Applicability of an e-Kanban system according to the Industry 4.0 paradigm: an applied practical study

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Abstract

Industry 4.0 is a reality, and organisations must assess the viability of their current Information Systems (IS) to integrate this paradigm change. In this work, a study within a Portuguese manufacturer is presented. Here, to overcome a set of problems and to understand the company's Industry 4.0 maturity, the implementation of a Kanban system, supported in the company's current IS was proposed. However, due its limitations, a physical Kanban had to be implemented instead, to convince top managers to invest in the development of a flexible e-Kanban system, which will fulfil the company's objectives, interconnect all factory areas and bring the company closer to Industry 4.0. The results in the pilot line showed that Kanban can effectively reduce stock and improve production processes. Moreover, they show the incompatibility of the current IS, for Industry 4.0 requirements, and the limitations of the physical Kanban system when compared to e-Kanban system.

Keywords: e-Kanban; Industry 4.0; Information Systems; Information and Communication Technologies

1. INTRODUCTION

Presently, the extreme market competition and dynamics, the crescent growth of technologies and the ever-rising customer requirements push organisations to be more efficient, agile, flexible and responsive (Emeka, 2018; Gunasekaran & Ngai, 2004; Saucedo-Martínez, Pérez-Lara, Marmolejo-Saucedo, Salais-Fierro, & Vasant, 2018). Due to this necessity, the concept of Information and Communication Technologies (ICT), which Nanda and Randhawa (2019) defined as: "[…] technologies that capture, transmit and display data and information electronically and includes all devices, applications, and networking elements that allow organisations as well as people to connect in the digital world", becomes remarkably strategic to organisations. Hence, applying these technologies through the entire value chain (horizontal integration) and within the manufacturing hierarchy (vertical integration) will, not only improve efficiency, agility, flexibility, responsiveness and product/service quality, but also align organisations with the paradigm of Industry 4.0 (Bigliardi, Bottani, & Casella, 2020; Lee et al., 2018).

Industry 4.0 is defined, by Hermann, Pentek and Otto (2016, p. 3928) , as the convergence of "industrial production and the information and communication technologies". This definition requires a real-time continuous information flow between every asset (human, machine, or product) of the value chain and, an increasing of automation and digitalisation, entirely achieved by the advancements in ICT (Bigliardi et al., 2020; Tao & Qi, 2019). From this description, two important terms, for the present work, can be highlighted, information flow and digitalisation. First, information flow corresponds to the data that stream around manufacturing processes and through the entire supply chain, providing the data needed to make decisions, for example, decisions on inventories, customer service, and others. Nevertheless, Industry 4.0 highly depends on an efficient and effective information flow and, for that, the information must be accessible, available to be shared accurately and in real-time (Browett, 2015; Hinchman, 2017). Muro, Liu, Whiton and Kulkarni (2017, p. 5) define digitalisation "as the process of employing digital technologies and information to transform business operations", this means that the application of digital technologies and information to transform processes, is the base for Industry 4.0. Thus, to prepare companies for the Fourth Industrial Revolution, it is imperative that organisations initiate their digital transformation, and they can start by investing in the digitalisation of their processes and information flows.

This work was developed in a Portuguese Company, belonging to an international automotive manufacturer group, which is present in more than 134 countries. This company produces gearboxes, which represent the core production volume, and motor components, such as oil pumps, crankshafts, and other parts. Due to its dimension and production volume, the organisation needs an efficient and real-time exchange of information through its internal production and logistics departments. This information sharing is of extreme importance since it enables the decision-makers to establish what needs to be produced, what is being produced in each process stage and, ultimately, what is ready to deliver. In order to be able to make a proper use of this information, it will have to be reliable and it must arrive at the appropriate locations in real-time.

Hence, for the presented company to give the first step towards Industry 4.0 it must have in its core an efficient and effective information system, that interconnects production processes and inventories to be in synchronism with the client. However, the increased complexity of production flows, a result of flow intersections and constant exits and re-entrances of components in the flow, together with the current product lead times, which are higher than the clients' delivery deadline, do not allow the intended synchronism between company and customer. Therefore, to achieve this goal, an e-Kanban system is necessary. A study of the actual production process was carried out and the following needs / problems were identified:

- The impossibility to achieve the flows ideal synchronism, due to the big difference between product lead times and the established delivery deadline;
- The need to reduce the current stock levels;

- The inevitable confluence of flows of different products from different locations, in some processes;
- The control of the exit and re-entrance of products that leave the normal flow process (quality problems, for example) and the products that, between processes must fall back to external suppliers.

To overcome these problems, the application of a Kanban system was proposed as the best solution. According to Ohno (1988), creator of the before-mentioned system, Kanban is an instrument used to transmit information from an upstream to a downstream process, indicating what needs to be produced, when it must be produced and in what quantity. Lage Junior and Godinho Filho (2010, p. 13) state that the Kanban, controls "[…] the delivery and/or production of parts, items, or raw material". There are two main types of Kanban cards (Kouri, Salmimaa, & Vilpola, 2008): the withdrawal Kanban and the production Kanban. The first describes the cards that authorize movements of batches/products/components and it signals the finished ones that are ready to be transferred to the next process stage. The second Kanban card is responsible for authorizing the production after the parts withdrawal from the supermarket of a previous workstation. Mojarro-Maganã et al. (2018) and Ohno (1988) mention that, through Kanban, enterprises can eliminate overproduction, reduce inventory and work-in-progress (WIP) levels, reduce waiting times and increase productivity, flexibility and efficiency.

