Smart manufacturing production line connectivity – case study in automotive sector

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Abstract. Industrial companies must continue to produce while guaranteeing the quality of their products and maintaining the availability of machines and equipment. In this context, the industrial success comes with a new way of organizing the means of production based on practical optimization solutions that integrate industry 4.0 and lean tools. Lean and Industry 4.0 are both production paradigms with a common goal: to efficiently manufacture highly customized products in small batches. Industry 4.0 aims to accelerate the flow of information and the Lean approach focuses on eliminating waste to accelerate physical flows: the synergy of the two methods contributes to operational excellence. This paper examines the misperception of the relationship between industry 4.0 and production, and examines the digitization of a complex production chain capable of implementing lean manufacturing. Digitization can be summarized as the application of digital technologies to the world of manufacturing. The digitization is the key to achieving this integration, as it allows for the interconnection of digital technologies and the implementation of a dialogue system between tools and workstations. By exchanging information, these technologies can improve productivity and working conditions within the company. Our approach is illustrated by a case study conducted in the automotive sector. The study compares a pre-digitization scenario with a post-digitization scenario and shows the positive impacts of digitization on the company's productivity..

1. Introduction

Today, the trend of the fourth revolution is at the forefront of life, marked by a rush of advanced technologies and the emergence of various digital industries through the transformation of nine pillars of advanced technology identified by the Boston Consulting Group[1], These include autonomous robots, simulation, horizontal and vertical integration of information systems, the Internet of Things, cyber security, cloud computing, additive manufacturing, augmented reality and mass data analysis. (Figure 1)[1].

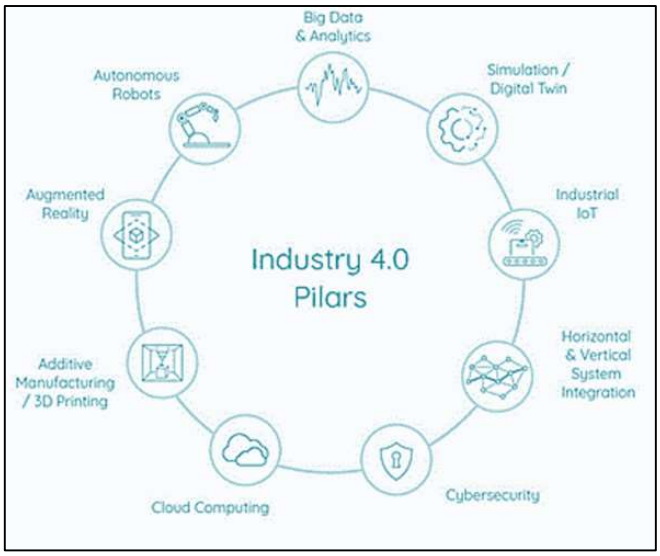

Fig. 1. Pillars of Industry 4.0

The knowledge and skill challenges that are closely linked to the era of disruption and Industrial Revolution 4.0 require a new strategy to prepare operators who can compete and meet diverse needs that continue to evolve [3], [4]. The Industrial Revolution 4.0 will result in a substantial reduction in various low-level skills relative to applicable standards in the world of work and an increase in highly skilled activities, including planning, control, and information technology (IT) tasks [2], [5]. information technology (IT) [2], [5], [6]. This development is also reinforced by the various 4.0 technologies used in industry to increase productivity and efficiency of companies. to increase productivity and efficiency of the production process [7]. Incorporating Industry 4.0 tools into a Lean production system may mitigate the risk of failure caused by the challenges of organizational implementation [8]. By implementing the Lean approach, substantial modifications in employee practices become necessary. However, this may benefit them by equipping them with the required skills and mindset to handle future developments such as Industry 4.0 technologies. With Industry 4.0's introduction, the industry and work environment's dependence on cyber-physical systems (CPS) will become apparent.

On cyber-physical systems (CPS) and their implementation in the smart factory[9]. The implementation of the Lean approach itself requires a large number of changes in employee practices, which could have the effect of better preparing them for the next major changes, such as real-time data acquisition, improved process transparency and product quality information. This helps employees make decisions by basing improvement activities (Kaizen) on complete and up-to-date information. In addition, visual performance management is facilitated by allowing faster updating of accessible data. This study aims to examine the trend of digitization in manufacturing companies as one of the main solutions conducted in the face of the 4.0 revolution, which is part of the new scheme found in Industry 4.0, namely the digital visual management. Companies and researchers can use this information to identify problems or unanswered questions in the literature and define the direction of future research on the trend of digitization in the industry and the preparation for the integration of Industry 4.0.

