Development and Application of an e-Kanban System in the Automotive Industry

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Abstract

Industry 4.0 did not just bring new requirements for today's industries, it also brought new technologies to increase its efficiency and effectiveness. In this work, an e-Kanban system for internal logistics and production is developed and implemented in the automotive industry. The system functions according to the kanban methodology, where the consumption usage of a part triggers its replenishment. The development of the presented e-Kanban system took into consideration the limitations and improvement opportunities of previous works where authors developed their own e-Kanban systems. Before the e-Kanban system's application, a simulation using the EKS© software was performed to obtain the number of labels and stock levels needed for the calibration of the e-Kanban system. The system was then applied, and the results show a 19% stock reduction and a 22% reduction in inventory costs. Additionally, the system proved to respond to the factory's necessities and allowed for real-time control of production and inventories.

Keywords
e-Kanban System, Industry 4.0, Automotive Industry, Information and Communication Technologies.

1. Introduction

Lean Manufacturing approaches are widely adopted in industry since they allow for cost reduction and efficiency maximization, which are obligations for today's global market. The kanban system is the most used tool for enhancing manufacturing efficiency (Sapry et al., 2020). Yet, due to increased supply chain complexity, product variability, uncertain demand, and the need for quicker information exchange, the traditional kanban system is now outdated and incapable of reaching the new market requirements. As well, Industry 4.0 pushes organisations to undertake a digital transformation of their processes and information flows. Thus, to adapt to both market and Industry 4.0 requirements, organisations must attain an active and accurate control of their production processes and an overall and real-time view of the value chain. For that, companies must have a continuous information flow throughout their value chain, which can be achieved through the current advancements in Information and Communication Technologies (ICT). The electronic Kanban (e-Kanban) system is an efficient way to combine the advantages of the traditional kanban with the technologies needed for Industry 4.0, and the upgrade in ICT brings the obvious solution to achieve it. The present work was developed in an automotive Portuguese manufacturing company, integrated within an international automotive group. The factory in the study presents a high product variability since it produces different products. The previous, together with the fact that most products use the same production machines (flow confluences), increases flow complexity and hampers production planning and scheduling activities (for further information, consult (Romeira & Moura, 2020)). In addition, the factory's current lead times (LT), surplus the clients' takt time. Consequently, the aforementioned problems led to:

- constant changes to the production schedule due to missing component references.
- an increase in the quantity of components in stock throughout the production process.
- a decrease in customer satisfaction.
- an increase of stress levels within the organisation.

As a Just-In-Time tool, the kanban system guarantees that the correct components are available for consumption in the right amount and at the right time. This is possible because the kanban system works according to a replenishment frequency and with strategically placed and calculated stocks. For these reasons, the kanban was seen as the solution to reduce the constant production scheduling changes and high stock levels and, as a result, increase customer satisfaction and reduce stress levels within the factory. Moreover, this system facilitates the management of priorities in the production machines where products converge. However, due to the high product variability, the reasons stated in Romeira and Moura (2020) and the need to bring the factory closer to Industry 4.0, instead of a traditional kanban system, an e-Kanban system was proposed, developed and implemented.

This paper presents the developed e-Kanban system and its results. For that, the paper is organized as follows: Section 2 discusses vital concepts surrounding e-Kanban and presents a literature review on its application. Section 3 presents the used methodology and shows the current and future product flows. In Section 4 the developed e-Kanban and its functionalities are introduced and in Section 5 the system's results are discussed and compared to the results presented by the authors cited in Section 2. Finally, Section 6 summarizes the main findings and offers future developments.

2. The E-Kanban System: A Literature Review

The traditional kanban system was initially developed in Toyota and, according to Taiichi Ohno, it is a core presence of the Toyota Production System. Ohno (1988) offers several benefits of the kanban system such as, waste detection, quality improvement, and manpower, inventory and breakdowns reduction. The traditional kanban is a card-based method that transmits information between workstations, providing what must be produced, when to produce it and in which quantity. For the system to work, it is necessary to define and control strategically placed stocks, also known as supermarkets. Thus, when a following workstation grabs what it needs from the previous one, a production signal is sent to the latter, to indicate what must be produced to restore what was consumed (Ohno, 1988). Nevertheless, this system has several drawbacks, such as loss, mishandling and misplacing of kanbans, delays between information and material flows, limited tracking and monitoring, etc. (Kouri et al., 2008; Maříková, 2008; Menanno et al., 2019; Ricky & Kadono, 2020; Sapry et al., 2020; Sly, 2018; Wan & Chen, 2008; Wijaya et al., 2019; Yasin et al., 2016). Considering the above and due to ICT evolution, a new type of system is being more sought out by industries, the e-Kanban system. According to Houti et al. (2017), this system integrates all features of the traditional kanban, combining it with a mix of other technologies. This replaces the traditional cards with an electronic signal that triggers real-time and continuous exchange of information, responsible for the materials' movements (Yasin et al., 2016). Several published works, regarding the implementation of the e-Kanban system, were analysed and their results resumed in Table 1, according to: Industry type; Type of work; System type; Place of application; and Results obtained. All the papers in Table 1 present implementation cases of the e-Kanban system, and, expect for Razafuad et al. (2018) and Hawari and Aqlan (2012), which were implemented in a pharmaceutical and an aluminum industry, respectively, all others were employed in the automotive industry. Using ICT, Menanno et al. (2019) upgraded the existent kanban to a web-based e-Kanban that enabled the exchange of information between the company's assembly lines and the supermarkets. The results obtained in Menanno et al. (2019) showed a reduction of 30% to 40% in Work in Progress (WIP) and a reduction in the supermarkets' quantities. Additionally, the company was able to overcome several limitations of traditional kanban. Similarly, Razafuad et al. (2018) and Svirčević et al. (2013) used an e-Kanban to manage the replenishment process of inventory inside each company's warehouse. In both papers, the number of part shortages decreased after the application of the e-Kanban system. Maříková (2008) developed a hybrid system for inventory management, using both a physical and an e-Kanban system between the company's production lines and warehouse. In the same way, Hawari and Aqlan (2012) and Jarupathirun et al. (2011) implemented an e-Kanban/ERP hybrid system between the production lines and the warehouse. In the first work, the authors used the WLAN and barcode/RFID technology to trigger the kanbans movements and integrated them in the enterprise's ERP systems. This resulted in a 50% reduction of WIP and an 88% reduction in the product lead time. In Jarupathirun et al. (2011), the system led to a reduction of 16% in the production lead time. At the same time, the results showed a reduction of 23% in inventory costs, and the elimination of 2 out of 7 non-value-added activities. Along with the previous, the number of cards was reduced in 24%, which contributed to the increase in effectiveness and efficiency.

