14th Annual International Conference on Industrial Engineering and Operations Management
Dubai, United Arab Emirates (UAE), February 12-14, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/AN14.20240025
Published: February 12, 2024

Digital Kanban for Agile Production Planning and Scheduling in Automotive Supplier Industry

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Abstract

Dealing with production planning and scheduling in modern production networks becomes more and more complex. Globalization and mass customization are two megatrends influencing this trend especially in automotive suppliers' industry due to the high internationality of plants and factory of an industrial company as well as the heterogeneous product portfolio. However, there are some tools, methods and principles which can counteract this trends and help making production planning more agile digital. During this paper, a digital and automated Kanban solution will be implemented at a certain process in an automotive supplier's plant. To make the effects visible, the current process and its weaknesses are visualized in a value stream map of the current situation with conventional Kanban planning during the Analysis phase. Thus, the future, optimized value stream with the use of a digital and automated Kanban solution is designed and mentioned in the results. In summary, the introduction of this Kanban solution can lower the costs of the planning process. In the example used in this paper, the total costs for this quantity of Kanban can be decreased by over 50%. Further, other weaknesses of this process could be erased as well. Those results are differentiated in a practical and a monetary comparison.

Keywords
Kanban, Agile Planning, Production Planning, Production Scheduling, Inventory Management.

1. Introduction
BANI - Brittle, Anxious, Non-linear, Incomprehensible. An apt acronym, to express the current state of the world. The term is a further development of the VUCA concept (Mattenberger 2021). This originated in the 1990s when the when the US Army used the words volatility, uncertainty, complexity and ambiguity as a model of the modern environment. In the further time, integration took place in universities and companies, which often associate it with digitalisation and changing world order. Therefore, it was also expanded to include the aspects of dynamics and diversity to VUCADD (Stöttlinger 2022).

The last decades have changed both society and existing structures, which in the eyes of the American futurologist Jamais Casico also led to the evolution from VUCA(DD) to BANI (Cascio 2020). The two previous years in particular show that it is not enough to consider current world events, but that future ones are also necessary in order to be able to reflect the resulting consequences in a meaningful way. This linguistic framework shows the opportunity to look at and present the overall picture of the challenges. Thus, not only for unstable but also for entirely unforeseen situations, such as the Corona pandemic, the increasing shortage of raw materials or the current the increasing shortage of raw materials or the current energy shortage. and, as a result, new approaches to solutions can be created. The approach of the BANI system provides the attributes of resilience, empathy, flexibility and transparency, flexibility and transparency as possible reactions in order to develop further steps with appropriate measures **(Cascio 2020)**. In turn, for other key performance indicators from production management like efficiency and quality, the beneficial aspects of industry 4.0 technologies are clearly evaluated. This has been discussed in detail by many authors over the recent years (Cascio 2020).

The automotive industry can also benefit from this framework, which is also forced to search for new solutions due to questionable market forecasts and constantly increasing customer demands. Outdated, rigid systems need an update to be able to respond quickly to new market demands despite a volatile order situation; synchronously, inventory and cost factors should be reduced for this purpose. Ohno (2013), the founder of the Toyota Production System, already stated that difficult situations are drivers for optimisation and can therefore be seen as the originators of sustainable competitive advantages (Ohno 2013): "There will be no progress if we are satisfied with the existing situations" (Ohno 2013).

1.1 Objectives
The objective of this paper is a concept for the optimisation of the digital Kanban system for the production of a specific plant of an automotive supplier. Kanban (Jap. card, container) is a method for agile, decentralized production planning and control (Geiger, Hering, and Kummer 2020; Werner 2020). The Kanban system links two adjacent production levels into a self-controlling control loop. The Kanban serves both as the consumer's order card and as the source's identification card for new production (Geiger, Hering, and Kummer 2020). In contrast to the material flow, the information flow is retrograde (Werner 2020). This corresponds to the pull principle, in the sense that the consumer triggers production and sends a message to the source (Geiger, Hering, and Kummer 2020; Werner 2020).