Several application studies have already been published regarding the Kanban systems implementation. Naufal, Jaffar, Yusoff, and Hayati (2012) present a case study about the Kanban system's implementation in a Malaysian manufacturing company. The results obtained with this implementation showed a reduction of 40% in the lead time, a reduction between 23 and 29% in WIP and inventory levels and also, an optimization of the finished goods area by 4%. In their final conclusions, the authors mentioned that the study demonstrated that the Kanban system "[…] is essential in ensuring of Just In Time practice and to create smooth flow of part throughout manufacturing system" (Naufal et al., 2012, p. 1726). Mukhopadhyay and Shanker (2005) implemented a Kanban system in a production line of a tyre manufacturer. The Kanban system application resulted in a reduction of WIP (from 3 shifts to 2.1 shifts), a 50% reduction in time lost due to several factors, an increase in equipment availability and reliability, a 50% reduction in the rejection percentage, and so on. The authors conclude that this system "[…] allows a company to use JIT production and ordering systems, which allows them to minimise the inventories while still satisfying customer demands with improved service and quality" (Mukhopadhyay & Shanker, 2005, p. 498).

Thus, based in these and other application examples, when applying Kanban, the company in study will be closer to synchronism, since the supermarkets inside the line will have the needed parts at the right time; will have a system to manage the production priorities based on the real consumption; and it will be able to, not only, control the parts outside the flow and in external suppliers, but also, the work-in-progress and inventory. However, implementing the Kanban using physical cards, may have several disadvantages, like the ones highlighted by Wan and Chen (2008):

- Loss of Kanban cards, which leads to problems related to lack of material, an increase in waiting times and cost and, in some cases, the reduction of the service level;
- Kanbans incorrectly delivered;
- An increase in transportation numbers and distances and also, the increasing handling activities, enhance the probability of human errors, which facilitates Kanban cards loss and mishandling;
- Lack of visibility, since there is not a way to track and monitor the Kanban cards throughout the entire flow;
- Difficulties in changing the number of Kanban cards in the entire value chain (retrieving and adding new cards);
- The measurement of performance is limited because there is not a lot of data in the cards;
- The management and control of physical Kanban cards use workforce.

These limitations, concurrently with the current industrial framework of higher demand and increasing complexity of supply chains, generate a hypothetical increase in incorrect handling, misplacing and even loss of Kanban cards. This reality and the simultaneous improvement of ICT open the path to a new Kanban system, named by many as e-Kanban (Wan & Chen, 2008). The e-Kanban is expected to eradicate the disadvantages of the physical Kanban and, if not all, to enhance some of the Kanban system advantages.

Hence, instead of the application of a physical Kanban system, the current case study proposes the implementation of a e-Kanban system supported in the company's current management and control information system with the following objectives:

- Overcome the mentioned problems and necessities found within the company;
- Evaluate the company current management and control information system's efficiency and/or viability to accompany and support the transition to Industry 4.0.

The present work is organised as follows: Section 2 introduces the methodology followed by the problem presentation. In Section 3, the definition of the proposed "TO-BE" scenario, which includes the characterisation of the inventory management system and the Kanban integration are presented. The implementation of the proposed solution is introduced in Section 4. Thereafter, in Section 5 the outcomes of the implemented solution and the justification for the need to redefine the Kanban system are discussed. Lastly, in Section 6, conclusions regarding the system's implementation and, current management and control information system are revealed, as well as some insight into the next project steps, currently in progress.

2. METHODOLOGY AND PROBLEM PRESENTATION

Figure 1 presents the methodology steps applied by the authors to evaluate the objectives mentioned in Section 1. The first step was the "Sector selection", which means that an analysis between the interested parties and the top management was held to determine the first sector to be studied. The next step involves the definition and characterization of the current situation or the so-called "AS-IS" process. Here, for each existing product in the selected sector, a flow analysis was performed to develop the respective flow diagrams and lines. In this phase, mandatory data to analyse the current scenario was also collected. As can be seen in Figure 1, the subsequent steps include the selection of the pilot production line. Since the chosen sector comprehends different models of the product, only one model must be selected to be the pilot. After that future operation mode, or the "TO-BE" process, must be developed. In this case, a flow diagram of the future process and also the operation mode of the physical Kanban will be developed.

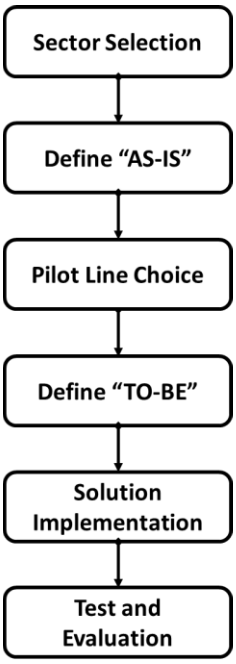

Figure 1 – Project Methodology.

Once everything is completely defined, the next step is the solution implementation. After implementation, the next phases are the test and evaluation phase. Here, the feedback of the results achieved are taken into account in order to improve and make the necessary modifications.

To better understand the project evolution the timeline in Figure 2 is presented. As can be seen, the project started in December of 2018 and lasted until October 2019. The project kick-off with the sector selection and with the data collection that defines the actual ("AS-IS") lines production flows. After this, the pilot line was selected, and its future production flows designed. Once this was completed, the proposed solution began to be developed. In June 2019, all collaborators involved in the project were trained according to the defined standards. The month of August does not appear in Figure 2 due to the company's vacation period. Therefore, the system was implemented in September and during this month and also in October all the tests and results evaluations were performed.