Table 1. Paper's comparison regarding the e-Kanban system's implementation.

Paper	Industry	Work	System	Place of Application	Results
(Menanno et al., 2019)	Automotive	Practical	e-Kanban system	-Internal	↓Human errors ↓WIP ↓Stock Real-time inventory Real-time kanban tracking Performance monitorization
(Ricky & Kadono, 2020)	Automotive	Practical	e-Kanban / ERP hybrid system	-Supplier -Internal	↑Flexibility ↓Cost ↓Lost card problems
(Maříková, 2008)	Automotive	Practical	e-Kanban / traditional kanban hybrid	-Internal -Warehouse	↑Reactivity ↑Flexibility ↑Transparency ↓Lost card problems
(Razafuad et al., 2018)	Pharmaceutical	Practical	e-Kanban system	-Warehouse	↓Part Shortages
(Hawari & Aqlan, 2012)	Aluminium	Practical	e-Kanban / ERP hybrid system	-Internal -Warehouse	↓LT ↓Inventory costs ↓WIP
(Svirčević et al., 2013)	Automotive	Practical	e-Kanban system	-Warehouse	↓Part Shortages
(Jarupathirun et al., 2011)	Automotive	Practical	e-Kanban / ERP hybrid system	-Internal -Warehouse	↓LT ↓Inventory costs ↓Stock ↓Lost card problems ↓Nº kanban cards ↑Efficiency ↑Effectiveness

As the previous authors, Ricky and Kadono (2020) used an e-Kanban/ERP hybrid system to handle the ordering process between company and supplier and employed a picking light signal to indicate the need to exchange containers within the factory.

3. Methodology & Case Study Presentation

Figure 1 presents the methodology applied to address the objective at hand. The first step consists in the definition and characterization of the current situation. For that, an extensive flow analysis of the existing processes is performed, and the processes' flow diagrams and lines are drawn. This step also includes the necessary data gathering to characterize the processes. The second step comprises the definition of the "want to be state" of the process, where the future flow lines are drawn. The following step, which is the core subject of the present work, consists in the definition and development of the new e-Kanban system. Once the prototype is finished, the next step involves the implementation of the system in the factory's shopfloor. Here, several sub-steps are performed: the simulation of the system's entry parameters using the EKS© simulation software; the E-Kanban system calibration with the simulation results; and the collaborators' training. Finally, the solution is tested and evaluated, during a 3-month period. After this period, the improvements are assessed and the necessary modifications to the system performed.

Figure 1. Project Methodology.

3.1. Definition of the Current and Future States of the Process

The factory in the study faces several problems being them:

- High production variability and flow confluency.
- Large product lead time and stock levels.
- Lack of synchronism with customers and suppliers.
- Challenges in production planning and scheduling.

Gearboxes represent the company's main production volume, due to this, they were chosen to test the new system. They are composed by various components manufactured inhouse and assembled in one of the two assembly lines. Figure 2 shows the flow diagram that represents the path each component follows during the manufacturing process. For this work, only 9 of those components were considered. During the manufacturing process, the components go through 4 main stages: WP, TTh, BP, and Assy. WP represents the machining of the raw material delivered by suppliers. In TTh, components are placed in ovens and then, depending on the component, are subjected to one or two distinct Shot Blasting (SB) processes. Note that, before the next stage, components 7 and 8 (C7 and C8) go through extra processes, namely a straightening process (Str) and then C8 undergoes its first rectification (Ret) process.