Already introduced and outdated Kanban control loops are to be re-dimensioned and set up. It is also important to make the workload of procurement and production planning more and more economically as well as to eliminate the weaknesses of the current Kanban system. Finally, there should be a general approach for companies out of the automotive supplier industry on how to deal with such outdated Kanban control loops depending on their specific organisational structure.

2. Literature Review
2.1 Basic Kanban Principle
Consequently, in Kanban production, the final assembly gives the production impulse for the upstream production stages (Werner 2020). It is done by taking a full Kanban container from the buffer store. The Kanban card then flows with comprehensive control details, such as material identification, consumer data, quantity the consumer data, the number of items, the type of transport or container, and gives source and provides feedback for replenishment (Werner

2020; Klevers 2009). The replenished Kanban then flows back into the buffer store, filling the deficit, see Figure 1 (Klevers 2009).

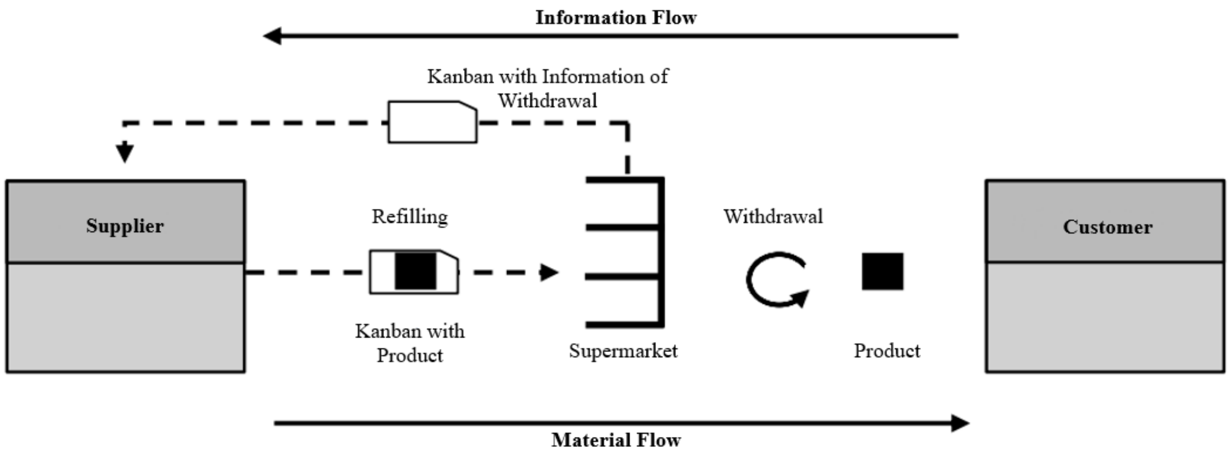

Figure 1. Kanban Control Loop Principle (Klevers 2009)

The integration of a Kanban system is according to Klug (2018) intended to optimize the value creation process in several areas (Klug 2018). On the one hand, the aim is to increase delivery performance and process reliability, and on the other hand, to reduce the internal planning and control effort. On the monetary side, the Kanban system aims to save capital commitment and internal transport costs. Furthermore, it helps to calm down the production process, to make it more flexible and transparent, while the lead time decreases. The limits of Kanban systems are reached in production processes with enormously fluctuating production requirements or high numbers of variants. Likewise, the reduced stock in the event of a malfunction entails a higher risk of failure for the downstream production chain (Klug 2018).
Before the introduction of Kanban, it should therefore be checked whether the prerequisites for production control meet the requirements for Kanban (Wannenwetsch 2021). These include, in addition to sufficient consumption forecasts, the harmonization and standardization of the production program. The employees should also have a high level of expertise and motivation. A well-planed Kanban process follows certain rules, as summarized in Table 1. (Dickmann 2015)

Table 1. Fundamental Rules for a Kanban System (Dickmann 2015, Institute for Occup. Safety)

