if a design change has been made.

To illustrate the concept of heijunka, let us assume that a company, have got a portfolio of three products: A, B and C. Under heijunka, rather than producing all the As, all the Bs then all the Cs with changeover process that takes too long, the customer orders for short periods of time are gathered and separated into small batches with a predefined pattern then finally distributed equally on the production schedule (Bebersdorf & Huchzermeier, 2022) (see Figure 1).

A	B	B	C	A	A	B	..	C

Figure 1. Production schedule under heijunka context.

It is only logical to think that changing from one model to another in the mix production system needs to be done as quickly as possible. For this reason, the implementation of heijunka needs to be preceded by the utilization of some techniques like SMED (Coleman & Vaghefi, 1994), to minimize/eliminate the setup processes (Bebersdorf & Huchzermeier, 2022).

Furthermore, heijunka has got two main objectives: the first one is to reduce inventories by the mean of small batch mix production (Coleman & Vaghefi, 1994). The second one is to balance loads in term of work to both operators and machines (process capacity) on one hand, and between production processes on the other hand (Coleman & Vaghefi, 1994).

This article is a systematic literature review (SLR) wherein the concept of heijunka will be discussed as the most basic one to TPS. It is important to note that this review is a second part of a previous work, which is a bibliometric study of the state of the art regarding heijunka (Boutbagha & El Abbadi, 2022). The remainder of this paper is structured into five sections. After the Introduction, the Methodology is introduced in section II to show how this research was conducted. The third section deals with the results which is nothing but a content analysis of the relevant research topics. In section IV, an agenda for future researches is outlined. The last section summarizes the results and draws the conclusion.

2. Methodology: Systematic literatura review

In order to pave the way for the researchers interested in heijunka, a systematic literature review is conducted. This kind of reviews, contrarily to others such as Meta-Analysis, requires a fewer number of papers to be studied and reviewed (Donthu et al., 2021). So that one can conduct a scientifically rigorous SLR, there are essential steps to follow (Okoli, 2015) (see Figure 2).

2.1. Research questions (RQs)

To define the objectives of this work, it was necessary to start the review formulating the RQs which are as follow:

RQ1: What is the state of the art regarding heijunka, especially in the last ten years?

RQ2: To what extent heijunka has been given importance in the academic literature?

2.2. Inclusion and exclusion criteria

The search was conducted using the following key-words: HEIJUNKA, PRODUCTION LEVELING/LEVELLING, PRODUCTION SMOOTHING, MIXED MODEL PRODUCTION, all as synonyms of heijunka and was done on several scientific databases and search engines (SCOPUS, GOOGLE SCHOLAR, SCIENCEDIRECT, IEEE, WEB OF SCIENCE, EBSCO, TAYLOR & FRANCIS). All the articles that contain the mentioned keywords in their titles, keywords section and cores were included.

All the references cited in those articles were also skimmed so as to broaden the dataset of articles to be studied.

Moreover, all the articles that are not written in English were excluded. The repeated ones were deleted. if two papers with the same authors and the same title were found, the prior one is excluded and the recent is kept.

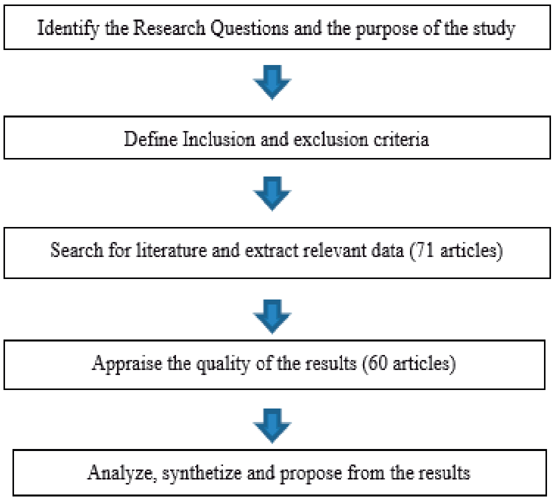

Figure 2. Systematic literature review steps (Chiarini, 2020).

2.3. Extracting data

The authors started this search using the above-mentioned keywords. They took into consideration studies from journals, proceedings and chapter books. 60 heijunka related articles were found (up to April 2022). It is to note that, from up now, this study will focus on the articles from only the last ten years (2012-2022), of which there are 45, as to find out the most recent research topics. Afterwards, the authors extracted the appropriate data: the title of the study, the year of publication, the corresponding authors and the main ideas discussed in each work, then put them into categories (Boutbagha & El Abbadi, 2022) (See Table 1).

3. Results

In this section, the content of each of the pre defined categories will be presented.

Table 1. Analysis of the most important topics related to heijunka during the last ten years.

