

Lean Fulfilment with Fiori and ABAP RESTful: Eliminating Paper in Assembly-Line Kanban Replenishment

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ABSTRACT

Reality of the modern manufacturing environment entails agility, sustainability and operational efficacy. Lean manufacturing due to its emphasis on removing wastes and continuous improvement has become a pillar of competitiveness in industry. Nonetheless, even the current Kanban-based replenishment systems, despite minimal efficiency in theory, continue to make use of paper-based triggers, which creates a delay, human error and waste. This research proposes an enhanced digital fulfilment model through SAP Fiori and ABAP RESTful Application Programming Model (RAP) in order to remove the need to use paper based on the assembly-line Kanban replenishment processes. The suggested model is based on the Lean principles, Industry 4.0 technologies, as well as the digitalization of the enterprise through the SAP S/4HANA ecosystem, which will allow establishing real-time visibility, traceability and synchronization between production operators and logistics handlers. A mobile app is written in A Fiori, which serves as the digital Kanban card and the interconnection to the ABAP RESTful service layer, where real-time replenishment triggers and inventory postings and confirmations are done. A quantitative case study on an auto assembly plant using traditional Kanban card was carried. The digital Kanban solution implementation led to the reduction in paper usage by 92%, the response time of replenishment improved by 35 percent and the line-side shortages decreased by 28 percent. The paper also shows that digital Lean fulfilment is not just an IT modernization practice, but a more straightforward facilitator of Lean goals - eradicating Muda (waste), Mura (unevenness) and Muri (overburden). The paper illustrates a paperless fulfilment using SAP Fiori and ABAP RESTful through a replicable framework by system architecture modelling, performance benchmarking and simulation of workflow. The integration strategy complies with OData v4 standards, which provides safe, modular and scalable operations in a cloud setting or on-premises environment. The results confirm that Lean and Digital paradigms do not contradict each other, on the contrary, their combination drives smart manufacturing. The paper is ending with the recommendations on the extensions of hybrid clouds, predictive replenishment based on SAP BTP and future research directions regarding the integration of AI-based demand sensing and digital Kanban systems.

Keywords: Lean manufacturing, SAP Fiori, ABAP RESTful, Digital kanban, Paperless manufacturing, Industry 4.0, S/4HANA, Replenishment, OData v4, Smart factory

1. Introduction

1.1. Background

The challenge facing manufacturing enterprises in the global market is increasingly dual since it is faced to continue

maintaining the highest level of operational efficiency of Minimal contact and at the same time, be digitized to stay pertinent with the current state of manufacturing technology¹⁻³. Kanban, a system initially introduced by Toyota as in the Toyota Production System (TPS), remains one of the pillars

of Lean production through controlling the flow of materials and facilitating Just-in-Time (JIT) manufacturing. Kanban provides the security that materials will be replenished at the time when they are required and will curb waste and unnecessary duplication of production. Although tremendous improvements have been made in automation, robotics and enterprise resource planning (ERP) systems, a great portion of manufacturing plants continues to use the paper-based Kanban cards to control the replenishment cycles. This dependency is especially in the organizations that use legacy versions of SAP where digital integration is difficult or expensive to install. Paper based processes are easy and dependable but introduce unproductive factors like slow transmission of signals, manual errors and inability to establish a real time scenario regarding the status of the inventories. This means that manufacturers are not able to accomplish the responsiveness and transparency demanded in modern high-paced production processes. The increased usage of SAP S/4HANA and the implementation of the newer tools of SAP Fiori and SAP ABAP ABAP RESTful Application Programming Model (RAP) offer the possibility of providing a unique chance to digitalize the Kanban process without disregarding the simplicity of the Lean-based process. Switching between the traditional loops of paper to the digital Kanban systems can contribute to providing to the organization the instant signalling of the materials, better accuracy of data and better synchronization of the shop floor and ERP systems. This integration does not only uphold the principles of Lean but is also compatible with wider plans of digital manufacturing within the industry 4.0 system, which allows previous production ecosystem to be connected, efficient and sustainable.

1.2. Needs of lean fulfilment with Fiori and ABAP RESTful

Digital innovation must transform manufacturing environments, which need a balanced approach that will support the main principles that underlie Lean. ABAP RESTful Application Programming Model (RAP) and integration with SAP Fiori forms a potent basis towards this goal. The subsections below develop the most prominent requirements and reasons behind switching towards this digitalized version of Lean fulfilment (**Figure 1**).