2. Literature review

Smart manufacturing is an interesting topic in all industries whose goal is to remain competitive. Its main objective is the migration of the industry to digitalization. It is one of 9 pillars of Industry 4.0[1], Which aims to connect the physical and virtual world in industrial production, and intelligent systems with improved human-machine interaction paradigms. enhanced. This enables identity and communication for each entity in the value stream and leads to massive personalization of manufacturing through IT[10] [11] [12], Incorporating information and communication systems in the industrial network results in a significant rise in automation levels. Intelligent machines capable of self-optimization throughout the production chain are synchronized with the complete value chain. [13],To understand how the digitalization of a factory is achieved, identifies digitalization principles by visualizing data on creation a digital twin to model the production line on a computer platform by setting up performance indicators[18]. introduced a digitalization philosophy based on the operator's responsibility to display performance indicators to the next team[19] [20]. It is noticeable that those results and findings need to be optimized because they eliminate entirely the operator's responsibility. Moreover, this will require deep integration and seam-less bidirectional data flow between all the design and manufacturing stages of the product development lifecycle preventing data loss. The previous results obtained have shown that many companies have already implemented some of these technologies, However, they are still used exclusively in an isolated way rather than in interconnected autonomous systems where technologies can cooperate and communicate smoothly and safely with each other's. This paper focuses on the connectivity of new technologies integrated in production lines aiming at involving operators and giving them more responsibility[21] [22]. Regarding social aspect, it improves the working conditions of operators and increases their availability for other tasks.

3. Problem description

In this section, a description of the model goals will be provided, along with the importance of a digital line and digital visual management, as well as the indicators assessed.

3.1 Objectives of the model

The customer's request is for large number of functional electrical wiring systems for vehicles in the range of 2000 wiring electrical cars (KSK) per day divided in different variants, each variant is decomposed of an average of 50 modules/KSK. In addition, the manufacturing of electrical wiring relies primarily on human intervention, which accounts for 70% of the total manufacturing process (100 operators per production line) so within this context in order to satisfy the customer while maintaining excellent quality and efficient time cost. Therefore, manufacturers will need to adopt new technologies and manufacturing theories to help them adapt quickly to the rapid changes and improve product quality while optimizing the use of energy and resources. The integration of new tools including connectivity concept into production lines and supply chains is necessary for a competitive industry.

3.2 Importance of a digital line

Production line digitalization is required for effective technological solutions based on the installation of detectors and sensors on the machines and the connectivity of different equipment. Thanks to this connectivity it is possible to achieve quality levels and reduce

overall costs of production in order to manage breakdowns, production stoppages in real time[7]. The automation of processes also makes it possible to reduce the margin of error[13] [23]. Making changes in a modern production chain is much easier and faster, The successful implementation of Industry 4.0 requires a prior optimization of the production organization through Lean principles, which must be established not only by the organization but also by involving all employees. [14]

3.3 Importance of digital visual management

Visual management is a set of communication techniques based on sight. This method facilitates the transmission of information in order to allow anyone to know in an area of activity whether the situation is normal or abnormal.

Digital Visual Management is the digital extension of this management, based on connected computer tools to retrieve information and synchronize it with all the media where it is to be distributed[15],[16]. Identifying opportunities for improvement and facilitating employee decision will improve the quality and flow of the production process. In concrete terms, it can be a connected screen displaying production objectives and the progress of the teams in relation to the latter[17]. Our objective is the automatic update of KPIs and their follow-up in real time and the reduction of time spent in meetings exchanging information. Once implemented, the goal of visual management is to make decisions more quickly, and the systematic update of KPIs and their monitoring in real time and the reduction of time spent in meetings exchanging information in order to automate the collection and distribution of information.

3.4 Objectives of the Key Performance Indicators

In a manual manufacturing process, the production steps include different wastes in terms of control time leading to remarkable non-quality costs, in this context, the integration of new technologies allows to:

1. Help checking the function module in digitized KSK
2. Minimize the risk: missing module in the KSK
3. Minimize the control time
4. Reduce testing time for each production step
5. Reduce the PPM
6. Improve the work conditions of the operators
7. Digitale Visual Management
8. Easy training for new operators
9. Poka-yoke system

4. Contribution

Several companies have already implemented some of these technologies, but use them only in an isolated way rather than in autonomous interconnected sys-tems where technologies can cooperate and communicate freely with each other, in this paper we have developed a model to improve the connectivity of different systems with different technologies integrated in the production chain by involving the human being in the process.