Categories	References
Implementation of heijunka and its benefits	Barbosa et al., 2013; Korytkowski et al., 2013; ElMaraghy & Deif, 2014; İşler & Güner, 2014; Aoki & Katayama, 2018; Rewers et al., 2017; Deniz & Ozcelik, 2018; Sodikin et al., 2018; Kulsum et al., 2019; Shetty et al., 2019; Santos, 2020; Altamirano et al., 2020; Rewers & Diakun, 2021; Gupta & Kumar, 2019; Conners et al., 2022
Heijunka related problem Solving using optimization	Matzka et al., 2012; Faccio et al., 2013; Bohnen et al., 2013; Tonelli et al., 2013; Korytkowski et al., 2014; Bautista-Valhondo & Alfaro-Pozo, 2018; Bautista & Alfaro-Pozo, 2018; Renteria-Marquez et al., 2020; Bautista-Valhondo, 2021a; Bautista-Valhondo, 2021b
Heijunka and industry 4.0 technologies	Kolberg et al., 2017; Żywicki et al., 2017; Wagner et al., 2017; Romero et al., 2018; Buer et al., 2018; Bateni & Liu, 2019; Kjellsen et al., 2021; Ciano et al., 2021; Spenhoff et al., 2021
Planning and scheduling of production	Wilson & Ali, 2014; Rewers et al., 2018; Rewers, 2019; Rewers et al., 2021
Inventory handling	Abed, 2015; Kurihara et al., 2019
Others	Tegel & Fleischmann, 2012; Bannister et al., 2014; Huchzermeier et al., 2020; Bebersdorf & Huchzermeier, 2022

3.1. Implementation of heijunka and its benefits

Implementing heijunka has turned out to be a competitive advantage. But before talking about its advantages, let us first introduce how it is implemented (see Figure 3). It is to note that those different steps were specifically investigated in a number of researches included in this SLR.

Back on topic, (Korytkowski et al., 2013) proved, by means of statistical analysis applied to a case study the positive impact that heijunka has got on system efficiency, using Work-In-Progress and Throughput Time indicators. In the same vein, (Rewers et al., 2017) applied the production leveling to a manufacturing enterprise which produces surgical instruments. They explained how they could reduce the Throughput Time and enhance the efficiency of the personnel group although their reluctance to this new production method (Rewers et al., 2017).

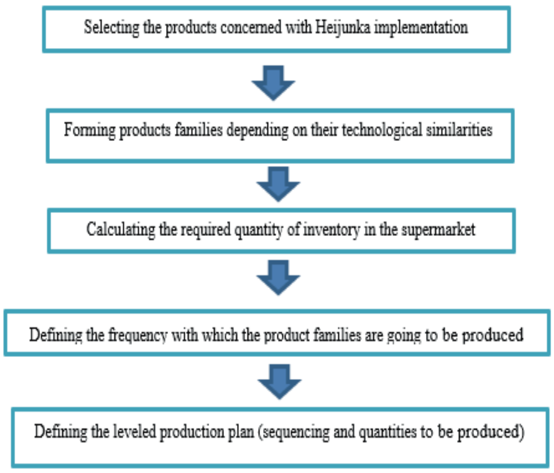

Figure 3. Phases of heijunka Implementation (Rewers et al., 2018).

Heijunka has the particularity to be applied to service companies as well. Indeed, (Deniz & Ozcelik, 2018) used heijunka along with other lean techniques to deal with the operational problems in a public hospital. Another example is its application, in concert with visual management, in a breast imaging reading room in order to "improve efficiency and minimize waste in the diagnostic" (Conners et al., 2022). Several other examples illustrating the advantages of implementing heijunka can be cited. Indeed, in (Gupta & Kumar, 2019), heijunka has been applied to an Indian Automotive OEM (Original Equipment Manufacturer) while in (Aoki & Katayama, 2018), the implementation was done in the agricultural industry in Japan. Another example is an electronic automotive parts manufacturing company in which heijunka has turned out to be "the most effective technique to stabilize the stock levels" (Shetty et al., 2019).

In addition, heijunka has also been effective in the construction sector. (Barbosa et al., 2013) developed a heijunka computerized system which helped in reducing the work stoppage and idle machines and improving the organization of the site along with workers productivity. As to (Altamirano et al., 2020), the authors proposed the application of a set of Lean Production (LP) tools including heijunka in order to eliminate waste and increase productivity of the system. Clothing industry does not make an exception either. Because it is an ever-changing sector, producing according to heijunka has been proven to be the most suitable solution (Sodikin et al., 2018), (İşler & Güner, 2014) for the need of producing less items but in many models (İşler & Güner, 2014).

Notwithstanding all the studies that cast the light on the advantages of heijunka implementation, (Kulsum et al., 2019) explained that it was not successful in producing the intended results of making a faster makespan value comparing with non-delay method. Nevertheless, this work cannot be taken into consideration as it is a unique case of study.

In addition, the use of heijunka is senseless in other contexts such as in enterprises that make use of the mass production system or unit production wherein "all the components that make part of the product are unique" (Rewers & Diakun, 2021). What's more, Implementing heijunka should not be judged only by its positive impact on the system behavior but also by taking into consideration its cost that must be thoroughly studied (ElMaraghy & Deif, 2014).

3.2. Heijunka related problem-solving using optimization

Optimization is used nowadays for problem solving in a very large number of scientific and engineering disciplines (Lange, 2013) for its ability to select the best solution from a selection of other solutions (El-Halwagi, 2006), and production planning under heijunka is not an exception.