Strict fundamentals	**Further rules**
Handover and transfer of parts always with the Kanban	Employees must treat rules as standards
Customers pull only when there is a demand	Discrepancies are to be reported to the manager
No passing on of scrap parts	Replacement only on demand
Number of Kanban in circulation must be controlled	First-in-first-out (FIFO) principle

2.2 Different Kanban Systems

Various types of Kanban can be distinguished in the Kanban system of a company. Schulte (2001) characterizes them into three types (Schulte 2001). The mapping of production orders and the control of the production process is carried out by a production Kanban. If it serves the pure transfer of parts, it is called a transport Kanban. However, as soon as an order is placed with an external supplier for this purpose, it falls under the third category of supplier Kanban. The execution of a Kanban control can be divided into single-loop and a double-loop system (Schulte 2001).

The single-loop system is the classic control loop. The consumer has the required parts directly available at the workplace or in the supermarket. In this case, a supermarket means a warehouse or storage close to production for all required materials, where the worker can help themselves (Klevers 2009; Klug 2018; Werner 2020). Therefore, it is suitable for processes with a clear variety of variants and low space requirements. The single-loop system offers the card, container and signal Kanban processes as design options. The processes differ in the generation of the retrieval pulse (Klevers 2009; Klug 2018).

The original variant corresponds to the card Kanban. In this case, the card moves first with the part to the place of consumption. Depending on the system, it is removed when the first part is taken or when all parts are consumed. collected. It then flows back to the source in a fixed cycle. It not produced directly for each individual card, but only when a fixed rounding quantity. This depends on the specific set-up costs and the replenishment time (RTI). For a clear Kanban boards with a traffic light principle have become established for clear production. The call-off impulse of the container Kanban is regulated by the transfer of an empty container to the source. Therefore, at least two circulating Kanban containers are necessary. The number of containers increases parallel to the distance and the fluctuations in demand. In another method, the Kanban call-off works via sight or signal. Accordingly, it is also called visual or signal Kanban. The signal impulse can be generated in various ways, e.g. by an empty shelf. It is used for frequently used C-parts or auxiliary and operating materials with an irregular demand, for which the administration should remain as low as possible. (Klevers 2009; Klug 2018).

A combination of the Kanban types explained at the beginning is used in a two-circuit system. In the control loop between the consumer and the supermarket the transfer is controlled by a transport or supplier Kanban. In the other control loop between the supermarket and the source, a production Kanban circulates. Here there is no direct withdrawal by the consumer, he only orders his current or next demand. his current or next demand. The production supplier takes a Kanban from the information from the supermarket and delivers it to the consumer. The withdrawal from the supermarket is in turn signaled by a Kanban card, which is sent to the source according to the procedure already described. The demand cards are usually kept on a board with compartments by the consumer. Each compartment represents a specific period of time for a delivery date or a demand message. Two-circuit systems require a higher degree of coordination. There needs to be a structured time lapse between an anticipated call-off and a reliable delivery. They are used for many variants, irregular requirements or large parts. Otherwise, it would require a high storage capacity at the point of consumption. If these parts were stored in a central supermarket, the consumer would be mainly concerned with transport to the point of consumption instead of production. Likewise, if the supermarket is further away due to spatial constraints. (Klevers 2009)