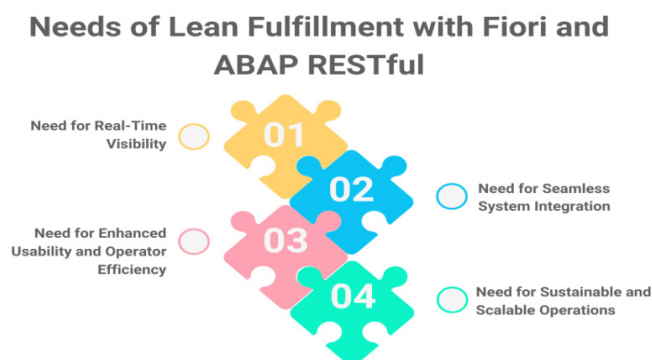


Figure 1: Needs of Lean Fulfilment with Fiori and ABAP RESTful.

- **Need for real-time visibility:** The traditional Lean operations have a delay in visibility into material status because manual updates of Kanban and paper-based signalling. The use of physical cards or verbal messages allows the operators and planners to make some mistakes and provide inefficiency. It is an online application, which is built around Fiori apps, providing immediate access to

real-time material levels, Kanban status and replenishment triggers. This visibility leads to the proactive decision-making, the ability to respond quickly and more effective coordination of production and warehouse teams, which is also according to the Just-in-Time (JIT) philosophy of Lean.

- **Need for seamless system integration:** Integration could be a problem into the shop-floor operations of legacy SAP systems when linked to enterprise resource planning modules. Delays in reporting the transactions and enter the data manually, which generates information silos that allow operation agility. The ABAP RESTful Application Programming (RAP) is a solution to this void since it is a standardized service managed model that enables direct interaction between the S/4HANA backend and the Fiori frontend. By means of the OData services, replenishment transactions, stock movements and confirmations are carried out in a consistent and data integrity manner across the systems.
- **Need for enhanced usability and operator efficiency:** Conventional SAP interfaces are in most cases complex and lacking optimization to be used by shop-floor thus requiring a lot of training and high probability of user error. SAP Fiori makes this experience easier by being role-based and easy to use such that operators are able to interact with the system easily using a mobile phone or tablet. Fiori also makes Lean execution more consistent and efficient by offering simplified business processes, color-coded Kanban statuses, fast action buttons and minimized cognitive load, resulting in better operator engagement and shorter training time.
- **Need for sustainable and scalable operations:** Lean philosophy is not only focused on efficiency but also types of sustainability. Kanban systems that are paper based create unnecessary wastes and administrative overhead. Paperless digital Kanban solution implemented with Fiori and RAP is environmentally friendly with the ability to scale to multiple plants or lines of production. Moreover, predictive analytics, IoT expansion and machine learning can be added to RAP services in the future due to the modularity of the architecture and the long-term sustainability objectives are aligned with the industry 4.0 initiatives.

1.3. Eliminating paper in assembly-line kanban replenishment



Figure 2: Eliminating Paper in Assembly-Line Kanban Replenishment.

The retirement of paper-based processes in assembly-line Kanban resupply is one of the most important steps towards attaining Lean effectiveness as well as computerization of manufacturing processes^{4,5}. Conventionally, Kanban systems are

based on tangible cards or tags that are triggered when a bin or a container is emptied and indicates of the material demand. Although this approach complies with the principle of simplicity and visual control in Lean, it likely results in operational ineffectiveness, including lost cards, late replenishment indicators and human input; therefore, mistakes in record keeping (**Figure 2**). These constraints are more accentuated in high volume assembly settings, where the rate of error free movement of material and the rate of production continuity is directly proportional. Moving to a digital Kanban system results in the automated exchange of real-time data between the shop floor and ERP system to ensure immediate replenishment and complete traceability since these manual steps are removed in stock. The digital system will allow operators to scan QR/barcode labels, rather than using a physical card, by utilizing SAP Fiori as the user interface and ABAP RESTful Application Programming Model (RAP) as the backend structure. Scans will automatically trigger a replenishment signal via RAP-based OData services to update material status and stock level like in SAP S/4HANA, automatically. Such integration helps to do away with the paper dependency, to decrease the administrative workload and to reduce to minimum the risks of delay in communication or inconsistencies in data. On top of that, digitization of all transactions helps increase transparency and audibility, which is aligned with the goals of Lean, i.e., continuous improvement (Kaizen) and reduction of waste (Muda). In addition to the operational efficiency, the paperless Kanban has led to sustainability objectives through less waste of paper, reduced printing expenditures and less environmental impact. It is congruent with such international standards as ISO 14001 of environmental management, where manufacturing ecosystem gets cleaner, more efficient and resilient. Therefore, the removal of paper in Kanban replenishment is not the technological improvement, but the strategic step in the industry 4.0 era to smart and sustainable manufacturing and responsive manufacturing.