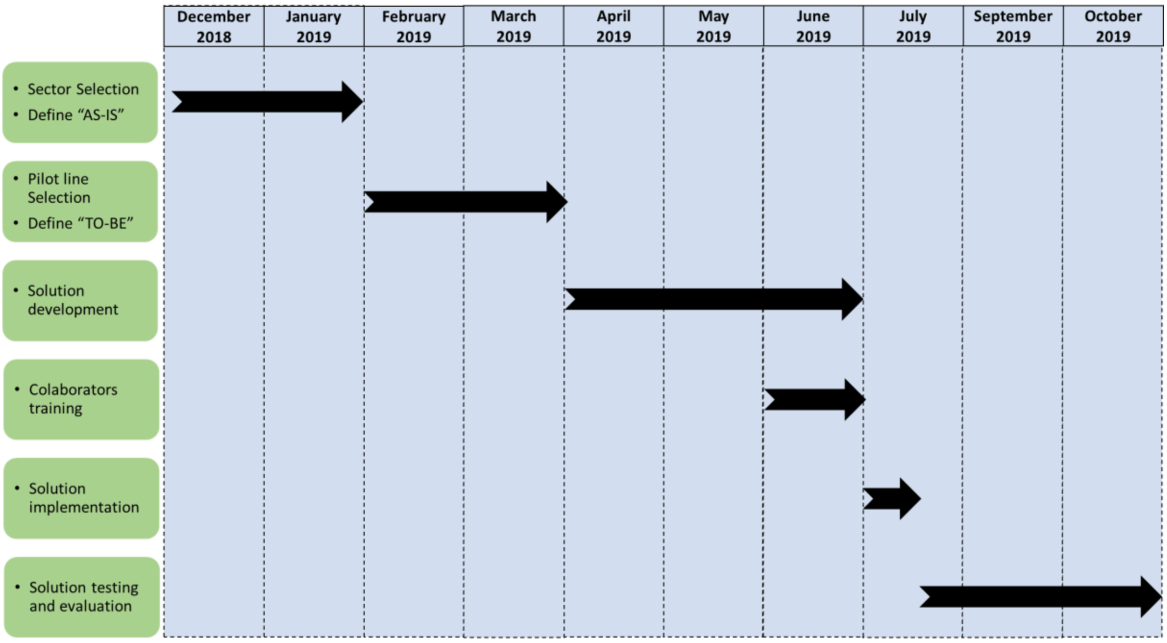

Figure 2 – Project timeline.

2.1. *Sector selection and the current ("AS-IS") state of the process*

At the beginning of the project, it was decided by the project team and top managers that the focus sector should be the Fixed Oil Pump. This decision was based on the following factors:

- The importance of the production line to the factory;
- The difficulty in managing products that have a subcontracted production in external suppliers (products that must leave and re-enter the factory);
- The production line working hour's flexibility, it can work on weekends or open an extra shift during the week if necessary.

This sector produces eight different fixed oil pump models. All the eight have two main components, the body and the cover. In the case of Models A and B, the cover is only assembled after an anodization process. So, in order to understand the current state, a global analysis of all the upper mentioned models was necessary. For that, a trace of the products throughout the production operations, was performed, obtaining the flow diagrams present in Figure 3.

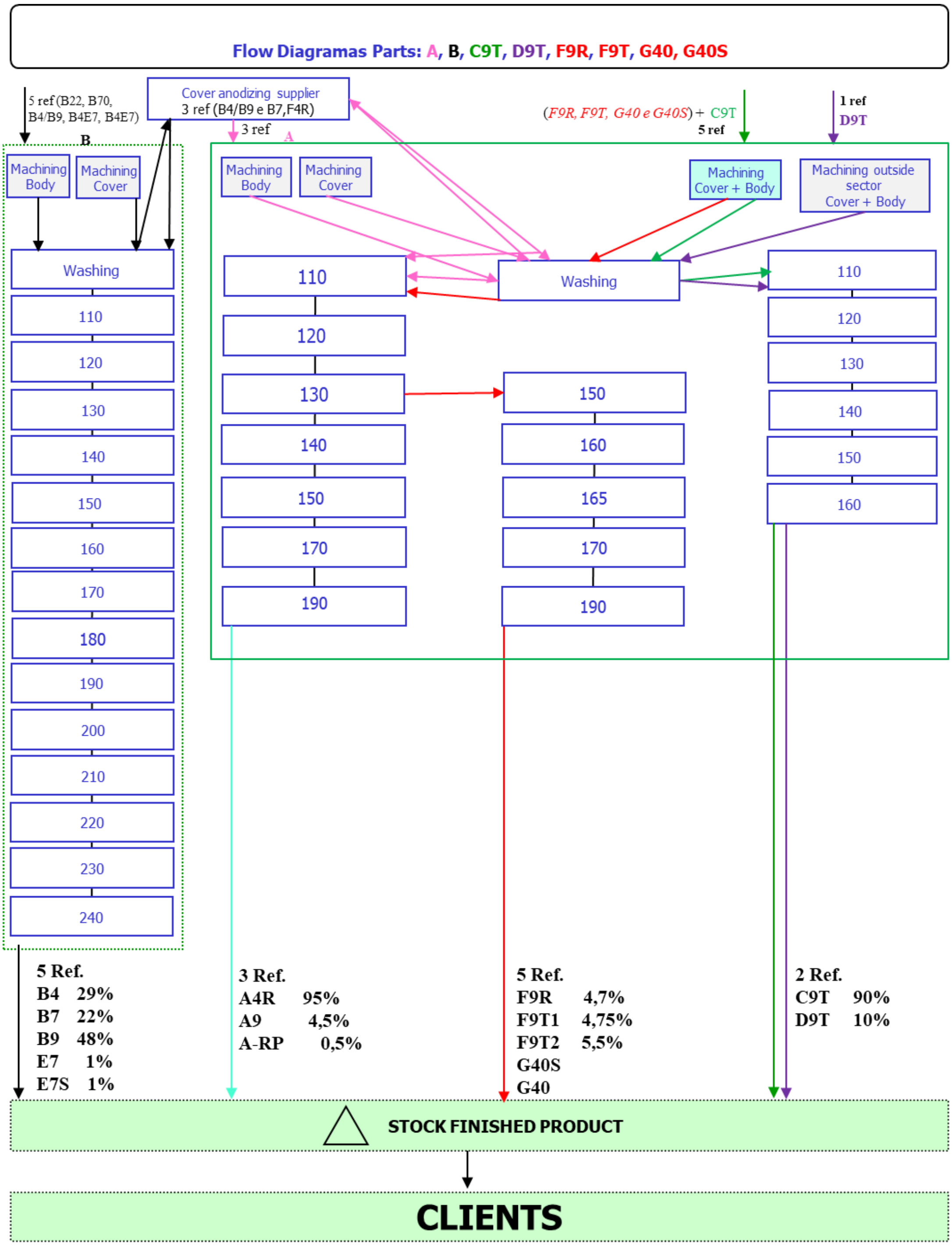

Figure 3 – Actual ("AS-IS") flow diagrams of the Fixed Oil Pump's models.