- ***Step 1***

Initialization :Preparation Dynamic database1 (with all KSK/module)

- ***Step 2***

PreparationDynamic database2 (with all Module / Operator / Position)

- ***Step 3***

Connectivity of two databases
Create a common database

- ***Step 4***

Integration of new technologies

- ***Step 5***

Communication database with new technologies

5. Case study in automotive sector

This case study is carried out within a multinational company "Dräxlmaier". This company is specialized in the manufacturing of automotive wiring harnesses

In this section, we will show the performance of our contribution compared to the scenario before digitalization based on the indicators mentioned above in Para-graphe 3.4

5.1 case study description

The optimization program created using Visual Basic platform linked to the line balancing based on two data bases. First, all KSK with module dynamic data instruction is obtained from MES-Reporting which contains all KSK correspond-ing to that day, and the set of modules of each KSK. Secondly, we have prepared the other database from OMP-DATA which contains all the modules with work-places and their positions. Another very important step, we have linked the two databases to give a common dynamic data platform which contains the KSK with all the modules associated with each work place and their own position. When scanning the KSK barcode, the screen displays the KSK variant and the starting position of each module per work place end per operator. Figure 2 represents the case study realized model.

Digital visual management requires the use of screens and software for moni-toring and organizing rather than a simple display on a board. This digital display is also simplified by the permanent connectivity to the Internet of our various screens and devices (scanner computers...), in figure 3 we have identified the points of the different process steps.

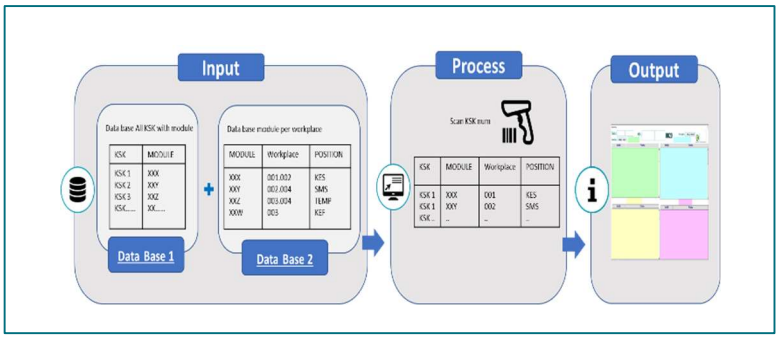

Fig. 2. Implication of Digitalization on a production line

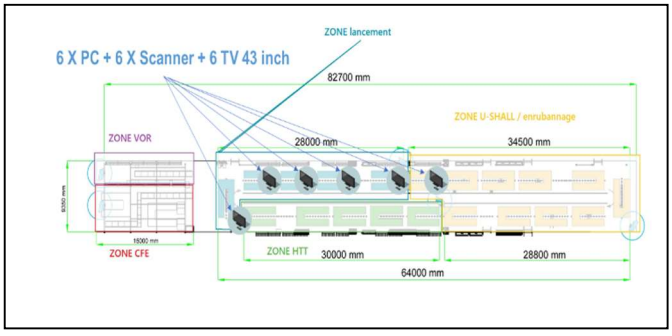

Fig. 3. Standards for manufacturing line connectivity

The implementation of modern tools brings its share of changes in methods. Real-time tracking of product location is possible with the principle of digitalization. Additionally, the communication between man and machine can be instantly enhanced with a straightforward product barcode scan. when scanning in displays the location of products and the tasks of each operator. Real-time data acquisition brings several benefits such as enhancing process transparency, providing information on product quality, and reducing waste.. In short, the role of the employee is to focus more on tasks with high added-value, then the machines control becomes much easier (figure 4).

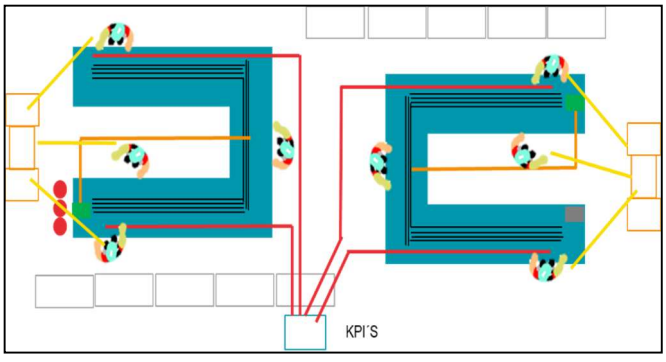

Fig. 4. Working board

5.2 Human Database Communication Interface

Thanks to this visual device (figure 5), the operators tasks can be displayed directly on the workstation in real time, everyone can detect the number of modules and types with their own specification, employees can reduce waste and make the processes more efficient. The visualization of improvements on the workstations is a visual communication technique that helps to strengthen the culture of continuous improvement,