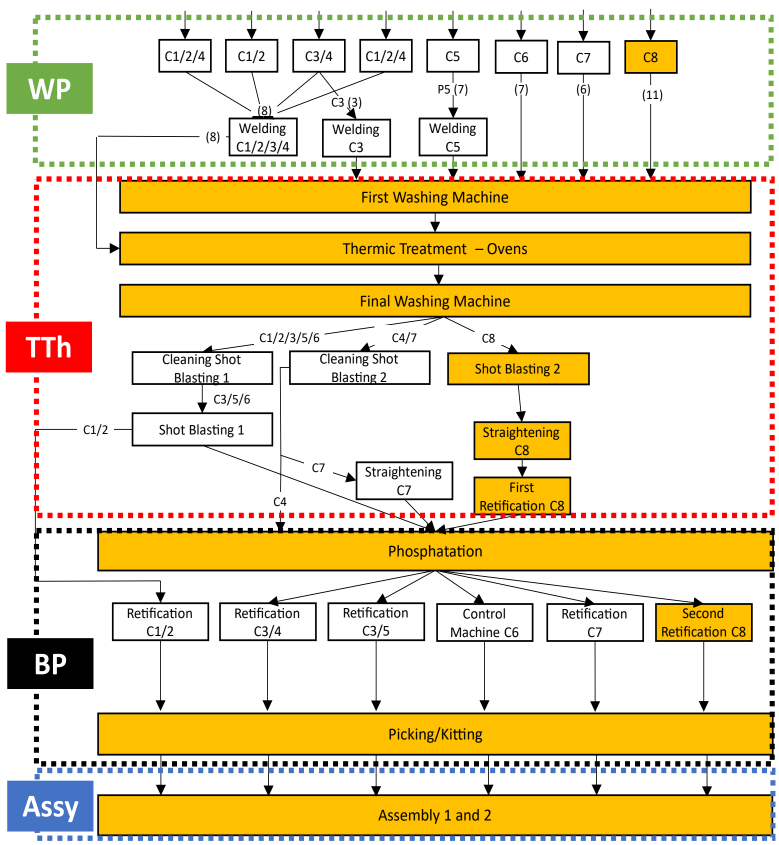


Figure 2. Flow diagram of the current processes for the gearbox's components.

The BP starts with a phosphatation (Php) process to all components, except C1 and C2. After that, a Ret process takes place, except for C6, which has a control process. Before Assy stage, all components are transported to the picking/kitting area. Finally, in Assy, the components are sent in a final kit (the right components in the right quantity to produce one specific gearbox), to each line. By analysing Figure 2 and the flow diagram of Figure 3 we can take the following conclusions:

- All components converge before TTh, Php and Picking/Kitting, therefore these are areas where the management of priorities is difficult;
- The majority of the processes produce according to a push system;
- In Picking/Kitting area, there is an accumulation of components, from C1 through C8. Thus, this area functions according to the pull system.

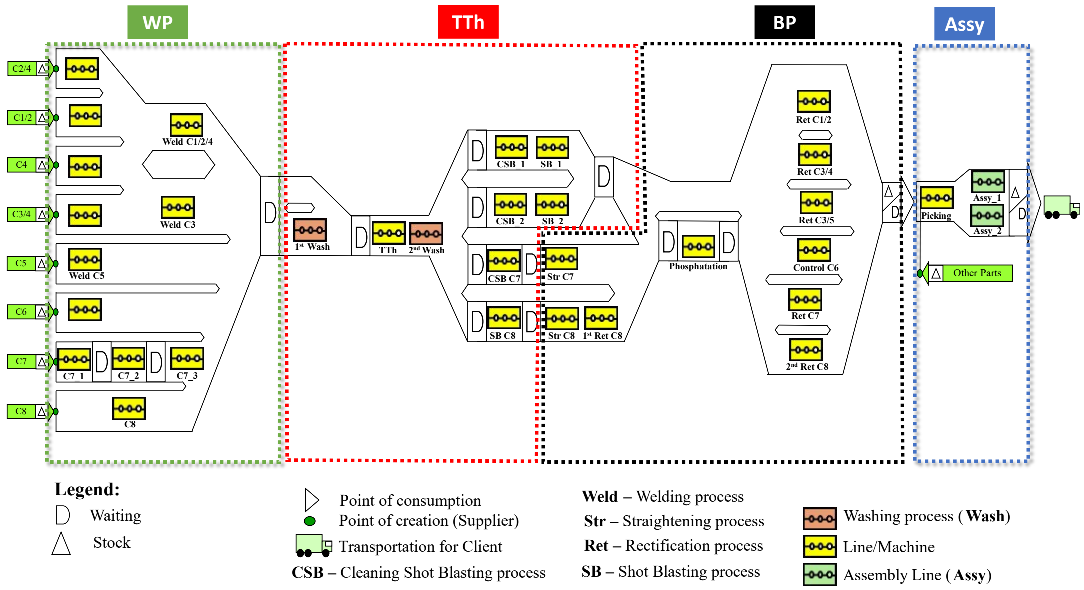


Figure 3. Flow lines of the current processes for the gearbox's components.

Due to the current working system, there is a poor priority management, which causes part shortages that lead to stock levels increasing. Additionally, a variation in the assembly lines' schedule causes massive setbacks in the previous processes, which in turn forces the company to have even bigger stock levels. To overcome these problems, as previously stated in Section 1, an e-Kanban system was proposed which allowed for:

- improved customer service rates and productivity.
- the reduction of cost related to stocks and the probability of part shortages.
- the reduction of the impacts of demand variation.
- the definition of priorities in the flow convergency places and the synchronism between processes.