In Figure 3, the blue rectangles are process operations, such as, for example, short shaft insertion. To develop the products flow lines, it was considered that all products that go through the same machine belong to the same product flow line. When that happens, there is a confluence of different models, which forces production to manage priorities before that junction, because different models cannot enter the same machine simultaneously. The products' flow lines are presented in Figure 4.

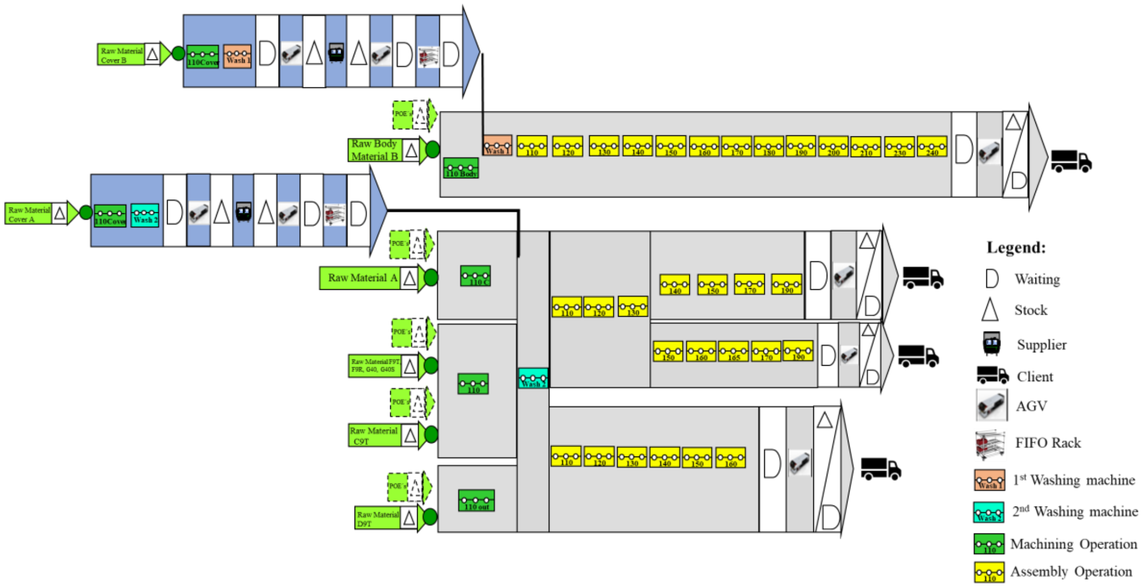

Figure 4 – Actual ("AS-IS") product flow lines of Fixed Oil Pump's models.

Six main product flow lines can be pointed out (Figure 4). The grey ones represent the pump flow, which means there is one body and one cover that will be assembled. Contrarily, the blue ones represent the covers before being assembled. The first grey product flow line is of Model B and it is independent of the other three grey product flow lines. These last ones converge in the washing machine and then, according to the product model, go through one of the two possible paths. As already mentioned, the blue product lines represent the cover flow, specifically, Model B and Model A covers. These two types are separated from the pump flow lines because they suffer an anodizing process, which is executed by an external supplier. This means that, before the cover is ready to be assembled it needs to be machined and washed, go to the supplier, come back and, only then, enters the pump flow before the washing machine.

2.2. Pilot Line Choice

As in every project, there is the need for a prototype or, in this case, a pilot line. Consequently, the project team decided to focus the study on the Model B product flow line for the following reasons:

- The line is independent of the others, which results in only one confluence (body and machined cover in the first washing machine);
- The machined covers go to an external supplier (one of the reasons to choose this sector in the first place).

3. The Future ("TO-BE") state of the process

The next step involves the development of the future product flow lines and, subsequently, the definition of the Kanban process for this particular product flow line. For the first, an extensive flow analysis and simulation study were performed with the goal of increasing service rate and reducing stock levels. It is important to note that the assembly line only works during the afternoon. The proposed future product flow lines are presented in Figure 5.

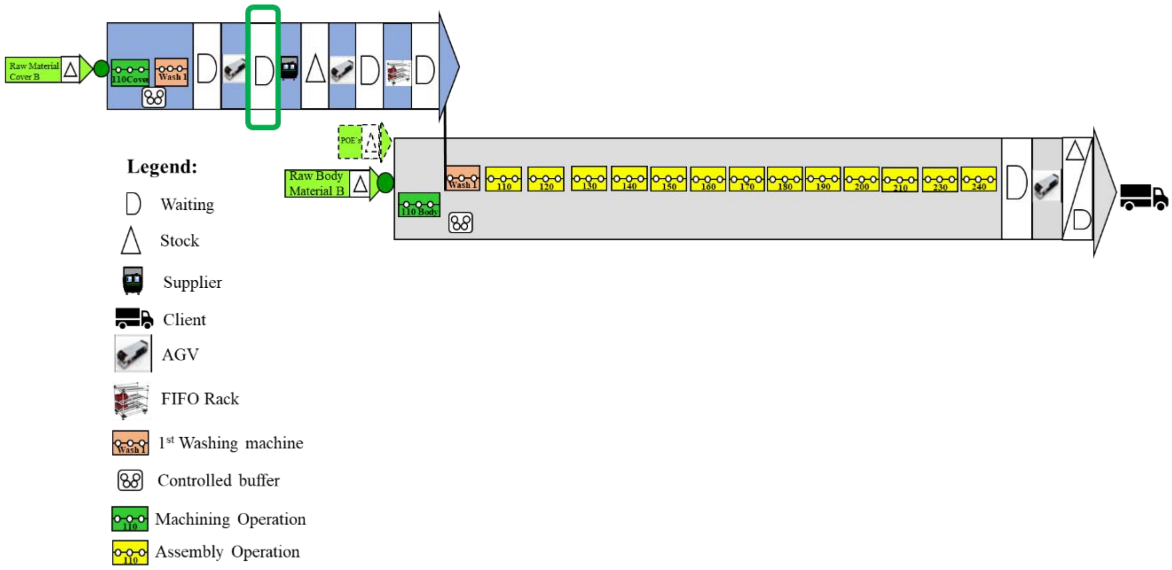

Figure 5 – Future ("TO-BE") product flow lines of Model B's Fixed Oil Pump.