In the case of production leveling, the majority of the optimization models pay particular attention to large scale production, and take the concern of finding the suitable leveling pattern/production sequence, to an analytical level, and this what's called Production Smoothing Problem (Bohnen et al., 2013). In spite of that, (Bohnen et al., 2013) suggested a systematic procedure to level the low volume and high mix production, based on methods of Group Technology whose purpose is to "decompose a manufacturing system into subsystems" (Kusiak, 1987). It uses clustering analysis in order to gather the technically similar products into groups/families so as to create the leveling pattern (Bohnen et al., 2013).

Another optimization issue is discussed in the work of (Korytkowski et al., 2014). They made an approach, which is a tradeoff between flexibility and stability, in order to define a production lot-size to be produced in a heijunka context based on an algorithm (Korytkowski et al., 2014). The purpose is to avoid demand fluctuations to pass to the manufacturing process, which means less pression on the production and a simplified shop floor management (Korytkowski et al., 2014). In a Heijunka-Kanban system wherein the production is controlled by kanban and leveled with heijunka, the number of kanbans to be used should be defined so as the percentage of customer demand which can be satisfied immediately attains the required value (Matzka et al., 2012). The calculation of the optimal number of kanbans for only one kind of product is done by modeling the production system as a queuing network, and the results are verified using SIMAN simulation language (Matzka et al., 2012). However, the simple application of the kanban system in a mixed model assembly system does not seem to be evident to the authors in (Faccio et al., 2013). Indeed, feeding the assembly lines, from the supermarket, is complicated because of "the replenishment lead time, the production mix variation and the commonality between the different models assembled" (Faccio et al., 2013). Thus, the authors suggested a procedure which optimally determines all the variables that are in relationship with this feeding system, including kanban numbers (Faccio et al., 2013).

As flexibility is a topic of interest of heijunka, it has been discussed by (Tonelli et al., 2013) as an optimization related issue, wherein the betterment of planning for a model flexibility management is assured by an Advanced Planning System completing the ERP (Entreprise Ressource Planning) regarding the planning capabilities, and based on Mixed Integer Programming model.

The permutation Flow Shop Scheduling Problem (PFSP) is discussed by (Bautista-Valhondo, 2021b) and (Bautista-Valhondo, 2021a). "The PFSP is a production problem for finding the best sequence of jobs that to be processed by machines in order to minimize the given objective function" (Kumar & Jadon, 2014). The objective function in that case is the total completion time for all the jobs (Bautista-Valhondo, 2021b). The (Bautista-Valhondo, 2021b), (Bautista-Valhondo, 2021a) suggested two methods (which were applied to a case study of one of Nissan plants) to solve such a problem: Mixed Integer Linear Programming and the MultiStart-Local Search algorithm. The case study proved, by mean of an economic analysis, the positive impact of transforming the assembly line into a Heijunka-Flow Shop (Bautista-Valhondo, 2021a). The same plant of Nissan has been subject of two other researches, both interested in the Mixed Model Sequencing Problem (Bautista-Valhondo & Alfaro-Pozo, 2018), (Bautista & Alfaro-Pozo, 2018). While the first one is interested in minimizing both of the work overload and the idle by means of evaluating their costs and using mathematical models (Bautista-Valhondo & Alfaro-Pozo, 2018), the second one used a GRASP (Greedy Randomized Adaptive Search Procedure) algorithm for the same purpose.

Finally, a discrete event simulation case study was performed by (Renteria-Marquez et al., 2020) to bring out a model that takes into consideration all the critical variables from the three most important sections of the system: the production floor, the warehouse and the material handling system. The objective of the study is to define the optimal batch size in the case of a complex production assembly (Renteria-Marquez et al., 2020).

3.3. Heijunka and Industry 4.0 technologies

It is the German government which first coined the term "Industry 4.0" (I4.0) as a "strategic initiative" in January 2011 (Bartodziej, 2017), whose objective is to increase the manufacturing industry competitiveness in the country (Chiarini, 2020). Thanks to I4.0 technologies, machines, software, warehouses, etc. can exchange data/information and control the whole production flow (Chiarini, 2020).

This section spells out the impact of Industry 4.0 technologies on LP tools in general and heijunka in particular as I4.0 is a promising concept, and a growing research area (Buer et al., 2018). Indeed, Industry 4.0 seeks to satisfy market demand by integrating Information and Communication Technologies into production (Kolberg et al., 2017) and to transform the industrial production system from physical to cyber-physical (Kagermann, 2013), (Wagner et al., 2017).

Again, the implementation of an Industry 4.0 system needs the management strategies, the business models and the business processes to be adapted to this change (Wagner et al., 2017).

However, it is remarkable that the works interested in studying the benefits of applying individual I4.0 technologies on specific lean manufacturing tools are sparse (Ciano et al., 2021). Nevertheless, it is noteworthy that the authors in (Żywicki et al., 2017) resorted to AnaPro, a software using advanced analytics and providing assistance in “separating product families, specifying the demand for products and implementing production” (Żywicki et al., 2017) for an effective implementation of the production leveling concept.

As such, the authors in (Kjellsen et al., 2021, p. 0) delved into the ability of Industry 4.0 technologies, namely: IoT, Big Data Analytics and Integration of IT systems (Mayr et al., 2018; Kjellsen et al., 2021), to improve and support heijunka practices in the process industry. They showed that IoT and Big Data Analytics provide information/data related to the process characteristics that can be used to do simulations allowing prediction of process behavior and increasing its reliability, which leads to reduced changeover and production processing times (Kjellsen et al., 2021).