The proposed future state is presented in Figure 4 and shows the flow lines after the kanban system application.

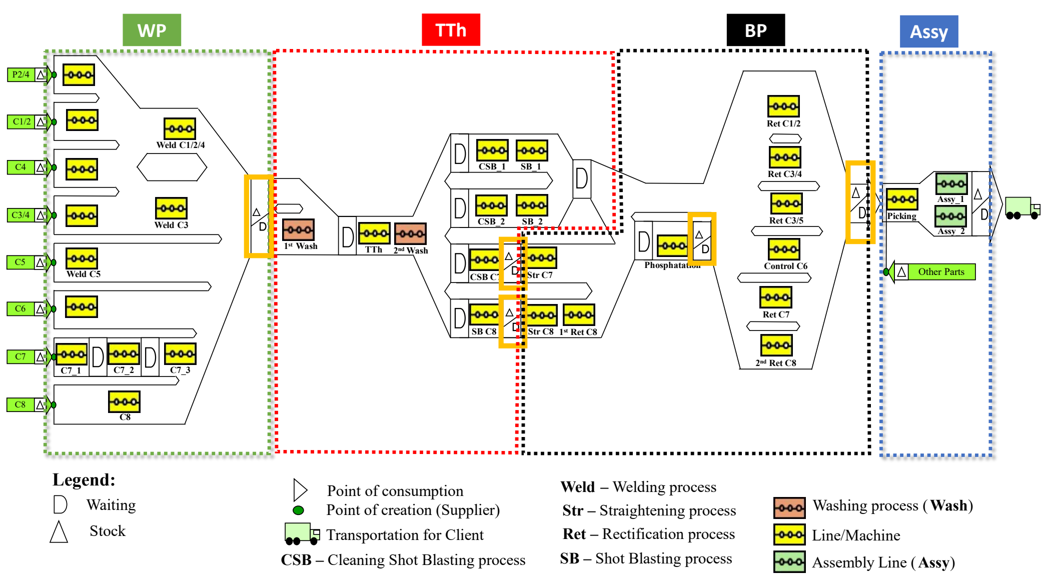
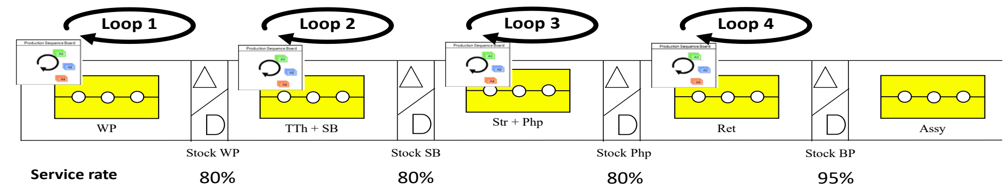


Figure 4. Future processes' flow lines for the gearbox's components.

The difference between the current and the future flow lines is the creation of 3 additional strategic stocks: one at the end of WP; one for C7 and C8, after the SB process; and another after Php. The main stock at the end of BP remains. Note that only the high runner references of each component will be stocked, these will be called Make to Stock (MTS) references. The remaining refences are referred as Make to Order (MTO), which means that there is no stock and they will only be produced at clients' request. The MTS references are stocked at a pre-determined quantity and when consumed, a replenishment order is emitted. For example, when an MTS of C8 is pulled by the 1st process of TTh, a production order is emitted in the 1st process of WP. In contrast, an MTO is placed in the 1st process of WP, when the client requests it, and goes from production loop to production loop, without triggering any replenishment orders. When it arrives to Assy, it is eliminated. Note that a production loop comprises the point of origin for the replenishment signal (a stock) and the point of destination for the same signal (a production board), as shown by the scheme of Figure 5.



Part	References total	MPS WP	MTS SB	MTS Php	MTS BP
C8	11	High runners Medium runners	High runners Medium runners	High runners Medium runners	High runners Medium runners

Figure 5. Production loops and stock distribution throughout the flow for C8.

This way, when a product is consumed in the downstream process, a replenishment signal is sent to the upstream process, in order to replace what was previously consumed.

4. The new e-Kanban system

As previously mentioned, in the current implementation context, the e-Kanban presents a wide range of advantages when compared to the traditional kanban, as it allows for:

- An overall visibility of production, production planning and stocks between processes that are far apart, for example the WP and BP stages are in one building but the TTh stage is in another.
- The management of a production with high product variability.
- The management of products' confluence in several machines, simplifying the definition of priorities.