The pump flow is represented by the grey product line and the cover flow by the blue product line. The cover flow starts with the machining of cover's raw material and then its washing. Once the covers are cleaned, they wait for the AGV (Automated-Guided-Vehicle) to arrive, to take them to the warehouse, where they wait to be sent to the supplier. This is the first change in comparison to the initial state. When analysing the possible scenarios, in concordance with the real consumption of Model B, it was detected that there was no need for the stock before the anodizing process (green framework in Figure 5). So, instead of having a stock, there would be a waiting queue. The cover supplier comes to collect the machined covers once a week, and when the supplier arrives, it takes the machined covers in the waiting queue and delivers the container with anodized covers from the previous week. The latter enters the factory stock and, when pulled, exists the stock and goes, by AGV, to the production. Once in the production, the operator places the container covers in the FIFO (First-In-First-Out) rack. Therefore, when the assembly line starts working, the anodized covers are ready to be placed alongside the machined body, in the conveyor (one body and one anodized cover by pallet). The referred pallet then goes into the washing machine, and finally into the assembly line. In the same way, the pump flow starts with the machining of the body. If the assembly line is not working, the machined bodies go to a controlled buffer. Contrarily, in the afternoon shift, as the assembly line is working, one body and one anodized cover go into the washing machine straight to the assemblage. Meanwhile, the machined covers wait to be washed in the next morning shift, which is possible because the capacity of the washing is higher when only covers are washed.

3.1. Inventory management system and its integration with the e-Kanban system

Once the planned process and general operating mode were defined, the next step was to integrate the current inventory management system and the Kanban cards. This aims to:

- Eliminate overproduction of machined bodies and covers;
- Better manage and control the stock levels inside the factory and in the supplier (control of possible delivery delays);
- The improvement of the working conditions, because now every single aspect of the operation is standardized.

The current inventory information system allows the company to, when the production is finished, declare what was produced. So, each time a batch is declared, the system increments its level in the current stock. The reverse logic is applied when the batch gets out of stock. The proposal is to use this system's data to create an interactive dashboard to follow the Kanban cards throughout the flow. Therefore, applying the Kanban principles, when a batch is consumed, the Kanban is sent to the production to restore the stock level and, when finished, it is, once again, removed from production and inserted into the stock. The entrances and exits of the stock can be tracked in the dashboard, which gives the visibility of what must be produced, what is in stock and, in the cover case, what is in the supplier. To provide the shop floor with the production sequencing and the stock level, two dashboards, one for the cover flow and another for the pump flow, illustrated in Figure 6, were developed.

Pump Flow Management

Production Order		Stock	
Product	Nº Kanban	Product	Nº Batches
B4	97	B4	5
B4	96	B7	3
B7	85	E7	2

Cover Flow Management

Production Order		Stock	
Product	Nº Kanban	Product	Nº Batches
B4/B9	1	B4/B9	2
B4/B9	5	B7	3
B7	9		

Figure 6 – Production Management dashboards in each product flow line.

The "Production Order table" (Figure 6) gives the sequencing of production and the Kanban associated with each order. Here, it is highlighted that, it is only possible to declare the produced reference and the respective Kanban in the first line of the "Production Order table", to respect the

FIFO strategy. This way, the first Kanban ID to be consumed is the one that will appear first in the "Production Order table" and, therefore, it will be the first to get out. Note that, each product reference is associated with specific Kanban identification (ID) numbers (for example, the Kanbans 1,2 and 3 are assigned to the Pump B4), to allow the FIFO compliance to be controlled. The "Stock tables" give the stock of each product reference. In this table, the FIFO strategy is not applied.

To manage the supplier, in order to understand its efficiency, the dashboard from Figure 7 was proposed. Through this board, it is possible to rapidly visualize if there is a delay in the delivery of covers. For example, in week 2 the supplier collected 3 batches and delivered 2, so in week 3 he should have brought 3 batches of anodized covers. However, as can be seen, the supplier only delivered 1, which means that there are 2 batches in delay. This last dashboard allows production to quickly react and reach the supplier to establish the reason for the delay.

Cover Supplier Management

Week	Collected covers	Delivered covers	Delay
W2	3	2	0
W3	3	1	2
W4	5	5	0
W5	3	-	-

Figure 7 – Supplier Management Dashboard.

To understand the material flow and the information flow, regarding the movement of parts between production, stock and supplier, Figure 8 and 9 are presented.

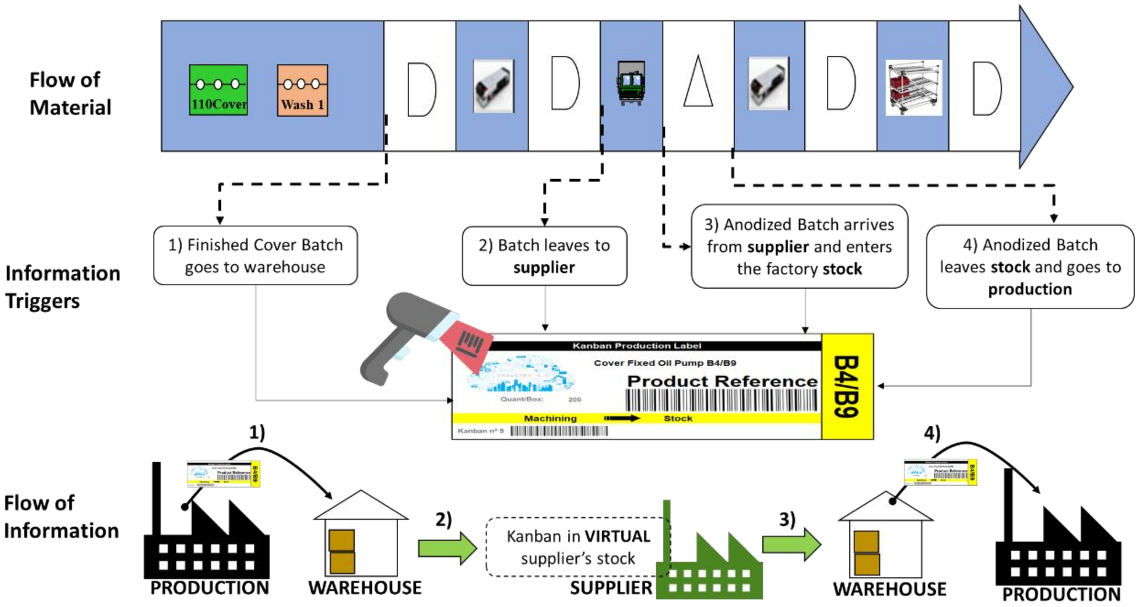

Figure 8 – Information and material flows in the cover product flow line.