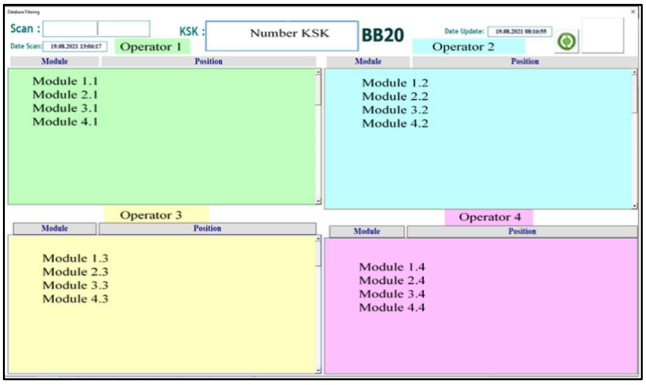

Fig. 5. Intelligent standards for identification of modules by the operator and their position

6. Examined scenarios

In this section, we will compare the performance of our contribution to the pre-digitization and post-digitization stages based on the indicators mentioned above. The number of defects per KSK was measured over 13 weeks, three weeks before the digitization and ten weeks After the digitization. During the three weeks CW33, CW34 and CW35 the number of defects per KSK is very low, the ratio of the number of defects to the number of KSK produced decreases from 1.95 to 0.31 as shown in figure 6. This figure shows the evolution of the number of nonconformities detected in the two stages.

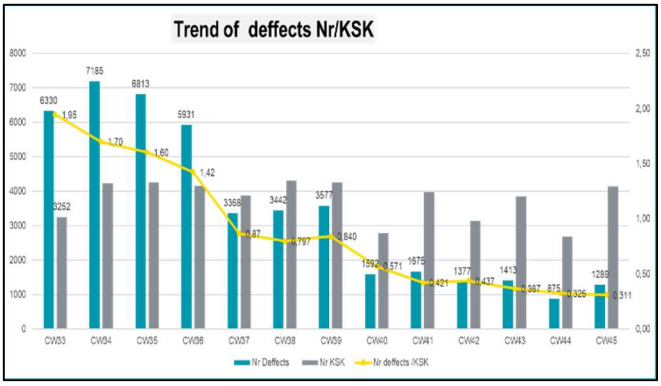

Fig. 6. Evolution Quantity of module missing before and after digitization

Another performance indicator is the minimization of the checking time as indicated above: before the integration of technologies the operator takes 20 seconds to read the modules of each KSK (using paper), in this case 4 operators are needed per working board (Figure 7). After scanning, the operator takes 2 seconds to check a KSK that requires three operators

(Figure 8). This action allows to increase the productivity by 1% represents a cost saving of 110 T€ per year-end to reduce one operator.

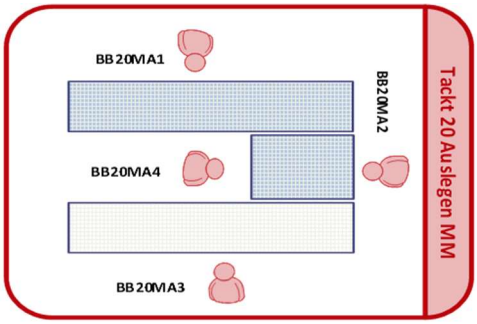

Fig. 7. Working board before digitization

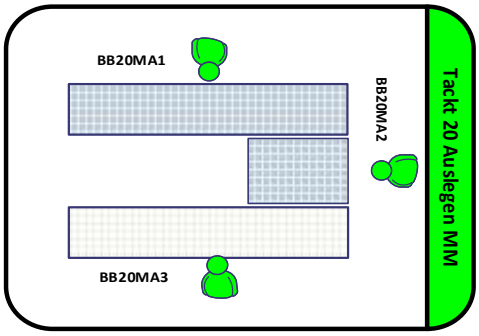

Fig. 8. Working board after digitization

7. Conclusion and perspectives

In this study, we addressed the problem of manual manufacturing process in the automotive industry Based on a list of performance indicators, we identified the benefits of integrating Industry 4.0 tools. The case study was conducted on a production line, digitizing interconnected autonomous systems where technologies can improve the product flow, track the location of products in real time, and improve instant human-machine communication. This supports the employee's decision-making by basing improvement activities on complete and up-to-date information, which is the basic principle of industry 4.0. The value of a small improvement in the context of industry 4.0 is obviously enormous and related results are remarkable.

The results suggest that the implementation of industry 4.0 depends on the level of lean maturity .So the challenge for companies is to know in what situation an industry 4.0 implementation type should be carried out, according to the current level of lean implementation. Among all the available industry 4.0 technologies, which ones should be chosen and implemented in priority.

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