Since the company has its software development team, top managers decided to build the e-Kanban system internally. This way, in addition to cost reduction, it was possible to create an entirely personalized e-Kanban system, adapted specifically to the factory's needs. Moreover, in the future, this will have the advantage of facilitating the connection with other software from the company. The new e-Kanban platform was developed using Angular 8 for the frontend and NestJS for the backend. To store its data, we used MongoDB, due to its simplicity and flexibility. In the developed platform, the traditional signals are replaced by an electronic signal that is emitted when an CU or a Batch changes states (Production state, WIP state, Accumulation state and Stock state). This change is triggered when the operators scan the references' barcodes throughout the processes. In production, this scanning is done by the production operators, while in the stock areas, the scanning is performed by specific operators (called stock operators). Each scanning location has a link so that the reference's state is automatically identified, upon the scanning. Furthermore, depending on the reference's production strategy, the signals will differ. In the case of an MTO reference, there is no stock to be refilled, therefore no replenishment signal is necessary. However, for an MTS reference, when a CU is removed from stock, a replenishment signal is emitted to the production. As the e-Kanban labels' movements are triggered by the references' scanning, to better understand the flow of information, the activity diagram of Figure 6 was developed. In the diagram, an e-Kanban label represents one CU, and a cumulative e-Kanban label represents one batch (set of e-Kanban labels). For example, for reference A of C8, the CU is 252 parts, and the batch quantity is 2x252=504 parts. When a reference is scanned, it can be in one of three different states: Production, Stock and WIP. The WIP state, is dependent on the time between the production loop's starting (production board) and finishing points (stock). If this time is not significant, then the WIP state is eliminated. If it is significant, then it changes to the Stock state. When a reference in the Stock state is scanned, the first thing the platform analyses is if the number of e-Kanban labels for that specific reference is enough to complete the respective batch. If so, there will be a verification of the production strategy. Hence, if MTS, then the cumulative e-Kanban label changes to Production state. Contrarily, if MTO or AVP (Advancement of production label), the e-Kanban label is eliminated from the current production loop. An AVP is a particular case of an MTS production strategy, where no replenishment signal is sent.

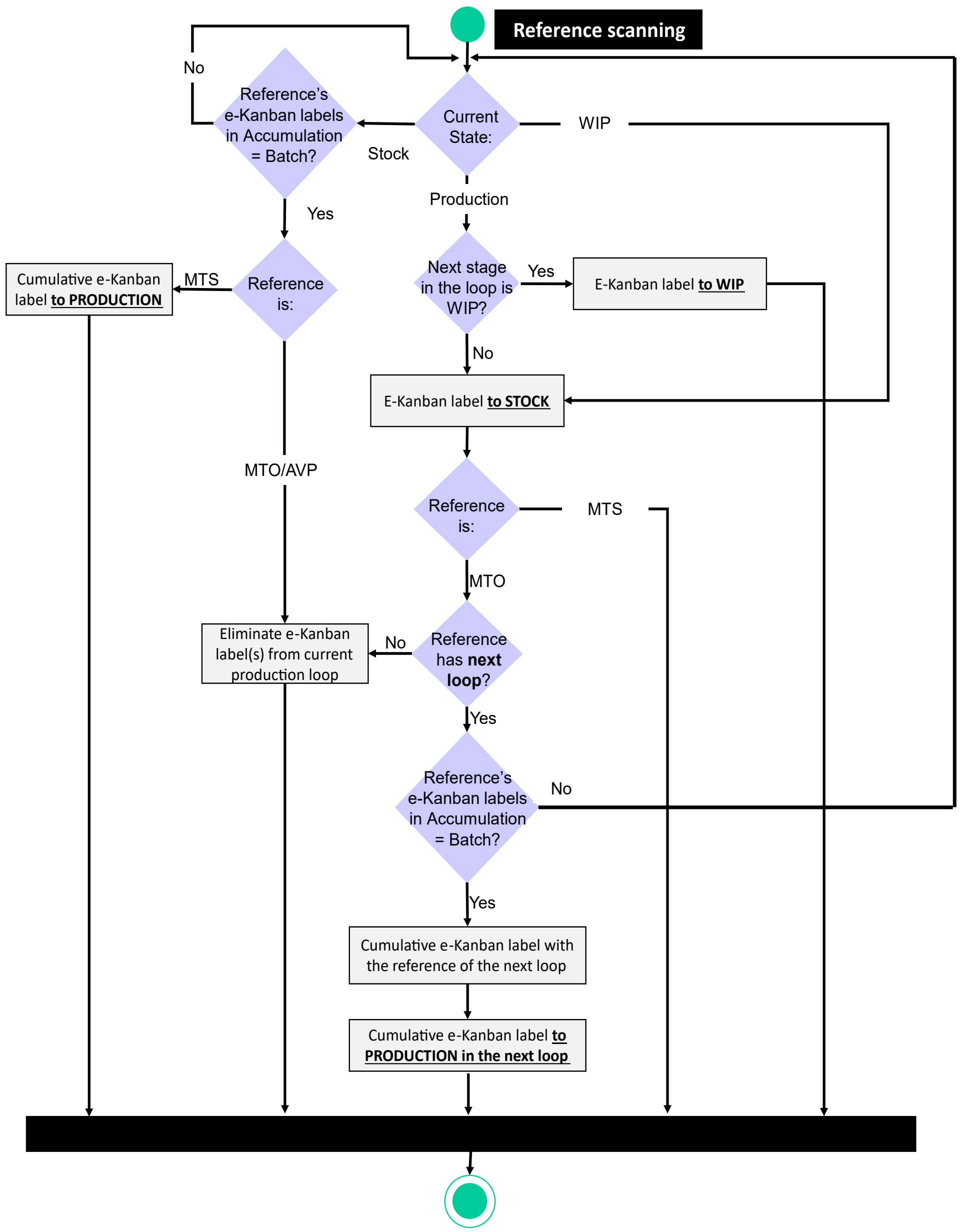


Figure 6. Activity Diagram for the Information flow through all product stages.

