Heijunka - Levelling customer orders: A systematic literature review

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

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

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**Figure 3. Phases of heijunka Implementation (Rewers et al., 2018).**
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 production, based on Group Technology (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 Gembka 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 financial 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 4.0 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