Wagner et al. (2017) developed a matrix in which they studied the impact of Industry 4.0 technologies on LP tools by rating the technologies, whether they have got low positive impact (+), high estimated impact (++) or highest possible impact (+++) on a specific lean tool, including heijunka. This matrix can be used as a conceptual framework to provide help in the development of Industry 4.0 applications (Wagner et al., 2017). The authors in (Ciano et al., 2021) stated that leveling workload can be ensured using Artificial Intelligence. They also inspected the effects of LP practices on I4.0 technologies (Ciano et al., 2021). Contrarily to most LP tools, heijunka has been identified to have no direct effect on I4.0 technologies (Ciano et al., 2021). Yet, authors in (Bateni & Liu, 2019) have a different point of view. They mentioned having been inspired by heijunka to solve data and memory management problem related to data-driven Autonomous Embedded Systems, which “may cause unpredictability in outputting autonomous control decisions” (Bateni & Liu, 2019).

3.4. Planning and scheduling of production

It seems obvious that the real challenge in production leveling is to define the adequate lot size and production interval that ensure customer demand satisfaction and a minimum stock level (Rewers, 2019).

As per with that fact, and in order to find the right combination of lot size and production intervals, the authors in (Rewers, 2019) developed a method, meant to be applied in the scheduling of leveled production, which aims to plan the inflow of products from production process. It consists of simulating 3 situations, in each one of them some parameters (namely: lot size, production interval, initial stock levels, order size and placement rate) change while the others remain constant (Rewers, 2019). In the same vein, (Rewers et al., 2021) developed a simulation model in which three variants of the production plan were proposed and simulated on a software. The best variant of the production plan was where the batch is the largest and where the production is done with the lowest frequency possible (Rewers et al., 2021).

Furthermore, (Wilson & Ali, 2014) have suggested the use of the Product Wheel concept to develop a production schedule in the context of shared resources/production lines in a process industry. It is important to note that the use of heijunka in a process industry needed to be adjusted and that is what brought out the concept of Product wheel (Wilson & Ali, 2014), also called block planning (Schouten, n.d.), which isn’t an optimization technique but rather a heuristic one (Wilson & Ali, 2014).

Finally, the authors in (Rewers et al., 2018) explained how defining a set of suitable priority rules is necessary for the development of a levelled production plan. However, many aspects of this issue haven’t been discussed yet as this work is a first stage of research (Rewers et al., 2018).

3.5. Inventory handling

The study in (Abed, 2015) paid particular attention to ameliorate the inventory handling in the optimal time and flexibility by proposing the use of a Dynamic Gemba model. To do so, the authors resorted to Traveler Salesman Technique and to Heijunka Matrix to fill in with the delivery time between stations (Abed, 2015). Based on minimum average-energy principle, the authors in (Kurihara et al., 2019) developed a new model to minimize the inventory in a context of production leveling. From the outcome of numerical experiments, it has been shown that, in case of the proposed model, the inventory level is lower than the one in traditional exponential smoothing (Kurihara et al., 2019).

3.6. Others

In this category, are gathered all the articles that could not be inserted in any of the above-mentioned categories, for they studied various issues.

Indeed, the authors in (Bebersdorf & Huchzermeier, 2022) showed that heijunka finds it roots in TPS philosophy which makes it in the basis of every production system of nowadays. They also discussed how “variable takt” is effective as a method to better level “an assembly line with different products in line balancing”. The same issue was also discussed by (Huchzermeier et al., 2020), wherein the “varioTakt” is developed and implemented in a German agricultural machinery manufacturer, ensuring a novel assembly line balancing and sequencing approach for mixed model assembly.

While the discrepancy between customer demand and process capacity is the subject of Bannister et al. (2014), Tegel & Fleischmann (2012) called attention to the relationship between fill time/fill rate, inventory and reserve capacity, in the case of a production line under heijunka control. The authors could give an estimation of the consequences that have capacity and inventory planning on fill time/fill rate and calculate the number of kanban cards necessary to guarantee a certain value of it (of fill time/fill rate) (Tegel & Fleischmann, 2012).

4. Discussion and agenda for future researches

The previous sections have revealed the existence of three categories/topics on which researchers have shown a growing interest, namely:

- Implementation of heijunka and its benefits: This has shown a broad applicability of this concept (both in manufacturing and service sectors), but has proven it is an immature field of study that still needs to be explored.
- Heijunka related problem-solving using optimization: Optimization has got rigorous methods to help in the decision making (Rao, 2019), this is why it is more and more used to solve heijunka related problems such as defining the optimal lot size and the sequence of the mix of products.
- Heijunka and Industry 4.0 technologies: Researchers are still investigating the impact of I4.0 on different fields, heijunka included, which explains the tendency in a number of publications to consider studying this topic.

As may be noticed below, very few publications interested in heijunka, all disciplines taken together, can be found. Only 60 relevant articles formed the dataset of our study, 45 of them were selected from the last ten years to be used in a topic trend analysis, which insinuates that heijunka has received little attention in literature although being TPS main concept. It is true that this conclusion has also been made by (Coleman & Vaghefi, 1994; Shah & Ward, 2003; Hüttmeir et al., 2009), but this review came to the same result using different reasoning. Indeed, (Hüttmeir et al., 2009) claimed that, when listing with details lean manufacturing practices, (Shah & Ward, 2003) did not include neither heijunka nor production leveling.