Basically, what happens is that when an AVP is scanned, the label is deleted from the current production loop and is not sent to the next production loop like an MTO. This state is needed because, once a month, the logistics planner needs to adjust the number of labels in use and therefore may use the AVP strategy to balance the stock levels. So, if, for an MTS, the number of labels increases, the user must create more labels for that reference. Contrarily, when the number of labels in use for an MTS decrease, the user must change the production strategy for the excess labels to AVP. For the Production state, if the next state in the production loop corresponds to WIP, then the label state changes from Production to WIP. If not, the e-Kanban label state shifts from Production to Stock. When this happens, the production strategy is analysed. For an MTO, the system verifies if there is a subsequent production loop, and the number of scanned e-Kanban labels is compared to the batch. If they match, a cumulative e-Kanban label is placed in the Production state of the next production loop. If the batch quantity has not yet been met, then the e-Kanban labels wait in the Accumulation state. To explain the e-Kanban system's key functionalities and the interactions that occur between the users and the platform, the use case diagram in Figure 7 was developed. The e-Kanban system is composed by 3 main menus and a Login functionally.

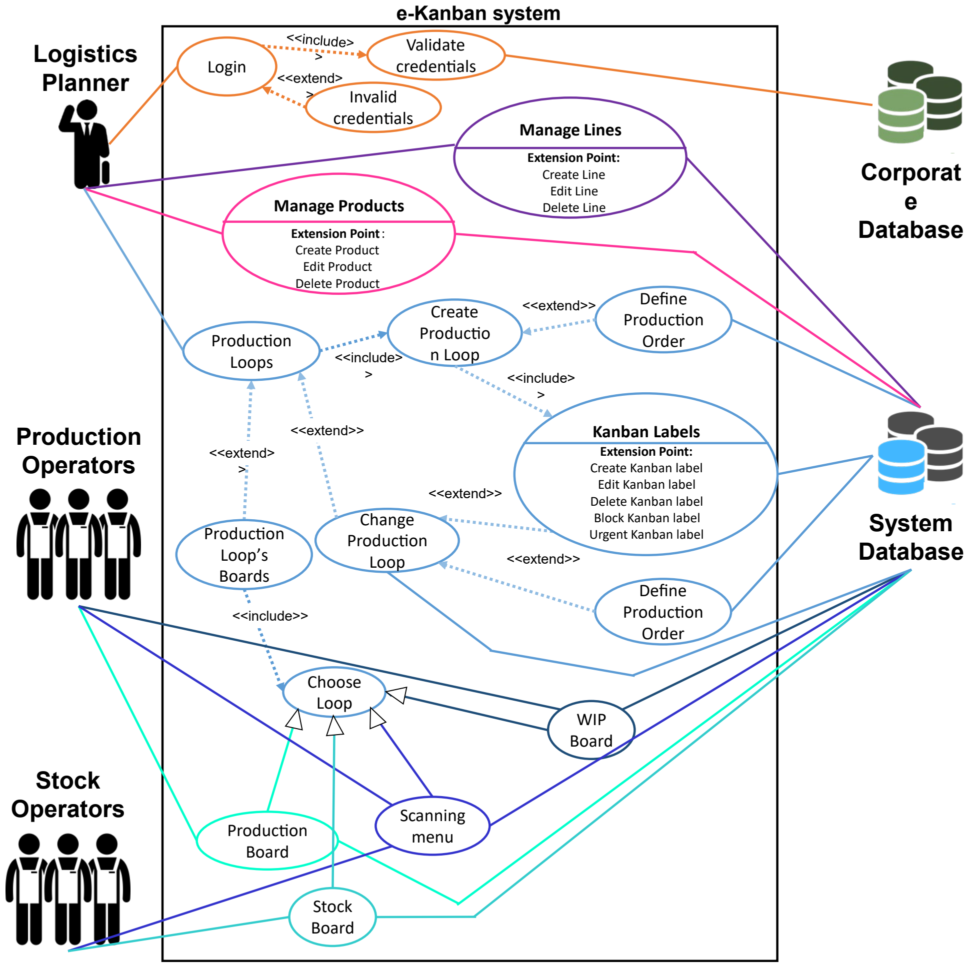


Figure 7. Use Case Diagram for the developed e-Kanban system platform.

The first menu is the "Manage Lines" menu. A line comprises a set of machines that produce a set of references of the same product. In this menu, new lines can be added, and existing lines can be edited or removed from the system. The "Manage Products" menu allows the user to create, edit and delete products' references. Each product reference has a different Identification (ID) number, according to the production stage. Moreover, the same reference ID can be used in different lines only if these lines belong to the same production stage. The "Production Loops" menu is the core menu for the e-Kanban system. Here, e-Kanban labels are created for each production loop. Once the user has filled the relevant information, the products' references (for that specific line) appear and, for each production loop it is possible to define which and how many:

- cumulative and e-Kanban labels must be produced, and thus are sequentially waiting in the production board.
- e-Kanban labels are in stock, and therefore in the stock board.
- e-Kanban labels are in WIP, and therefore in the WIP board.