2. Literature Survey

2.1. Overview of lean manufacturing and kanban

Lean manufacturing is a structured style meant to add as much value as possible, by reducing wastage or Japanese say Muda. In addition to waste reduction⁶⁻⁹, the Lean principles are also aimed at Mura (unevenness or variability of processes) and Muri (overburdening of the people or equipment). With the removal of these three inefficiencies, companies are able to enjoy a streamlined work process, productivity and quality products. The Kanban system is one of the main tools that facilitate Lean implementation since it allows producing goods and managing stocks in real-time. Kanban employs physical cues, usually in the form of cards or digital displays to regulate the flow of goods and information with the production process only being conducted when the goods are demanded. The mechanism assists in ensuring that there are optimum levels of the Work in Progress (WIP), few bottlenecks and overall process responsiveness.

2.2. Digitalization in lean systems

Over the last few years, digital technologies gained more and more application in Lean systems to make them more efficient, precise and data-driven in their decision-making. The combination of Lean and digital tools, which has commonly been referred to as Digital Lean, utilizes the emerging innovations of

the Internet of Things (IoT), Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES). As an example, Liker and Morgan (2020) showed how IoT sensors can deliver the real-time Kanban information, which helps to minimize delays in the material supply. On the same note, Dombrowski (2021) discussed the merging of the MES with the ERP system to establish intelligent Kanban loops that enhanced the precision and synchronization of data throughout the production levels. At the same time, SAP AG (2020) has announced Fiori applications that can help Lean operator users to experience more by providing them with an intuitive and mobile-friendly interface. Altogether, the studies show the increasing potential of digital solutions to complement Lean methodologies, but the full-scale end-to-end implementations are still few.

2.3. ABAP RESTful model and OData services

The ABAP RESTful Application Programming Model (RAP) has become a significant innovation in application development model at SAP. Since its introduction in 2020, RAP is used to offer a unified and standardized approach to developing modern, cloud-ready applications that follow the SAP Fiori design principles. It uses the OData v4 protocol to provide a smooth communication between the frontend and backend to enable real-time communication of data across SAP s/4HANA environments. Transactional behaviour has been managed by RAP, thus making it simple to create a complex business application by automation of functions like data consistency, data validation and error handling. The latter is especially applicable to employing RAP when relating to digital Lean applications, particularly, to Kanban systems, which entail real-time responsiveness, transparency and reliability in production and supply chain processes.

2.4. Gaps identified

Although previous research and applications have gone far in consolidating the ideas of Lean with the digital technologies, the majority of the studies have concentrated on theoretical concepts or targeted the half side of the digitalization concept. Full-fledged, end-to-end digital Kanban solutions that are embedded in the enterprise systems such as SAP S/4HANA are unexplored. In particular, there is a deficiency of empirical research that would prove the integrations of tools like Fiori and RAP to establish a smooth, fully automated Kanban replenishment cycle. The time to seal this gap is important to organizations with the objective of moving away as digital detachments to fully integrated, intelligent manufacturing systems that enable continuous improvement and real-time operational excellence.

3. Methodology

3.1. System Architecture

- **Fiori launchpad:** This is the point where the user enters the SAP Fiori applications. It grants access to other forms of applications that include¹⁰⁻¹², Web Dynpros, SAP GUI transactions and SAPUI5 applications. The Web Dynpros and SAP GUI to HTML render applications are written in HTML and SAPUI5 applications are written in OData services.
- **SAP web dispatcher:** The SAP Web Dispatcher is a reverse proxy / load balancer. It manages the incoming HTTP(S) requests and relays them to the corresponding SAP system maintaining security, scalability and effective routing between the frontend and backend servers.