On the basis of the review in literature of the most researched topics related to heijunka, the authors found that there are some remaining issues that haven’t been solved yet and on which work should be continued. In this way, the proposed agenda for future researches is as follows:

- Human being is at the center of the TPS philosophy (Liker, 2004). From this point, it is noticed that there is a lack in works interested in studying the effect of heijunka implementation on people, their productivity in addition to the reluctance they show during the transition to a lean system.
- More research into heijunka implementation cost is still necessary since studying the only positive impact on the system behavior is not sufficient. A cost estimation study is needed as well as a comparison of the current and target situation (before and after implementing heijunka).
- The works interested in studying the benefits of applying I4.0 technologies on specific LP tools are sparse (Kjellsen et al., 2021). Obviously, further researches are required, especially about the type of solutions proposed by those technologies that can facilitate the implementation of heijunka and the adaptation of the workforce to it. But since the adoption of those technologies is cost intensive, there is also a need to study its financiel benefits.

5. Conclusion

Through the SLR that has been carried out, the authors tried to answer two RQs:

- **RQ1**: What is the state of the art regarding the concept of heijunka, especially in the last ten years?
- **RQ2**: To what extent heijunka has been given importance in the academic literature?

To their knowledge, this is the first work that used a SLR to study the concept of heijunka.

Findings showed that the answer to the first research question **RQ1** is included in Table 1, in which the most important topics related to heijunka and discussed in academic literature during the last ten years are presented. It is also concluded that there is a tendency to study the impact of heijunka implementation on the production system, in different industries such as automotive, agricultural and construction industry, which turned out to be a competitive advantage. Moreover, heijunka can be implemented in service companies as well. The authors also focused on using optimization to solve the problems related to heijunka, such as finding the optimal production lot size and defining the optimal sequence of the mix of products. Besides, particular attention is paid to the impact of the I4.0 technologies on LP tools in general and heijunka in particular despite that those last ones are remarkably fewer comparing to other LP tools.

The second research question **RQ2** can be answered basing on the number of articles used in this SLR, which is only 45. Contrarily to other important concepts of Lean Manufacturing, such as kanban (Boutbagha & El Abbadi, 2022), it was noted that heijunka has received less attention in the academic literature.

In fine, this SLR is not without limitations. Firstly, the articles studied in this review are intersections between different disciplines. As a consequence, the fact that they are included in a given category and not in another is not conclusive. Secondly, a lot of articles in this SLR did not talk about heijunka as a main subject but as being one among many of LP tools. Finally, it is possible that, unintentionally, some articles which would permit a more meticulous analysis of heijunka might have been skipped to be included.

References

Abed, A. M. (2015). Create Heijunka 5's Matrix to Control the Dynamic Gemba as Lean Tool. *Journal of Human Resource Management*, *3*, 6–16. https://doi.org/10.11648/j.jhrm.20150302.11

Altamirano, E., Cruz, H., & Carpio, C. (2020, January 1). *Lean model to reduce picking time delays through Heijunka, Kanban, 5S and JIT in the construction sector*. https://doi.org/10.18687/LACCEI2020.1.1.92

Aoki, R., & Katayama, H. (2018). Heijunka Operation Management of Agri-Products Manufacturing by Yield Improvement and Cropping Policy. In J. Xu, M. Gen, A. Hajiyev, & F. L. Cooke (Eds.), *Proceedings of the Eleventh International Conference on Management Science and Engineering Management* (pp. 1407–1416). Springer International Publishing. https://doi.org/10.1007/978-3-319-59280-0_118

Bannister, A. R., Bickford, J. P., & Swanke, K. V. (2014). Demand Smoothing. *IEEE Transactions on Semiconductor Manufacturing*, *27*(3), 335–340. https://doi.org/10.1109/TSM.2014.2312358

Barbosa, G., Andrade, F., Biotto, C., & Mota, B. (2013). *Heijunka system to level telescopic forklift activities using tablets in construction site*. https://www.researchgate.net/publication/287074376_Heijunka_system_to_level_telescopic_forklift_activities_using_tablets_in_construction_site

Bartodziej, C. J. (2017). *The Concept Industry 4.0*. Springer Fachmedien. https://doi.org/10.1007/978-3-658-16502-4

Bateni, S., & Liu, C. (2019). Predictable Data-Driven Resource Management: An Implementation using Autoware on Autonomous Platforms. *2019 IEEE Real-Time Systems Symposium (RTSS)*, 339–352. https://doi.org/10.1109/RTSS46320.2019.00038

Bautista, J., & Alfaro-Pozo, R. (2018). A GRASP algorithm for Quota sequences with minimum work overload and forced interruption of operations in a mixed-product assembly line. *Progress in Artificial Intelligence*, *7*(3), 197–211. https://doi.org/10.1007/s13748-018-0144-x