In Figure 8 the material flow, the information triggers and the information flow are shown. The information triggers represent the event that provokes a change in the state ("production", "waiting queue before supplier", "supplier" or "stock") of the Kanban card. So, once the batch finishes production, the Kanban ID attached to it in the "Production Order table" is scanned (**step 1,** Figure 8) to allocate a Kanban card to a specific batch number. This step, also known as the production declaration, triggers the modification of the Kanban from "production" to "waiting queue before supplier". This state alteration also triggers the removal of the referred card from the "Production Order table" and its addition to the supplier management dashboard in the column of "Collected covers". This state is only altered to "supplier" when the batch is collected (**step 2,** Figure 8). In the same way, when the batch arrives, it goes from "supplier" to "stock" (**step 3,** Figure 8), also adding the number of batches that arrived in the column of "Delivered covers". The last stock modification occurs when the batch is needed to produce pumps. Here, the Kanban moves from "stock" to "production" again (**step 4**, Figure 8), which triggers the Kanban's removal from the "Stock table" and its entrance at the end of the "Production Order table". If, for some reason, the Kanban is not scanned in one of the scanning points, an error occurs and the system blocks. To unlock the system, the operator must validate the Kanban ID in the missing scanning point. Therefore, the Kanban card must pass for all the states in the previous defined order.

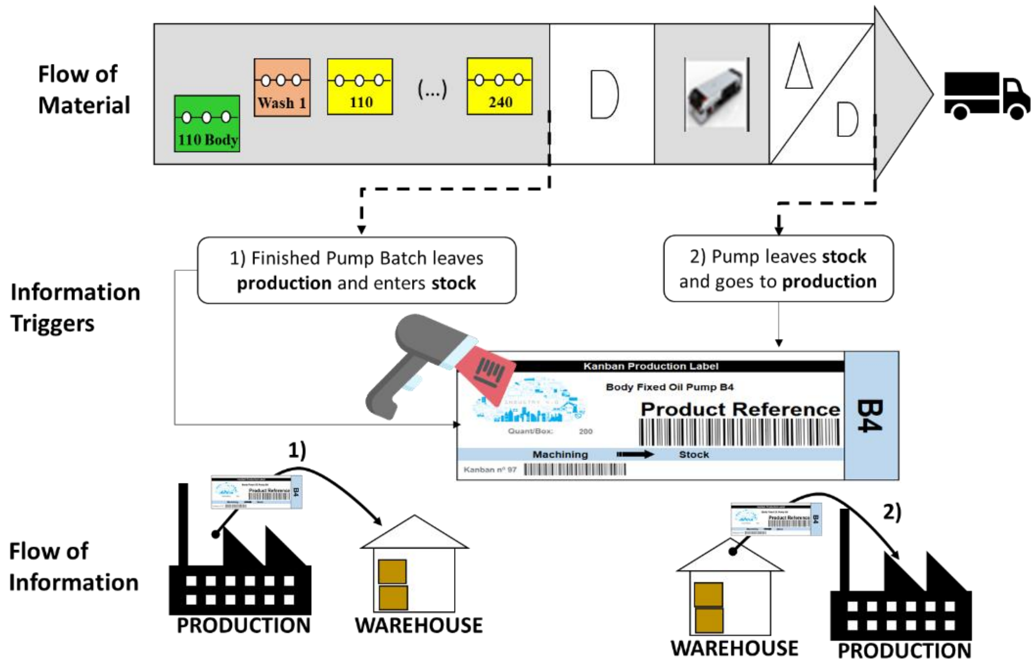

Figure 9 – Information and material flows in the pump flow.

Figure 9, shows how the material flow triggers the information flow for the pump. Here, the information flow only assesses the stock inputs and outputs. Once the pump batch is produced, the Kanban ID is scanned, triggering its removal from the “Production Order table” and its entrance in the “Stock table” (**step 1,** Figure 9). When the batch is sent to the customer, the respective card is scanned, and two things happen, the card is decremented from the stock and it moves to the end of the “Production Order table” (**step 2,** Figure 9).

4. Solution Implementation

The solution presented in the previous section was analysed. However, the following problems with the current inventory management system were detected:

- It did not allow the introduction of new scanning points, so only the scanning at the end of production was available;
- It did not allow to insert and retrieve existing data to create the dashboards presented in Figure 6 and Figure 7;
- It did not allow the integration of a new input (Kanban card ID number) in the existing production declaration menu.

Basically, the Kanban operating mode, supported in the current information system, cannot be applied since the latter is a closed software and cannot be adapted to the new proposed solution. Due to these limitations, the applied Kanban system had to be entirely physical. So, new working standards were developed and implemented. In Figure 10 the work standard for the cover flow is presented.