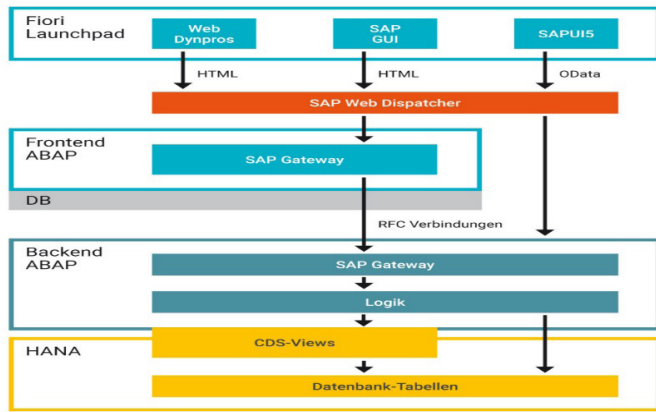


Figure 3: System Architecture.

- **Frontend ABAP server:** The SAP Gateway is located in this layer and it deals with the interaction between the user interface (Fiori apps) and the back-end system. It receives OData requests in the SAPUI5 applications and converts them into ABAP calls, performs authentication and session management.
- **Backend ABAP server:** This is what the business logic is about. It has another SAP Gateway and the ABAP logic layer of application. It interacts with the database layer and processes the data requests and also executes the business rules. The frontend Airbus system is connected to a backend Airbus system that is normally connected through RFC (Remote Function Calls).
- **HANA database:** SAP HANA is the in-memory database which stores and processes data in a fast way. CDS (Core Data Services) Views give semantic data models and a virtual data layer to the applications. The CDS Views retrieve data of database tables and make it available to the ABAP logic layer in an efficient manner.

3.2. Flowchart of digital kanban replenishment

The material movement process and visibility through the digital Kanban replenishment process is based on the SAP Fiori applications, the ABAP RESTful Application Programming Model (RAP) that provides real-time visibility in the entire supply chain. The process starts with scanning of a Kanban card to flow and ends with a system replacement confirmation making sure that the process is automated and smooth flowing.

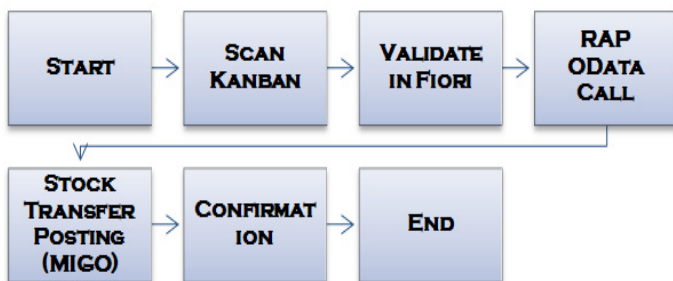


Figure 4: Flowchart of Digital Kanban Replenishment.

- **Start:** The cycle starts when a material bin or a container gets to its lowest level and this creates the necessity of refilling it. This point is where the Kanban cycle occurs and it is an indication that the digital workflow must begin. The system gets ready to record information and start validation with the help of the Fiori interface.
- **Scan kanban:** The operator then looks up the Kanban card

or label with a bar code or QR scanner built into the Fiori application. In this scanning move, the material, place of storage and the amount are automatically obtained in the SAP S/4HANA database. It is the electronic scan that does not allow any error of human entry and it allows the process of manual entry to be done automatically.