This menu also allows the user to change the production loop information, number of circulating labels and production order sequencing, and access the different boards of each production loop, namely, the Production, WIP and Stock boards. Furthermore, there are two more functionalities that can be applied to the labels:

- The Blocking kanban label functionality allows the user to block any kanban label independently of its stage. A blocked label cannot be scanned and, therefore cannot be moved to another stage until it is unblocked.

- The Urgent kanban label functionality: it may be required to give a "free pass" to a specific label in production. When urgent, the label automatically goes to the first place of the production board, having a priority above all others.

As it can be seen in Figure 7, there are 3 main users, each one with specific access requirements: the Production Operators; the Logistics Operators and the Stock Operators.

4.1. Number of Kanbans and stock levels calculations

To calibrate the e-Kanban system, the number of Kanbans and stock levels for each component reference are necessary. To obtain them, a simulation was performed with the EKS© simulation software from CLD Conseil (n.d.). For the simulation, the following input data were inserted:

- Production strategy (MTS or MTO) and average daily consumption for each reference.
- Service rate: in the WP, TTh and BP stages an 80% service rate was applied, and for the Assy stage, a 95% service rate (values imposed by the company managers), to minimize the risk of not meeting the clients' deadlines.
- Number of parts inside the conditioning unit (CU) and Batch (minimum number of CU's necessary to produce the reference) throughout the product flow.
- Setup time, cadence (parts/hour), machines and operation efficiency for each Transformation process.
- Average time of transport for each transportation process.
- Average waiting time of each waiting queue.
- Line producing time, called line opening time.
- Production visibility for each MTS reference (i.e., 24-hour visibility is chosen, then the production knows what it will be producing during the next 24 hours).

All the previous data was inputted into EKS© and the number of kanban labels per MTS reference and stage and, the minimum, average and maximum stock levels per reference and stage were obtained. It should be noted that, due to production order's fluctuation, there may be a need to update the average daily consumption once a month, which may require adjustments in the number of labels in circulation and in the stock levels.

5. Results and Discussion

The next phase of this study consisted in testing the new e-Kanban system. Since the factory area, in which the study was carried out, is large, the system was tested in the flow of C8 (highlighted in yellow in Figure 2). Before testing, the workers were trained in the kanban methodology and in operating the e-Kanban system. At the same time, the e-Kanban system was calibrated with the number of labels and stock levels retrieved from the EKS© simulation (Section 4.1). So, after calibration and during the following 3 months the new system was tested in real production conditions. To summarize the results regarding the number of parts in stock, before and after the system's utilization Table 2 is presented. Here, the simulations results obtained using EKS© are also shown. From this table is visible that, before the new e-Kanban system, when a push system was in place, the parts were not evenly distributed through the production flow. The stock levels in WP and BP were bigger than the amount of stock between TTh and Ret, which comprise most of the production lead time. Moreover, the cost of a part in BP is 19% and 31% higher than its cost, after TTh and WP, respectively. The EKS© simulation balanced and distributed the parts throughout the value chain, reducing the BP stock by more than a quarter. And, since the lead time associated to WP is smaller, the stock levels were substantially reduced.

Table 2. Stock levels for C8.

	Stock WP	**TTh→Ret**	**Stock BP**	**Total Stock**	**ΔStock**	**ΔCost**
Before e-Kanban	3500	3064	4142	10706	-	-
EKS©	1386	6053	1220	8659	-19%	-22%
After e-Kanban	1392	6037	1200	8629	-19%	-22%

Therefore, according to the EKS© simulation, a 19% reduction in the stock levels of C8, which corresponded to a 22% reduction in the inventory costs, was expected. After the 3-month testing, and as expected with the pull system application, the company had a reduction of 19% in the stock levels and a 22% reduction in the inventory costs associated. These reductions are in concordance with the results obtained in the works presented in Table 1. Moreover, as can be seen, the EKS© simulation results and the results obtained after the e-Kanban system are similar, which proved that the simulation's input data were correct. Also, in agreement with the results of Table1, the number of parts shortages inside the factory was reduced. Besides the previous advantages regarding the pull and push system, the e-Kanban allowed to overcome several disadvantages of the traditional kanban system highlighted in Table 1 and in Romeira and Moura (2020). First, it eliminated the loss of kanban labels, which was the most common and made it possible for everyone to have the visibility of the entire value chain anywhere and in real-time. The labels' monthly update was also simplified since it can now be done remotely in the e-Kanban platform. Another advantage noted with the e-Kanban application, that was not discussed in the works of Table 1, is related to the definition of production priorities. With the system's application, the order, and quantities in which the components needed to be produced were automatically displayed in the production boards. This simplified the process of priority management and stopped the constant changes in production priorities. Also, with the e-Kanban system, the number of parts in stock was automatically displayed in the stock boards. In fact, in the papers of Razafuad et al. (2018), Ricky and Kadono (2020) and Svirčević et al. (2013), the authors do not present any production boards, only stock boards, and the developed e-Kanban systems are mainly a graphical way of seeing the level of stock available. Contrarily to the previously, Jarupathirun et al. (2011), the authors present a production board and not a stock board, however the system only displays what to produce, without considering upstream real consumption. Moreover, with the introduction of the Urgent kanban label functionality, the developed system was able to overcome a limitation exposed in the work of Menanno et al. (2019). Here, the developed system allowed the creation of urgencies, however, does not restrict them. Has this may produce a huge number of urgencies at the same time, and thus everything is urgent, which orders must be done first? In contrast, the system we propose only consents to the creation of one urgency per production loop. Our e-Kanban system also surpasses a problem detected by Maříková in (2008), regarding the creation of e-Kanban labels by the operators. As the author stated, labels were emitted when not needed, creating excessive stocks in the production lines. In contrast, the current e-Kanban system only gives clearance to the Logistics Planner to create e-Kanban labels. Lastly, in comparison to Hawari and Aqlan (2012), we created a more user-friendly interface, where just the needed information appears to the workers. Therefore, in the production/stock boards, the operators only have a table with the reference, designation, and quantity in the order that they must produce (Figure 8 (a)), and in the scanning menu the place for the scanned reference (Figure 8 (b)).