The conventional Kanban system is also undergoing an update in the course of digitalization. Electronic Kanban controls (eKanban) enable the reduction of application errors and personnel costs through high automation (Kreutz et al. 2021). It follows the principles of lean and integrates IT-supported logistical processes such as procurement, inventory management or transport. such as procurement, inventory management or transport logistics into the Kanban system (Dickmann 2015). With the help of an ERP system, outgoing stocks are totaled on an account, and when a certain economic rounding quantity is reached, replenishment takes place. At the same time, the number of Kanbans is shown on the basis of the circulating stock. In addition to warehouse stocks and collective quantities, this also includes purchase orders and production orders. In this way, the Kanban types can be digitized and displayed in the system with all the necessary information on a Kanban board. In addition to its function for information and control, it can be used to manage the Kanbans and their associated statuses. In this way, status changes, e.g. from "Full" to "Empty" and the associated retrievals and bookings can also be implemented in the system. In addition, there are further options for retrieval and synchronous stock bookings. For example, through sensors on flow racks, call-off buttons or the widespread scanning of barcodes on the Kanbans. In internal production, RFID transponders offer particularly simple and error-free processing. Data such as batches for traceability can thus be stored decentral and directly on the part. High costs and complex integration are still preventing small and medium-sized companies in particular from implementing them. Battery-powered autonomous "plug and play" sensor modules based on AI could offer an affordable alternative here in the future (Kreutz et al. 2021). The advantages of e-Kanban include not only immediate data transfer, but also the reduction of manual handling and inventory differences. A disadvantage is that errors in the ERP system have a greater influence on the material flow. For example, due to an inadequate master data basis or careless bookings. Consequently, internal processes should be analyzed in detail before implementation. In order to generate a material and information flow that is as precise as possible. The reliability and quality of the data is the decisive prerequisite for the success of the system (Dickmann 2015).

3. Methods

Science offers various approaches for the as-is analysis of an existing process or system. In conjunction with the Kanban process, value stream analysis is a common method for analyzing existing production processes in the industry in the sense of Lean Management.

With the aid of the value stream mapping, the current situation of a production process should be analyzed fully and comprehensible. This approach follows the basic idea of customer-oriented production without waste. It includes production processes and their material flow as well as the associated control and information flow. Before taking up the value stream, a benchmark was first set for consideration by analyzing the individual process sections. With reference to the intention of the work, all relevant processes between the provision of materials from the incoming goods warehouse to final assembly are examined. The result of the value stream analysis is to reach out to a comprehensive framework for the Kanban system. It should develop an understanding of the process and to identify weaknesses and to identify weak points. The analysis should cover the following aspects are to be recorded: (Klevers 2009; Erlach 2020)

- Involved processes
- Material flow in between processes
- Data flow in between processes
- Resulting waste / muda
- Existing framework conditions

The value stream mapping usually started upstream at the customer's site. In this example of the intralogistics of an automotive supplier, the assembly represents the internal customer. Starting from this, the value stream was recorded all the way to the goods receipt.

Furthermore, the superordinate, operative processes of production planning were examined. In the course of the recording, various employees were interviewed, processes in the ERP system were observed and existing process documentation was evaluated. Furthermore, the transport Kanban system of a production area for the transfer of raw material to another plant was examined as an example. The individual process sections of the material and information flow are further elaborated in the following analysis. The entire value stream of the current Kanban system as well as the process after optimization can be found in the upcoming chapters. Weaknesses identified in the value stream were visualized in the value stream in the form of lightning bolts.

4. Data Collection

The results are based on a practical example done in cooperation with an automotive Tier 1 supplier having its headquarter in Germany as well as multiple plants all over the world. This group is common for automotive suppliers, since the Just-In-Time and Just-In-Sequence principles in this industry benefits from being quite close to the OEMs factory.

Resulting from the used methodology, there are some aspects that are considerable as potential areas of optimization (see Tab. 2). In general, they can be split into System as well as Person-centered issues. In terms of the system, areas for optimization could be found regarding the current Enterprise Resource Planning (ERP) software in use. In this software, inconsistent times in the material master, outdated orders, incomplete mapping as well as obsolete production supply areas and control loops have been identified as waste. Regarding the person, there was no clearly defined responsible, some individual faults during application, high planning effort, inadequate calculation of control loops and no First-In-First-out (FIFO) principle in use which was defined as room for optimization.

Thus, there are further conditions set in the current situation that are potential optimization, but not going to be changed during this Kanban project. For instance, SAP R/3 is the ERP system in use at the automotive supplier’s site. Also, there is no Warehouse Management or Manufacturing Execution System implemented. The internal transfer and its transport cycles are currently not changeable due to personnel capacities and structural conditions cannot be changed.