- **Validate in fiori:** After scanning the Kanban, the Fiori application will validate the input data in relation to pre-established business rules and master data in SAP. This authentication guarantees that the scanned Kanban is pertinent to an active material and that the request of replenishment conforms to the conditions of the plants and storage. Any anomalies, including inactive Kanban IDs or wrong quantities are reported immediately to be corrected to ensure data integrity and reliability in a process.
- **RAP OData call:** Upon a successful validation, the system invokes an OData service call that has been created on ABAP RESTful Application Programming Model (RAP). This call provides the communication channel between the Fiori front end and the SAP backend and sends the proven Kanban data in real time. RAP model provides that all operations are made transactionally consistent, that is, in the event of posting, updating and confirming, all the operations must be performed as one managed transaction environment in SAP S/4HANA.
- **Stock transfer posting (MIGO):** The stock movement in this step is automated whereby the movement of stock is posted automatically on a MIGO (Goods Movement) transaction. The quantity of replenishment is transported out of the supplying point (e.g., warehouse or supermarket) to the consuming point (e.g., production line). The automated transfer will help in eradicating manual posting and the transfer will be reflected immediately in the system, ensuring the availability of accurate inventory is denoted in all departments.
- **Confirmation:** After transferring stocks, the system creates a confirmation message that the replenishment process was done successfully. This validation is shown in the Fiori application where it displays real-time feedback to the operator. It also changes the status of Kanban to Full or available so that the material can be re-used in the subsequent production cycle.
- **End:** The last step in the process is the reset of the Kanban loop, which is prepared to undergo the replenishment process again. The SAP database contains all the records of transactions such as timestamps, user information and movement information in a way that this can be audited and traced. This digital end to end procedure does not only facilitate the process of handling materials, but also increases the levels of transparency, accuracy and responsiveness in Lean manufacturing environments.

3.3. Implementation Steps

- **Requirement definition:** The initial step is ensuring that the present Kanban process within the production environment is analysed in detail. [13-15] This involves establishing areas of Kanban loops, line of materials movement, triggering points and departments in charge. The interviews with process owners and shop-floor operators will capture the ways in which physical Kanban cards are circulated and where delays or areas of inefficiencies are taking place. The

plan is to transform the manual replenishment system to the digital version without losing the Lean principle of pull-based production and minimum wastage.

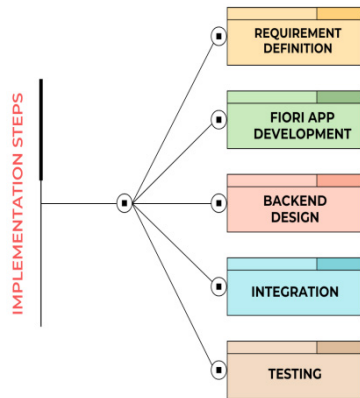


Figure 5: Implementation Steps.

- **Fiori app development:** After outlining the requirements, customisation of a user-friendly SAP Fiori application is established through the use of SAP UI5. This application can be seen as the primary interface of shop-floor operators who are able to scan the Kanban cards, monitor the material state and manually activate replenishment using the tools of handheld and desktop computers. It is designed as per the Fiori UX guidelines which guarantee continuity, responsiveness and availability on different devices. The main functions are the ability to scan barcode or QR-code, visual Kanban status display and fast-action buttons to post replenishments.
- **Backend design:** The backend code is written in the ABAP RESTful Application Programming Model (RAP) and offers a modern and standard framework to create OData v4 services. The RAP service reveals inventory and Kanban data using secure API communicating with the Fiori frontend. It manages transactional behaviour through managed business logic including validation, posting of stock transfer and managing errors. This will make every replenishment transaction uniform, traceable and all proxied with SAP S/4HANA core modules.
- **Integration:** The digital Kanban solution can be embedded and run on SAP Business Technology Platform (BTP) in those instances that preference is given to cloud deployment. The installation is scalable, has centralized control and can be easily integrated with other enterprise applications or IoT systems. Moreover, BTP environment contributes to other services like automation of workflow, analytics dashboard and machine learning, which allows improvements of Lean operations to be constant. The hybrid integration model has a component that makes sure that on-premise and cloud elements are working together.
- **Testing:** Rigorous testing is carried on the system after development and integration to ensure functionality and performance of the system. Test scenarios are a simulation of actual production environments where transaction volumes are high and there are one or more users concurrently. The aim is to test the response times, data accuracy and stability of the system under the realistic loads. Production staff is also engaged in user acceptance testing (UAT) to ensure usability and support of operation requirements. Testing is a successful process that contributes to the reliability,

efficiency and clear readiness of the digital Kanban system to be deployed in real life.