Bautista-Valhondo, J. (2021a). Exact and heuristic procedures for the Heijunka-flow shop scheduling problem with minimum makespan and job replicas. *Progress in Artificial Intelligence*, *10*(4), 465–488. https://doi.org/10.1007/s13748-021-00249-z

Bautista-Valhondo, J. (2021b). Solving the Permutation Heijunka Flow Shop Scheduling Problem with Non-unit Demands for Jobs. In E. Alba, G. Luque, F. Chicano, C. Cotta, D. Camacho, M. Ojeda-Aciego, S. Montes, A. Troncoso, J. Riquelme, & R. Gil-Merino (Eds.), *Advances in Artificial Intelligence* (pp. 170–181). Springer International Publishing. https://doi.org/10.1007/978-3-030-85713-4_17

Bautista-Valhondo, J., & Alfaro-Pozo, R. (2018). An expert system to minimize operational costs in mixed-model sequencing problems with activity factor. *Expert Systems with Applications*, *104*, 185–201. https://doi.org/10.1016/j.eswa.2018.03.031

Bebersdorf, P., & Huchzermeier, A. (2022). Heijunka: Fast like a Tortoise. In P. Bebersdorf & A. Huchzermeier (Eds.), *Variable Takt Principle: Mastering Variance with Limitless Product Individualization* (pp. 69–90). Springer International Publishing. https://doi.org/10.1007/978-3-030-87170-3_3

Bohnen, F., Buhl, M., & Deuse, J. (2013). Systematic procedure for leveling of low volume and high mix production. *CIRP Journal of Manufacturing Science and Technology*, *6*(1), 53–58. https://doi.org/10.1016/j.cirpj.2012.10.003

Boutbagha, M., & El Abbadi, L. (2022). Production Leveling or Heijunka: A Bibliometric Study. *2022 IEEE 3rd International Conference on Electronics, Control, Optimization and Computer Science (ICECOCS)*, 1–5. https://doi.org/10.1109/ICECOCS55148.2022.9982975

Buer, S.-V., Strandhagen, J. O., & Chan, F. T. S. (2018). The link between Industry 4.0 and lean manufacturing: Mapping current research and establishing a research agenda. *International Journal of Production Research*, *56*(8), 2924–2940. https://doi.org/10.1080/00207543.2018.1442945

Chiarini, A. (2020). Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research. *The TQM Journal*, *32*(4), Article 4. https://doi.org/10.1108/TQM-04-2020-0082

Ciano, M. P., Dallasega, P., Orzes, G., & Rossi, T. (2021). One-to-one relationships between Industry 4.0 technologies and Lean Production techniques: A multiple case study. *International Journal of Production Research*, *59*(5), 1386–1410. https://doi.org/10.1080/00207543.2020.1821119

Coleman, B. J., & Vaghefi, M. R. (1994). *Heijunka (?): A key to the Toyota production system—ProQuest*. https://www.proquest.com/openview/a513208ef093a1e2314d74213a0bf4c2/1?pq-origsite=gscholar&cbl=36911

Conners, A. L., Clark, S. E., Brandt, K. R., Hunt, K. N., Chida, L. M., Tibor, L. C., Ruter, R. L., & Khanani, S. A. (2022). Leveling the Workload for Radiologists in Diagnostic Mammography: Application of Lean Principles and Heijunka. *Journal of Breast Imaging*, *4*(1), 61–69. https://doi.org/10.1093/jbi/wbab090

Deniz, N., & Ozcelik, F. (2018). *Improving healthcare service processes by lean thinking*. *24*, 739–748. https://doi.org/10.5505/pajes.2017.89814

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

El Abbadi, L., Elrhanimi, S., & Manti, S. (2020). *A Literature Review on the Evolution of Lean Manufacturing*. *10*, 13–30. https://doi.org/10.33168/JSMS.2020.0402

El-Halwagi, M. M. (Ed.). (2006). Overview of optimization. In *Process Systems Engineering* (Vol. 7, pp. 285–314). Academic Press. https://doi.org/10.1016/S1874-5970(06)80012-3

ElMaraghy, H., & Deif, A. M. (2014). Dynamic modelling of impact of lean policies on production levelling feasibility. *CIRP Annals*, *63*(1), 389–392. https://doi.org/10.1016/j.cirp.2014.03.108

Elrhanimi, S., & EL Abbadi, L. (2020). Assessment model of lean effect (AMLE). *The TQM Journal*, *33*(5), 1020–1048. https://doi.org/10.1108/TQM-02-2019-0039

Elrhanimi, S., el Abbadi, L., & Abouabdellah, A. (2019). Lean Global Effect Evaluation. *Journal of Advanced Research in Dynamical and Control Systems*, *11*, 932–941. https://doi.org/10.5373/JARDCS/V11/20192653

Elrhanimi, S., el Abbadi, L., & Bouabdellah, A. (2016). *What is the relationship between the tools of Lean manufacturing and the global performance of the company?* 1–6. https://doi.org/10.1109/GOL.2016.7731718

Faccio, M., Gamberi, M., & Persona, A. (2013). Kanban number optimisation in a supermarket warehouse feeding a mixed-model assembly system. *International Journal of Production Research*, *51*(10), 2997–3017. https://doi.org/10.1080/00207543.2012.751516

Gupta, P., & Kumar, S. (2019, June 14). *Productivity improvements in an Indian automotive OEM using Heijunka, a lean manufacturing approach: A case study*.