Batches and lot sizes are to be regarded as fixed due to the sizes of the products and packaging specifications required by the customer.

For the purpose of this analysis, a sample process will be used. A production process in a certain factory of an automotive supplier looks like the following: There are three process steps that have a daily delivery of semi-finished parts. The parts are customizable out of five platforms. Before the first process step, there is a warehouse for incoming goods. Further, in between are supermarkets under Kanban control. The Kanban Board is transposed as hardware board and the current Kanban planning is updated every three months using an Excel-file as base for the calculation. Figure 2 visualizes this using standard value stream characters. Also, there are some Kaizen-Marks to determine optimization potential that the automotive supplier is already aware of. These weaknesses in the process are very similar to the ones already listed in Table 2.

Table 2. Summary of potential Areas for Optimization

System	• Inconsistent in-house production times in the material master • Outdated production orders and delivery schedules • No full mapping in the system • Obsolete production supply areas and control loops
Person	• No clearly defined responsible person • Individual human faults during application • High planning effort regarding time and complexity • Inadequate calculation of the control loops results in disproportionate number of Kanbans • No FIFO principle due to huge amount of production orders

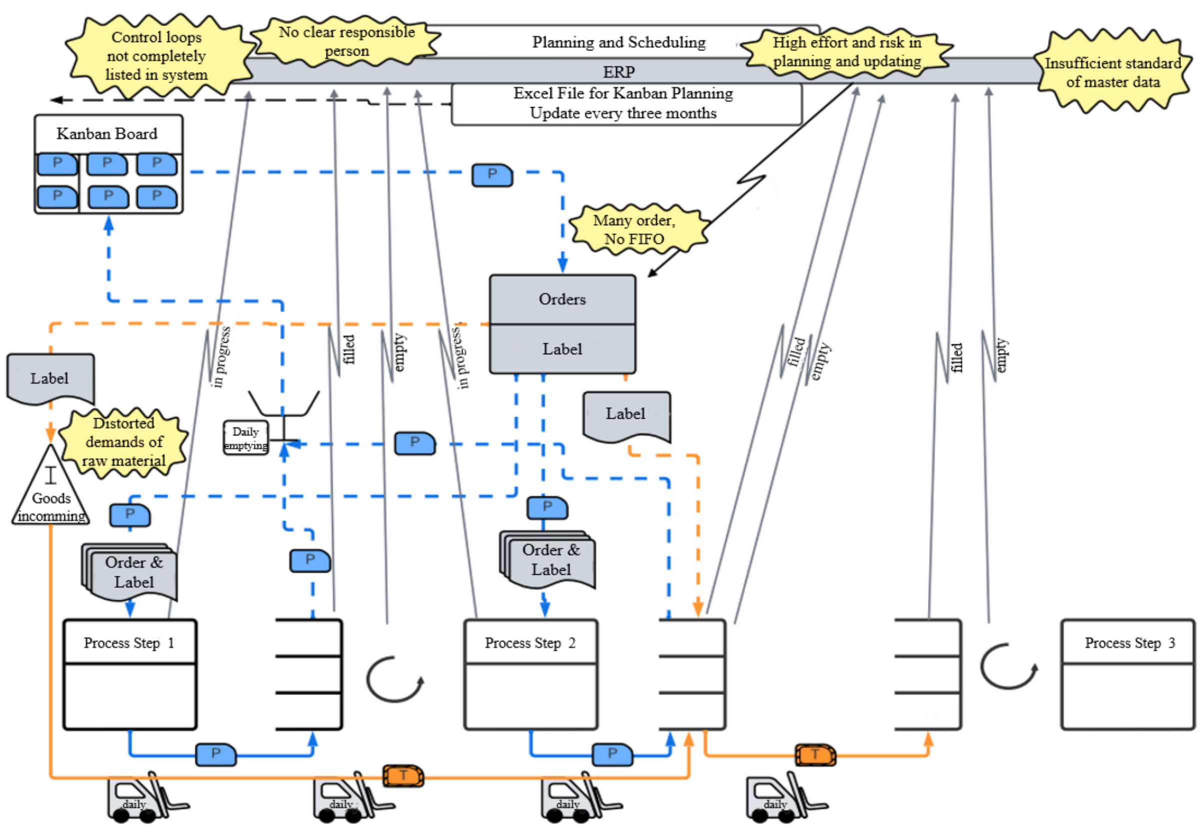

Figure 2. Value Stream Mapping of current Process before automated / digital Kanban Implementation

5. Results

5.1 Graphical Results

Based on the identified weaknesses and framework conditions, a target concept for optimizing digital Kanban is now derived. The result of the concept is an optimized value stream. Since all waste originates from the system and its application, the following potential for improvement of the target concept mainly takes place on the digital level.

The automatic Kanban calculation is intended to serve as a solution. In its favor is the fact that it is a standard SAP application. This eliminates the weaknesses of the previous two-part planning. On the other hand, the biggest advantage is that this avoids manually re-dimensioning the large number of control loops as well as the need to update them manually.

In the ERP software in use, there is also the function for evaluation in the form of a graphic. With this function the smoothing compared to the regular requirements becomes apparent on the one hand and on the other hand, the composition of the Kanban calculation is visually displayed. Figure 3 shows the monthly smoothing for almost four weeks in the time of March 2023 and the corresponding calculation parameters. All Sundays as well as one additional Monday were off.