3.4. Mathematical model for replenishment

The time all it takes to go through a Kanban replenishment loop which is denoted as T_c is the overall time that is taken to complete a single¹⁶⁻¹⁸ loop in the replenishment cycle that includes the time that is taken when a demand signal is triggered up to the time of restocking the material and reporting into the system. This cycle time depends on three main items color-coded like signal transmission time (T_s), transport delay (T_t) and update latency in the ERP system (T_u). Signal transmission time is the delay in between the recognition of an empty Kanban bin and communication of this need to the system or operator in charge. In traditional paper-based Kanban, this step consists of card-gathering, card-sorting and actual delivery which highly enhances T_s . With a digital system, though, a scan of a barcode or a QR code sends the replenishment signal electronically instantly over the Fiori application and therefore this delay is minimized down to a few seconds.

$$T_c = T_s + T_t + T_u$$

Where:

T_s T_s = Signal transmission time

T_t T_t = Transport delay

T_u T_u = Update latency in ERP

The second element is transport delay (T_t) which is the time that is required to physically move the substances stored in the warehouse or the place of supply to the place of consumption. This factor largely relies on logistics of operation, distance and efficiency of handling. Digitalization has the benefit of changing the traditional flow of time in the physical transport of the goods that they keep but will help shorten the physical biscuit transport time as it increases coordination and visibility using metrics such as mess ages being processed immediately and appropriately prioritized in the system. The third variable is the update latency (T_u), which is the period of time when the ERP system must process the completed stock transfer and update it in real-time in inventory records. This in a traditional system takes a long time to post manually, in batch or delayed confirmations and the data does not match causing discrepancy and inaccuracies. The digital Kanban solution proposed, which will be combined with SAP Fiori and the ABAP RESTful Application Programming Model (RAP) reduces the T_s and T_u minimal since they are automated in transmitting signals or posting transactions. This causes the overall replenishment cycle time T_c to be close to the real-time responsiveness which contributes towards the Just-in-Time (JIT) material availability and enhances the overall process efficiency.

4. Results and Discussion

4.1. Performance metrics

Table 1: Performance Metrics.

Metric	Improvement
Paper Usage	92%
Replenishment Time	35%
Stockout Incidents	28%
Operator Satisfaction	24%

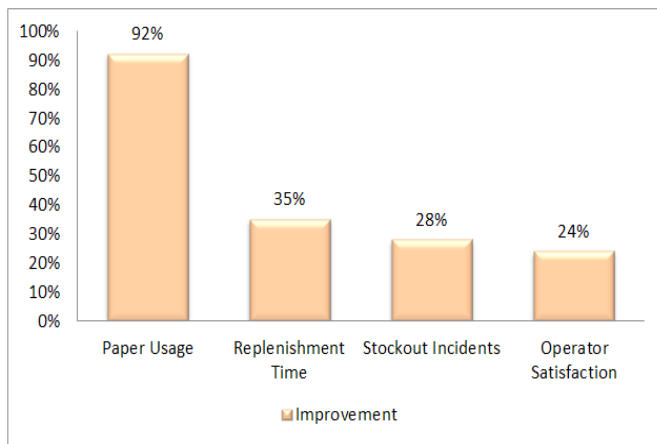


Figure 6: Graph representing Performance Metrics.

- **Paper usage:** The dramatic decrease in paper usage is considered to be one of the biggest benefits when the digital Kanban system is implemented as the estimated result is a 92 percent decrease versus the traditional process. On manual Kanban, there are corporeal cards, printouts and documentation used to notify and document replenishment activities. Switching to a Fiori-based digital interface will render the use of printed material unnecessary since all a transaction, status updates and approvals will be done electronically. It not only helps in the sustainability initiatives in the paper waste reduction but also administrative overhead costs in printing, storage and replacing misplaced Kanban cards.
- **Replenishment time:** Digitization of Kanban processes resulted in 35 percent faster time of the whole replenishment. In the past, delays were experienced because of the manual processing of cards and verifications and delayed receipt of postings in the ERP system. Through real time scanning, automatic validation and RAP-based OData connection, the replenishment signals are completed in real time and postings of inventory transfer is done automatically too. This cycle time minimization makes the flow of materials efficient and keeps production lines supplied with necessary items in time needed, which contributes to the operations of Just-in-Time (JIT) and saves idle time.
- **Stockout incidents:** The digital Kanban system also reduces the number of stockout events that take place each month by almost a quarter because it allows real-time visibility of the material levels and replenishment status. Delays in the movement of cards or in data entry of the traditional systems could result in the replacement requests being missed or ignored. The new system will automatically change the status of the Kanban and send notifications when the stock arrives at specific set limits and create an opportunity to replenish it beforehand. This makes sure that there is continuous availability of materials and that there is continuity in the manufacturing production and not any sudden interruption.
- **Operator satisfaction:** The satisfaction of the operators escalated by approximately 24 percent after the implementation of the system. The user-friendly SAP Fiori platform eases the work of users, minimizes redundant manual work and offers immediate response as a result of the successful transaction. Kanban status is easily tracked by the operators, moreover, real-time updates can be viewed