Hu, S. J. (2013). Evolving Paradigms of Manufacturing: From Mass Production to Mass Customization and Personalization. *Procedia CIRP*, *7*, 3–8. https://doi.org/10.1016/j.procir.2013.05.002

Huchzermeier, A., Mönch, T., & Bebersdorf, P. (2020). Case—The Fendt VarioTakt: Revolutionizing Mixed-Model Assembly Line Production. *INFORMS Transactions on Education*, *20*(3), 141–153. https://doi.org/10.1287/ited.2019.0224cs

Hüttmeir, A., de Treville, S., van Ackere, A., Monnier, L., & Prenninger, J. (2009). Trading off between heijunka and just-in-sequence. *International Journal of Production Economics*, *118*(2), 501–507. https://doi.org/10.1016/j.ijpe.2008.12.014

İşler, M., & Güner, M. (2014). *HEIJUNKA TECHNIQUE FROM LEAN PRODUCTION TOOLS AND ITS APPAREL APPLICATIONS*. 4.

Kagermann, H. (2013). *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0: Securing the Future of German Manufacturing Industry; Final Report of the Industrie 4.0 Working Group*. Forschungsunion.

Kjellsen, H. S., Ramillon, Q. J. L., Dreyer, H. C., & Powell, D. J. (2021). Heijunka 4.0 – Key Enabling Technologies for Production Levelling in the Process Industry. In A. Dolgui, A. Bernard, D. Lemoine, G. von Cieminski, & D. Romero (Eds.), *Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems* (pp. 704–711). Springer International Publishing. https://doi.org/10.1007/978-3-030-85874-2_77

Kolberg, D., Knobloch, J., & Zühlke, D. (2017). Towards a lean automation interface for workstations. *International Journal of Production Research*, *55*(10), 2845–2856. https://doi.org/10.1080/00207543.2016.1223384

Korytkowski, P., Grimaud, F., & Dolgui, A. (2014). Exponential smoothing for multi-product lot-sizing with heijunka and varying demand. *Management and Production Engineering Review*, *5*(2), 20–26. https://bibliotekanauki.pl/articles/406946

Korytkowski, P., Wisniewski, T., & Rymaszewski, S. (2013). Multivariate simulation analysis of production leveling (heijunka)—A case study. *IFAC Proceedings Volumes*, *46*(9), 1554–1559. https://doi.org/10.3182/20130619-3-RU-3018.00285

Kulsum, Muharni, Y., & Pratiwi, A. S. (2019). Comparison of job shop production scheduling by using the non-delay method and the Heijunka method at PT XYZ. *IOP Conference Series: Materials Science and Engineering*, *673*(1), 012089. https://doi.org/10.1088/1757-899X/673/1/012089

Kumar, S., & Jadon, P. (2014). *A Novel Hybrid Algorithm for Permutation Flow Shop Scheduling* (arXiv:1407.5931). arXiv. https://doi.org/10.48550/arXiv.1407.5931

Kurihara, T., Kawanaka, T., & Yamashita, H. (2019). Dual Approach to the Harmonized Model between Inventory Reduction and Heijunka (Production Leveling) based on the Minimum Average-energy Principle. *International Journal of Industrial Engineering and Operations Management*, *01*(02). https://doi.org/10.46254/j.ieom.20190204

Kusiak, A. (1987). The generalized group technology concept. *International Journal of Production Research*, *25*(4), 561–569. https://doi.org/10.1080/00207548708919861

Lange, K. (2013). *Optimization*. Springer Science & Business Media.

Liker, J. K. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer* (Reissue édition). McGraw-Hill Professional.

Ma, J. (2014). *The adoption and implementation of Kaizen in Sino-Japanese automotive joint ventures* [Thesis, Newcastle University]. http://theses.ncl.ac.uk/jspui/handle/10443/2543

Matzka, J., Di Mascolo, M., & Furmans, K. (2012). Buffer sizing of a Heijunka Kanban system. *Journal of Intelligent Manufacturing*, *23*, 49–60. https://doi.org/10.1007/s10845-009-0317-3

Mayr, A., Weigelt, M., Kühl, A., Grimm, S., Erll, A., Potzel, M., & Franke, J. (2018). Lean 4.0—A conceptual conjunction of lean management and Industry 4.0. *Procedia CIRP*, *72*, 622–628. https://doi.org/10.1016/j.procir.2018.03.292

Ohno, T. (1988). *Toyota Production System: Beyond Large-Scale Production*. https://www.routledge.com/Toyota-Production-System-Beyond-Large-Scale-Production/Ohno/p/book/9780915299140

Okoli, C. (2015). A Guide to Conducting a Standalone Systematic Literature Review. *Communications of the Association for Information Systems*, *37*(1). https://doi.org/10.17705/1CAIS.03743

Rao, S. S. (2019). *Engineering Optimization: Theory and Practice*. John Wiley & Sons.