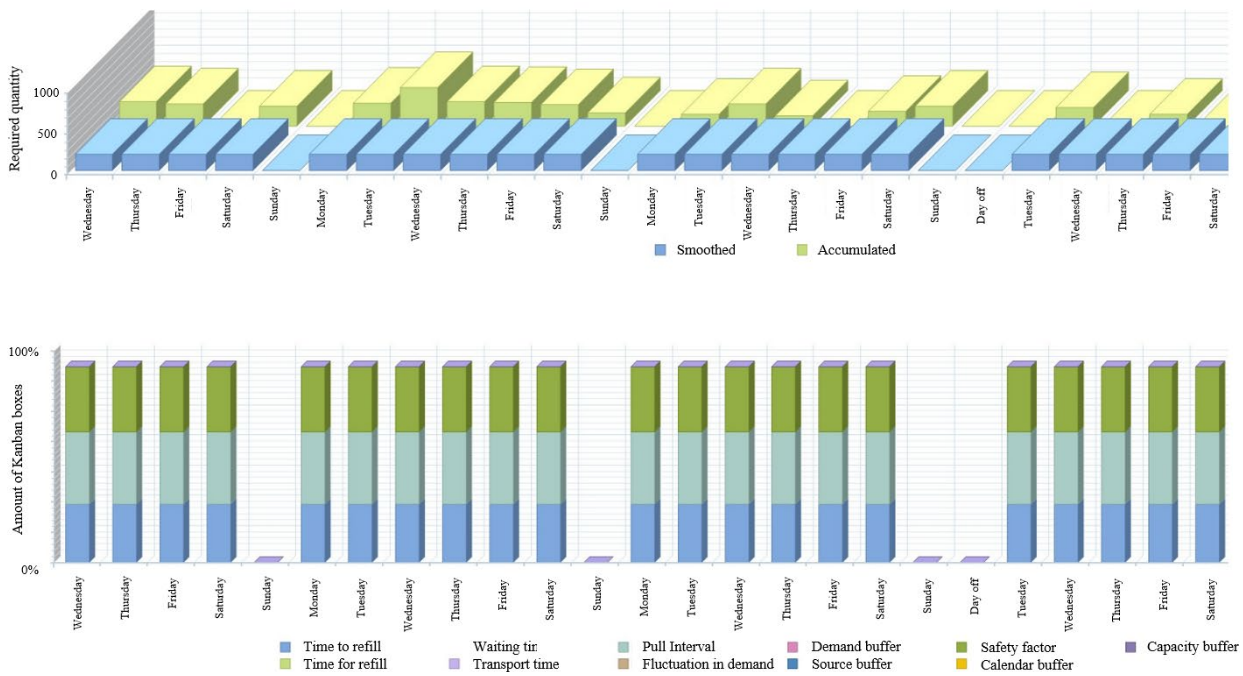

Figure 3. Graphical representation of the Automatic Kanban Calculation

5.2 Practical Results and Improvements

Based on the previous calculations, it can be determined that the results of both formulas differ by approximately three daily requirements. Furthermore, it is important to note that the automatic Kanban calculation requires a responsible person as well as an initial six-month introduction phase in order to smooth the system's demand data. This way, old orders can be processed and the FIFO principle can be applied in the future. A cleaned-up system subsequently has a positive effect on all areas of the plant. The monthly evaluation of the target concept is more frequent compared to the quarterly evaluation of the current Kanban system. Nevertheless, this calculation in a system with a maximum of one working hour is less time-consuming than the current parallel use of Excel and SAP. In addition, fewer clerical errors occur than with a manual re-dimensioning of 804 control loops. Furthermore, the person responsible for this can achieve a better understanding of the system through the initial increased involvement and repetition rate. On a practical level, the implementation of the Automatic Kanban Calculation provides long-term relief for the planning logistics department in the example plant. Since the digital Kanban boards can also be used and the parameter

"maximum empty" can be correctly used for prioritization, production can also benefit from shorter processes and less manual handling in the developed target value stream (Figure 4).
Further, the future-state value stream shows the use of the digital Kanban board as well as a FIFO principle for the first production steps. This eliminates some of the optimization potential mentioned in the analysis. Also, the planning via Excel-File has been replaced with a monthly planning of the Kanban loops with the ERP software used in our sample factory having a clear responsible person.