and automated validations will reduce errors. This increase in the ease of use and transparency of processes creates better engagement and confidence in the shop-floor staff, which leads to an easier operation and increased productivity of the workforce (in general).

4.2. System evaluation

System evaluation was aimed at testing the functionality and reactivity of the intended digital replacement of the Kanban replenishment system especially the effectiveness of the RESTful interface that was created based on the ABAP RESTful Application Programming Model (RAP). In testing, the RAP-based OData service was found to have an average response time of about 220 milliseconds which is quite fast as compared to the traditional Intermediate Document (IDoc)-based communication that had a latency of about 1.8 seconds on average. This decrease in the latency indicates the benefits of the RESTful APIs in facilitating practically real-time data transfer between the SAP S/4HANA backend and SAP Fiori frontend. This can be explained by the fact that stateless, lightweight nature of RESTful services employ normal HTTP methodology and JSON payloads as opposed to the bulky XML structures in transmissions via the IDoc. As opposed to the asynchronous and often batch update IDocs which are usually queued and processed as a batch, transactions conducted by the RAP service are made in real-time, resulting in a real-time acknowledgement and a quick response to user demands. The promptness of this sensitivity is much needed in the lean manufacturing set ups wherein prompt communication of information between the shop floor and the ERP system translates directly to the continuity of production and also accurate inventory. Moreover, it was shown that the digital Kanban system was able to sustain its stability even during modelled production loads when there were numerous simultaneous users. The system was effective in managing parallel requests without significant changes in the response times, which indicates that it was scalable and robust. Along with the increase in speed, the managed transactional behaviour of RAP guaranteed the preservation of data integrity, as well as transaction consistency, as the database changes are automatically validated and committed automatically, as a single logical unit of work. On the whole, it can be stated that the system assessment indicates that, in comparison to artificial IDoc-based transactions, the RESTful approach will be superior in terms of performance, reliability and scalability. All these enhance the visibility of the processes, help make decisions quicker and run more agile operations inside the digital Kanban replenishment framework.

4.3. Discussion

The outcomes of the system implementation and evaluation reveal that the principle of Lean manufacturing can go hand in hand with digital transformation activities. Conventionally, the concepts of Lean and digitalization were regarded as opposing sides because the former is based on simplicity and minimalism, whereas the latter brings technological complexity. Nevertheless, the fact that the SAP Fiori applications could be used with the ABAP RESTful Application Programming Model (RAP) demonstrated that electronic tools could benefit, but not impede the Lean practices. Automating manual Kanban operations, providing real-time visibility throughout the replenishment process will solidify such Lean objectives as waste reduction, flow efficiency and continuous improvement.

One major conclusion in the deployment phase was that the time spent on training the operators was reduced by almost 40 percent in relation to the traditional SAP operations involving GUI. This advancement has been greatly bound to the modern and intuitive user experiences (UX) of Fiori. The role-based interface provides ease of navigation and reduces learn curve among the shop-floor people since they can accomplish replenishment tasks fast and correctly without much knowledge of the system. Consequently, new operators are able to scale on the system accordingly and reduce workforce flexibility and productivity. The other vital point of the conversation is the introduction of colour meaning Kanban statuses, which is an effective visual instrument of management. These live indicators can be a colour scheme of green, yellow and red to give real time feedback on the condition of every bin; whether it is stagnant, in transit or empty. This will improve the awareness of the situation and expedite the process of decision-making of operators and supervisors. In addition, the constant loop of feedback created by these visual aids helps underpin the Kaizen philosophy of Lean, where the initial response towards an abnormality is proactive and an introduction of a culture of constant improvement is created. Essentially, the integration confirmed the fact that digital systems can maintain agility of Lean operations and inject more transparency, responsiveness and control on operations in the modern manufacturing contexts.