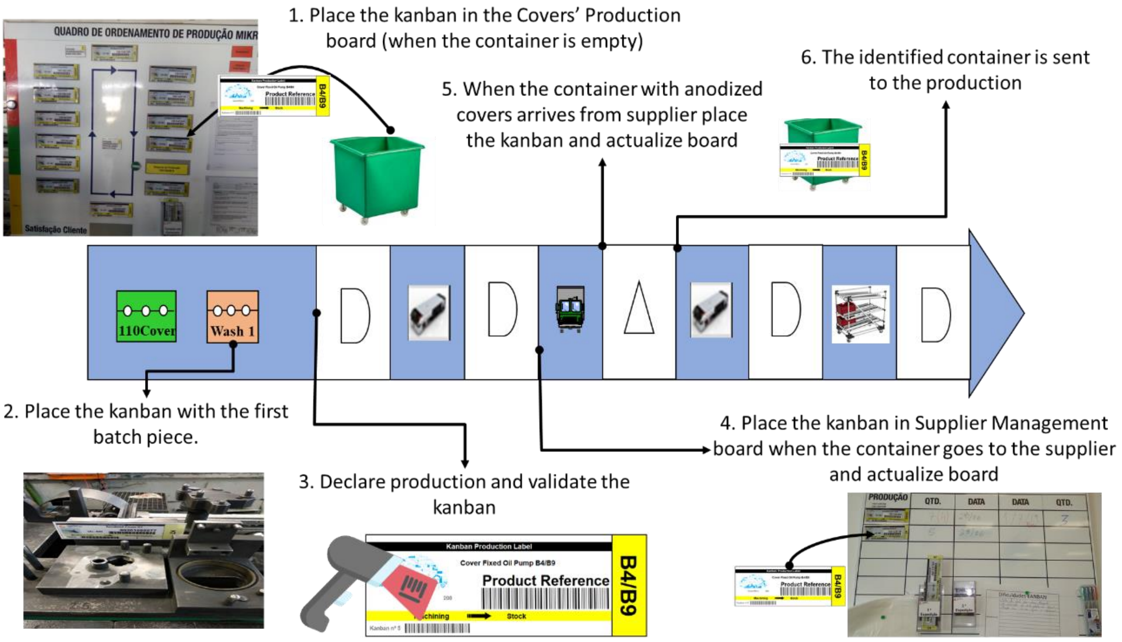

Figure 10 – Implemented work standard in Cover's Flow.

In the moment that the container of anodized covers ends, the operator takes the Kanban identifying it and puts it in the Cover Production Board, accordingly to the defined order of arrival (**step 1**). This means that the Kanban placed last will also be the last one to be produced. Similarly, if the assembly line is stopped, the covers, after machining, are washed. Thus, when putting the machined covers in the conveyor to be washed, the respective Kanban also needs to accompany the first piece of the batch (**step 2**, Figure 10). When the batch of machined covers is complete, the production is declared and the Kanban ID is validated (**step 3**, Figure 10). In contrast with the proposed solution in the previous section, here, after the production is declared and the Kanban validated, no trigger occurs. The validation of the Kanban ID only works as a *poka-yoke* (According to Saurin et al. (2012) a *poka-yoke* is used to prevent or detect abnormalities), to hinder the operator from sending the final batch to the warehouse without identifying the Kanban ID card. When the supplier comes to collect the available machined cover batches, the logistics operator takes the respective Kanbans and places them in the Supplier Management Board (**step 4**, Figure 10), which operates in the same way as the one presented in Figure 7, however, in a manual way. The anodized covers delivered are immediately identified with previous week Kanbans, which were waiting in the board (**step 5**, Figure 10). After identification, the batches are put in stock. Thus, when requested, the container with anodized covers is sent to the production (**step 6**, Figure 10) and the process is repeated.

Additionally, due to the same circumstances, the pump flow also suffers several modifications as shown in Figure 11.

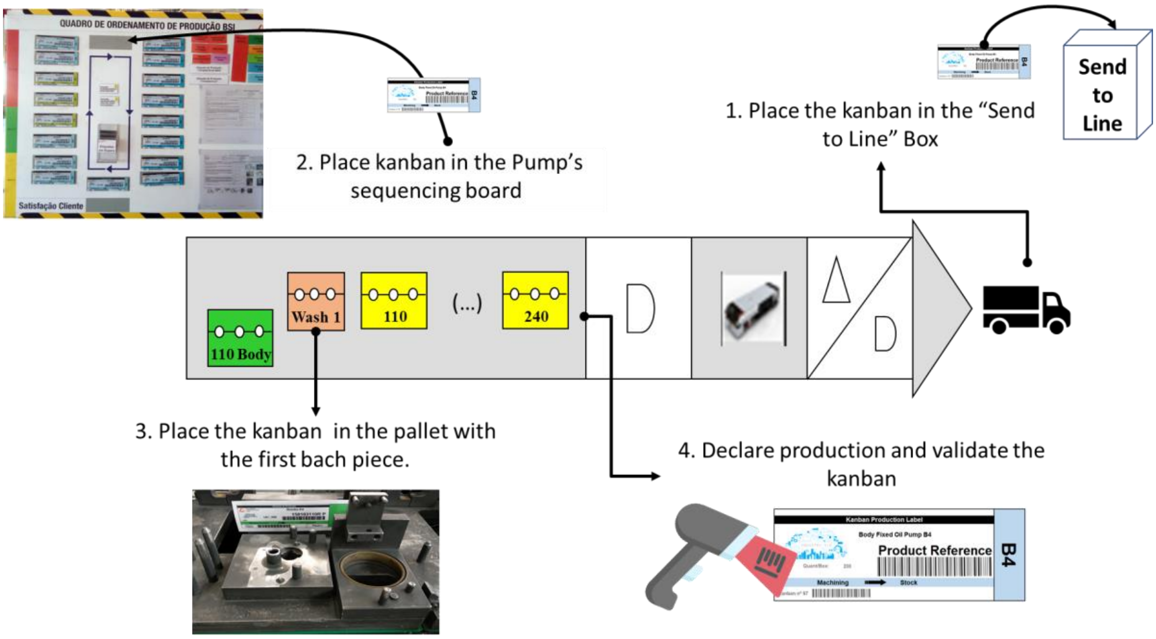

Figure 2 – Implemented work standard in Pump's Flow.