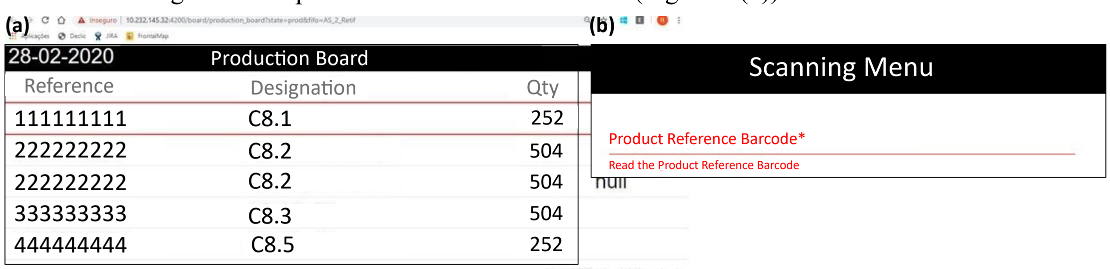


Figure 8. (a) The production board of the e-Kanban system; (b) The Scanning Menu of the e-Kanban system.

Despite the advantages mentioned, it was noted that, from time to time, the operators forgot to scan the references. Although it happened less than before, the application of the e-Kanban system forced the weekly verification of the number of labels in each state and recalibration accordingly. Nevertheless, the tests showed that, with the new system, the factory was able to control and balance the stock level which addressed the impact of demand variations and allowed the synchronism between production stages. It also allowed real-time monitoring of production and inventory and, due to a 24-hour visibility, the production and logistics managers know what would be in production until the next 24 hours creating increased flexibility and responsiveness. Table 3 synthetizes the results obtained in this work.

Table 3. e-Kanban system positive results and limitations synthesis.

Positive results	Limitations
↓Stock and associated costs ↑Stock and costs distribution through production ↓Part shortages ↓Impact of demand variations ↑Visibility, Flexibility, Reactivity ↓Lost card problems and Human errors ↑Production management, planning and scheduling simplification ↑ Synchronism	Manual scanning of references, which creates the need for a weekly verification of the virtual and physical stocks

6. Conclusions and Future Work

In this work a new e-Kanban system for production and stock management is presented and tested in an automotive manufacturer company. Its implementation intended to overcome the problems detected regarding priority definition, clients' satisfaction, stock levels and synchronism between production and assembly lines. Since the company possesses in-house software development teams, it was ruled more cost-efficient to develop a new e-Kanban system internally rather than adapting an existing e-Kanban market software to their specific requirements. Moreover, it must be noted that, in the development of the new system, the limitations of previously implemented e-Kanban systems were considered. The detected limitations in the literature were analyzed and the following solutions proposed:

- Limitation to only one urgency per production loop with the Urgent kanban label functionality.
- The Logistics Planner is the only one with clearance to create/delete e-Kanban labels.
- The existence of production boards with the order of production based on consumption, which facilitates the priority management activity.
- The existence of stock boards which show the stock levels throughout the products' production flows.
- The creation of a user-friendly dashboard for the production operators.

Once developed, the new system was tested in operating conditions for component 8 (C8), along a 3-month period. The results show that the stocks were reduced by 19% (which equals a 22% reduction in the cost related to stock), and that the number of parts shortages was also reduced, proving the benefits of a pull system compared to a push system. To the reduction of the latter, the automatic definition of priorities was also essential. Additionally, it was noted that the problems related to kanban labels' loss were eliminated and that a real-time control of the component's internal value chain was now possible. Also, the even distribution of stocks allowed for a mitigation of the demand variations' impacts and permitted the synchronism between the production lines of the different processes.

As future work and to further test the system, we propose its applications in the remaining factory components (C1 through C7). Additionally, to bring the system closer to Industry 4.0 requirements and reduce human errors related to the scanning process, the authors propose the introduction of RFID technology to track the CUs' movements through the production. This way, instead of the operators having to scan each label, the RFID tags are placed in the containers and automatically trigger the state changes. As well, we propose the system's connection to the factory's ERP. This would allow for an autonomous update in the number of MTS labels according to the clients' consumption and an automatic release to the production of the MTO labels based on the client's deadlines.

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Biography

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