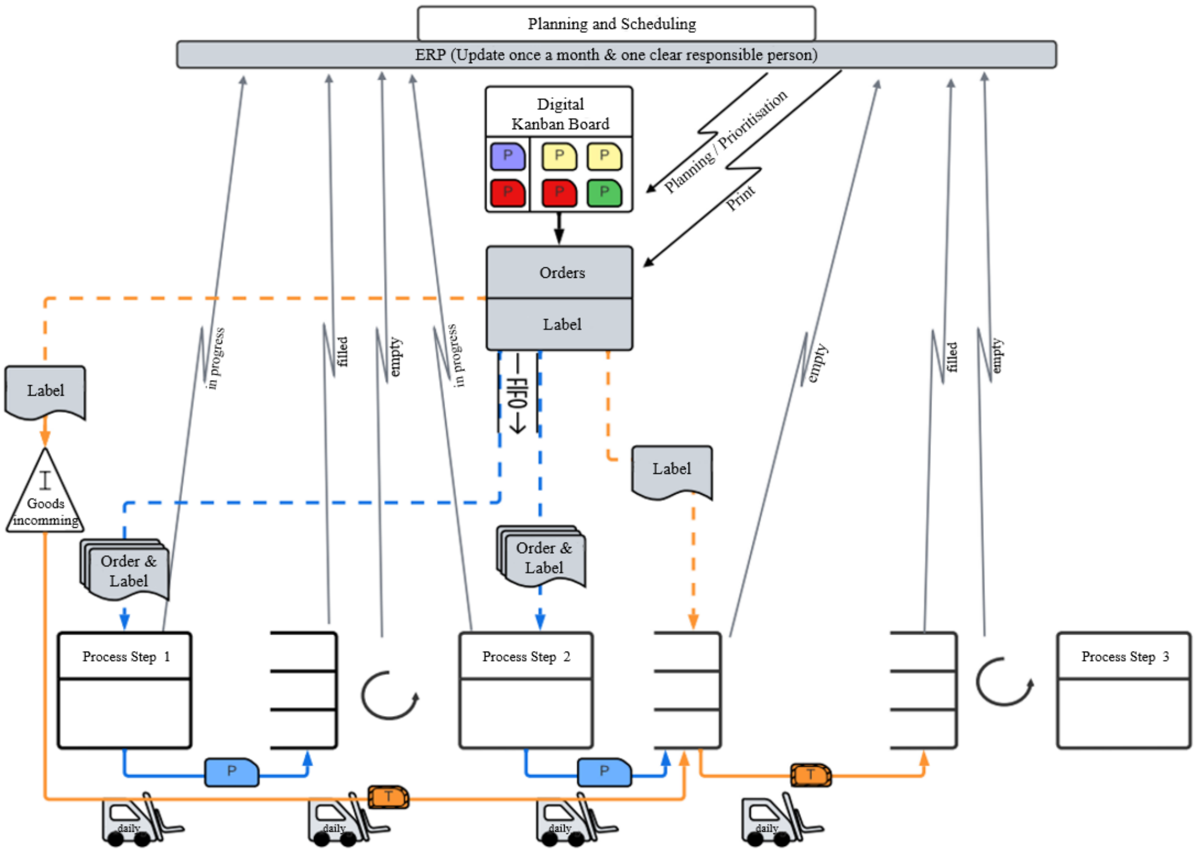

Figure 4. Value Stream Mapping of Processes after automated / digital Kanban Implementation

5.3 Monetary Results and Improvements

The economic efficiency of the system is calculated on the assumption that all Kanbans in the control loops are filled. control loops are filled, the capital commitment costs are calculated using the standard price, the quantity per Kanban and the current number of Kanbans per control cycle as suggested number of Kanbans per control cycle. It should be noted that normally the maximum stock in circulation is not the average stock. average stock. Since usually some Kanbans are empty and are waiting to be replenished (Dickmann 2015). This was simulated for comparability purposes. For the monetary comparison, we compare the five platforms that are produced in the respective sample process. The control loops are spread over the five platforms in a certain percentage (see Table 3). When we consider the quantity (respective the costs) of the Kanbans before optimization as 100%, we can compare them to around 43,2% after implementing digital and automated Kanban.

After the purely monetary evaluation, the application of the Automatic calculation represents one way of reducing the capital commitment costs.

Table 3. Summary of potential Areas for Optimization

Production Supply Area	**Control Loops**	**Kanban Quantity before**	**New Quantity**
Platform 1	33%	100%	54,7%
Platform 2	7%	100%	79,0%
Platform 3	23%	100%	28,0%
Platform 4	17%	100%	28,7%
Platform 5	20%	100%	37,0%
Total	**100%** in total	**100%**	**43,2%** on average

6. Conclusion

In addition to the recording of material and information flows, a data analysis of the key figures of the Kanban system was also carried out. Through the methodology of value stream design, it was possible to identify weaknesses and framework conditions. Based on these requirements for the target concept could be derived. The first step was to optimize the of the Kanban system within the framework of the value stream design. Automated Kanban calculation was considered as a solution. For this purpose, the prerequisites for implementation and application were created. These consisted of the re-dimensioning of the areas, the parameterization of calculation profiles and control loops. This enabled the system to perform the calculation system, so that the results obtained could then be compared with a with a common formula in the literature. Despite a discrepancy of both results of approximately 10 %, caused by the distorted system situation, a practical and monetary comparison showed the potential of the Automatic Kanban Calculation. If the target concept created is compared with the principles of Lean Management, the following is achieved through the automatic Kanban calculation and the omission of Excel planning the principle of integration is made possible. Further, the principles of flow, clock and pull are supported and improved by the Kanban system. Thus, the complete design of an electronic Kanban system can be realized. Physical cards and manual Kanban cards can thus become obsolete. This outlook corresponds to the endless principle of perfection and the necessary striving for continuous improvement.

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