After the batch of final product is consumed (**step 1**, Figure 11), the Kanban card is placed in a specific box to be sent to the respective production workstation. Once it arrives, the Kanban is placed in the Pump Production Board, accordingly to the FIFO strategy (**step 2**, Figure 11). When the assembly line is working, the machined body, together with an anodized cover, are placed in the conveyor and sent first to the washing machine and then to the assembly line. It is important to note that the Kanban card associated to the produced batch is placed alongside the body and cover in the conveyor (**step 3**, Figure 11). When the final pump is set in the container, the operator declares what was produced and validates the correspondent Kanban ID (**step 4**, Figure 11). This procedure is solely a *poka-yoke* and the data cannot be utilized.

A training, both theorical (Kanban fundamentals) and practical (operating mode in the field) to all the company's collaborators, that would have direct or indirect contact with the present Kanban system, was held. Today, the Portuguese manufacturer is currently working with the standard operating mode presented in this section.

5. Outcome Discussion and the Justification for not applying the e-Kanban solution

The impossibility of applying an e-Kanban system in the Fixed Oil Pump was only due to the current information system. The company's current information system is a closed software, which did not allow the sharing of information and the insertion of new vital data to the e-Kanban system's operation.

In order to solve this problem, it was decided to develop internally a dedicated information system that allows to apply the e-Kanban system to synchronize all the information and consequently interconnect all production processes. But before taking this step, which will lead to a large investment of human resources, money and time, the company wanted to have concrete data on the Kanban system's effectiveness to fulfil the company's current needs and to overcome its problems. This is, the improvement that the e-Kanban implementation will achieve in the problems described in section 1.1: stock reduction; flow confluence management; control of external products and synchronism. Therefore, the need to prove the e-Kanban effectiveness resulted in the implementation of a physical Kanban system in a pilot production line. The implemented physical Kanban system is currently working with seven different references of Model B (5 references of pump and 2 references of cover) and the total number of cards circulating is 111: 62 Pump Kanbans and 49 Cover Kanbans. However, and despite the thorough training given to all collaborators in contact with the Kanban system (training given June 2019 – Figure 2), after the first week several problems appeared:

- The disappearance of Kanbans;
- The increased number of non-added-value movements, in order for the Kanban ID card to be always attached to the respective batch pieces;
- The increase in the inventory auditing times because now, besides counting the number of batches, the collaborator also has to check the Kanban ID number to know which one is missing;
- Sometimes, for forgetfulness reasons, the Kanban card does not accompany the batch.

The aforementioned problems, if it were not for the constant Kanban card auditing, would, probably, have had severe consequences in production, being the most harmful the reduction in customer service rate. However, even though it was possible to reduce the need for daily production order re-sequencing activities (i.e. the number of times that the production has to change the production order to meet the customer requirements), the drawback was that the auditing sessions had to increase.

Nonetheless, and according to the collected data during the experimentation period, with the Kanban system implementation, in the long-term, it is expected a reduction of 34% in the overall cover stock of Model B and a reduction of 33% in the final stock of Model B Pump. Maintaining the clients' requested product volume constant, in a short period, right after the implementation (beginning and middle of July 2019), a stock decreasing was achieved, the pumps' stock had a 16% reduction and the covers' stock had a reduction of 30%, in comparison to the real stock before the Kanban implementation. The decline in the covers' stock is mostly due to the removal of the stock before the supplier and its replacement by a waiting queue. Yet, to achieve the expected reductions (34% in the cover and 33% in the pump), it is still required that the system stabilizes.

The results obtained with the supplier management were also revealing. It was noted that, regularly, the supplier did not comply with the FIFO and the quantity collected was not the same that arrived in the subsequent week.

In this pilot line it was not possible to evaluate the effectiveness of Kanban in priority management of the flows confluence, since the flow confluence the washing machine was controlled by the opening hours of the assembly line (in the morning shift, only machined covers where washed, and in the afternoon shift a body and an anodized cover were washed).

Despite the system’s advantages in rising service rate (which means that there was an increase in the deadline’s compliancy rates), reducing stock levels and improving supplier management, the constant uncertainty, and therefore auditing, caused by the Kanbans disappearance, led to a certain mistrust towards the physical system. Still, the authors agree that the implementation of a physical Kanban came to be important, since it proved, undoubtedly, its potential in inventory reduction and priority management. It also allowed the operators to palpable understand all the operations behind Kanban.

6. Conclusion and Future Work

The present case study intended to evaluate the effectiveness of the e-Kanban system, to help the company overcome its internal problems, and to evaluate the current information system’s efficiency and viability to accompany and support the transition to Industry 4.0. However, the inflexibility of the current information system precluded the e-Kanban application which led to the implementation of a physical Kanban system. This latter reached the company’s requirements but also proved the e-Kanban system’s advantages in comparison to the physical Kanban.

The system’s pilot line consisted of a 7-reference production line with 111 Kanban cards circulating. However, despite the small scale, managers and operators experienced several difficulties in managing the physical cards manually. If this situation is occurring at this scale, when Kanban is disseminated throughout the factory, where there would be thousands of Kanban cards, there is a high probability that the system would be unsustainable.

Although automobile industry is one of the top industries when it comes to innovation, during the present study it was also verified that the current inventory management and control information system does not allow to insert, treat, utilize and share the existing information. As seen in Section 1, Industry 4.0 depends of accessible, available to be shared and real-time information (Browett, 2015; Hinchman, 2017), which the current system effectively lacks. Indeed, the absence of these characteristics, precluded the use of this system and, consequently, led to the implementation of a purely physical Kanban.

In conclusion, the existing information system is outdated and is not aligned with, not only the intended Kanban system needs but also the Industry 4.0 paradigm. Additionally, the possible advantages of an electronic Kanban system convinced top managers to invest in new technologies to develop an entirely digital management and control Kanban system. The latter will allow for a higher concordance between the flows of information and material and will require minimal human interference. Therefore, future works include1 the development of a flexible and adaptable digital Kanban system that would allow for the management and control of production and WIP-inventories, logistics and other internal service providers (for example, maintenance and tool repairers). Once this is achieved the company is one step closer from interoperability and interconnectivity, which are pre-requirements to achieve the smart factory of Industry 4.0.

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