Renteria-Marquez, I. A., Almeraz, C. N., Tseng, T.-L. B., & Renteria, A. (2020). A Heijunka Study for Automotive Assembly Using Discrete-Event Simulation: A Case Study. *2020 Winter Simulation Conference (WSC)*, 1641–1651. https://doi.org/10.1109/WSC48552.2020.9383927

Rewers, R. (2019). Planning the inflow of products for production levelling. *Machines. Technologies. Materials.*, *13*(10), 439–442. https://stumejournals.com/journals/mtm/2019/10/439

Rewers, P., & Diakun, J. (2021). A heijunka study for the production of standard parts included in a customized finished product. *PLOS ONE*, *16*(12), e0260515. https://doi.org/10.1371/journal.pone.0260515

Rewers, P., Czaja, M., Janczura, K., & Diakun, J. (2021). Determination of the Production Frequency and Batch Size for the Manufacturing Process. In V. Tonkonogyi, V. Ivanov, J. Trojanowska, G. Oborskyi, A. Grabchenko, I. Pavlenko, M. Edl, I. Kuric, & P. Dasic (Eds.), *Advanced Manufacturing Processes II* (pp. 72–82). Springer International Publishing. https://doi.org/10.1007/978-3-030-68014-5_8

Rewers, P., Hamrol, A., Żywicki, K., Bożek, M., & Kulus, W. (2017). Production Leveling as an Effective Method for Production Flow Control – Experience of Polish Enterprises. *Procedia Engineering*, *182*, 619–626. https://doi.org/10.1016/j.proeng.2017.03.167

Rewers, P., Trojanowska, J., Diakun, J., Rocha, A., & Reis, L. P. (2018). A Study of Priority Rules for a Levelled Production Plan. In A. Hamrol, O. Ciszak, S. Legutko, & M. Jurczyk (Eds.), *Advances in Manufacturing* (pp. 111–120). Springer International Publishing. https://doi.org/10.1007/978-3-319-68619-6_11

Romero, D., Gaiardelli, P., Powell, D., Wuest, T., & Thürer, M. (2018). Digital Lean Cyber-Physical Production Systems: The Emergence of Digital Lean Manufacturing and the Significance of Digital Waste. In I. Moon, G. M. Lee, J. Park, D. Kiritsis, & G. von Cieminski (Eds.), *Advances in Production Management Systems. Production Management for Data-Driven, Intelligent, Collaborative, and Sustainable Manufacturing* (pp. 11–20). Springer International Publishing. https://doi.org/10.1007/978-3-319-99704-9_2

Santos, P. V. S. (2020). Leveling of production through the application of the Heijunka method. *Journal of Lean Systems*, *5*(1), Article 1. http://leansystem.ufsc.br/index.php/lean/article/view/3329

Schouten, W. (n.d.). *Synchronization of supply chain planning processes: Design of a production wheel at an outsourced company*. 72.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: Context, practice bundles, and performance. *Journal of Operations Management*, *21*(2), 129–149. https://doi.org/10.1016/S0272-6963(02)00108-0

Shetty, D. K., Abakari, G., Rodrigues, L. L. R., Oommen Mathew, A., & Motlagh, F. G. (2019). To develop Lean Systems in Electronic Automotive Parts Manufacturing Industry: A System Dynamics Modelling Approach. *2019 International Conference on Automation, Computational and Technology Management (ICACTM)*, 277–283. https://doi.org/10.1109/ICACTM.2019.8776803

Sodikin, I., Yusuf, M., Hendrayana, H., & Rusianto, T. (2018). *Design of Toyota Production System Based on Heijunka Principles to Increase Human Work Productivity*. https://doi.org/10.21276/sjeat.2018.3.5.8

Spenhoff, P., Wortmann, J. C. (Hans), & Semini, M. (2021). EPEC 4.0: An Industry 4.0-supported lean production control concept for the semi-process industry. *Production Planning & Control*, *0*(0), 1–18. https://doi.org/10.1080/09537287.2020.1864496

Tegel, A., & Fleischmann, B. (2012). Fill Time, Inventory and Capacity in a Multi-Item Production Line under Heijunka Control. In D. Klatte, H.-J. Lüthi, & K. Schmedders (Eds.), *Operations Research Proceedings 2011* (pp. 415–420). Springer. https://doi.org/10.1007/978-3-642-29210-1_66

Tonelli, F., Paolucci, M., Anghinolfi, D., & Taticchi, P. (2013). Production planning of mixed-model assembly lines: A heuristic mixed integer programming based approach. *Production Planning & Control*, *24*(1), 110–127. https://doi.org/10.1080/09537287.2011.609647

Wagner, T., Herrmann, C., & Thiede, S. (2017). Industry 4.0 Impacts on Lean Production Systems. *Procedia CIRP*, *63*, 125–131. https://doi.org/10.1016/j.procir.2017.02.041

Wilson, S., & Ali, N. (2014). Product wheels to achieve mix flexibility in process industries. *Journal of Manufacturing Technology Management*, *25*(3), 371–392. https://doi.org/10.1108/JMTM-03-2012-0026

Womack, J. P., Jones, D. T., & Roos, D. (2007). *The Machine That Changed the World: The Story of Lean Production--Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World... Wars That Is Revolutionizing World Industry)* (Reprint edition). Free Press.

Żywicki, K., Rewers, P., & Bożek, M. (2017). *Data Analysis in Production Levelling Methodology*. 460–468. https://doi.org/10.1007/978-3-319-56541-5_47