4.4. Sustainability impact

A significant and positive contribution to environmental sustainability and operational efficiency was proven by the implementation of a digital system of paperless Kanban. This led to the organization saving the approximate 18,000 pieces of paper annually through the removal of the need to use printed Kanban cards and documentation that comes in form of papers. The result of this decrease is directly linked to the reduction of carbon emissions during the production of the paper and printing and its disposal. Alongside preserving the natural resources like wood, water, the initiative complements the overall environmental management approach taken by the company, which is in line with what the ISO 14001 standard of continuous improvement of the environmental performance and efficiency of the resources it uses. In addition to decreasing paper use that is quantified, the use of the digital Kanban method will encourage more sustainable production processes by enhancing energy-efficient workflows and minimizing the amount of waste throughout the value chain. The process of digitalizing the Kanban indicates, thanks to SAP Fiori and RAP, the absence of physical stores, transportation and reuse of paper resources. Additionally, the data accessibility and transparency of a new digital record-keeping system boost how data is accessed, compared to a traditional system where physical audits or hand-checking are required. This does not only save the administrative time, but also reduces the indirect environmental footprint caused by documentation management. Social and economic sustainability is also achieved in the project as it will give a more organized workspace which will be cleaner and increase the engagement of employees. The operators also waste less time with paper work and take more time with value activity which enhances over-all morale and job satisfaction. The project also enhances a corporate sustainability reporting effort because it offers digital metrics on the utilization of resources that are traceable, which can be reflected in the Environmental, Social and Governance (ESG) framework of the organization. In general, the introduction into a digital Kanban system indicates

that operational excellence and environmental responsibility can coexist. It brings to the fore the possible benefits of technology-based Lean activities to ensure realization of sustainable manufacturing objectives without reducing efficiency and adherence to global environmental requirements.

5. Conclusion

The research has managed to prove that customization of SAP Fiori and the ABAP Restful Application Programming Model (RAP) can make a digital transformation on traditional production assembly-line Kanban replenishment systems in the form of complete automation and real time digital digitization. The implementation was effective at cutting wastes in the processes, cutting down manual involvements and also increased transparency on the production value chain. The RESTful architecture based on RAP allowed blistering, reliable and consistent data exchange between the Fiori frontend interface and the SAP S/4HANA backend. Compared to legacy transactions with IDoc messages, the system obtained a substantial decrease in the response latency, making operational responsiveness much better. In addition, the solution led to a reduction of paper-based Kanban cards, which was part of the sustainability, as about 18,000 sheets were saved on a yearly basis. All of the results together confirm that digital transformation, being driven by the principles of Lean, can be used to both attain efficacy and environmentalism without undermining the simplicity and discipline of Lean manufacturing.

The system developed can offer physical operational and managerial gains. To begin with, it will allow real-time integration between the shop floor and the ERP environment, so that the status of material and inventory updates on the status of material and material replenishment will be available immediately to all stakeholders. This coordination would improve the process of decision making, minimization of production wastage and Just-in-time (JIT) manufacturing. Second, the manufacturing process is less polluting due to digitalization and paperless operations, which complies with the corporate sustainability and ISO 14001 standards. Finally, the solution enhances traceability and compliance as all transactions are properly recorded in time-stamped digital form, which streamlines and increases the efficiency and reliability of audits. When combined, these results indicate that Lean and digital systems might be used in a mutually supportive way, leading to an improvement in process transparency, agility and control.

Although the implemented system attained significant gains, future studies can stretch the applications of the system. By combining with SAP Business Technology Platform (BTP) predictive analytics, it may be possible to make proactive decisions based on the prediction of material consumption patterns and accordingly plan the replenishment process. Also, adding machine learning algorithms on the demand sensing would increase the flexibility of the system to changing production demands, reducing overstocking and shortages. Lastly, the implementation of the solution in multi-plant multi-planet operations would involve trying the solution in respect to their scaling, interoperability and performance in distributed manufacturing. Not only would these improvements increase the resilience in operations, but also make the system a foundation of smart and sustainable manufacturing of the Industry 4.0 era.

6. References

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