Digitalization of Restrictions for Assigning Workstations

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Abstract. Industry 4.0 has made it possible to better integrate and streamline different stages of the production process mainly through the support of a collection of technologies. One of these technologies that might give businesses a competitive edge is digitalization, which can improve the effectiveness of corporate operations. This paper reports a research carried out in a Bosch factory, in the division responsible for Termotechnology, which designs, manufactures, and sells water and heating solutions for homes. Digitalizing the process related to operator allocation to workstations was the project's main goal. In order to do this, a platform was created to compile all the data required for assigning workers to workstations based on facts, increasing transparency in the process by informing platform users of each worker's degree of training and ergonomic restrictions. Another objective was to reduce the Full-Time Equivalent indicator. A pilot was run in one of the production lines of the factory to validate the developed platform. Lean tools and the action-research approach were used to address and accomplish the goals. Outsystems platform was used in the development of the application in addition to these tools. The outcomes showed that the operator allocation procedure using the new platform took less time overall, saving around 20 min per allocation. The division saw a decrease in assembly mistakes and rework, easier access to the information needed for allocation, and a shift in the allocation process from one based on empirical knowledge to one based on facts when this platform was implemented on the factory floor.

Keywords: Digitalization · Technologies · Industry 4.0 · Lean · Action-Research

1 Introduction

Beginning in the 20th century, the industrial sector was marked by a rapid growth and fundamental changes in the ways that goods or services are manufactured or delivered. These changes are not superficial or minor but rather deep and impactful, often involving the adoption of new technologies. In the 1990s, developed nations embarked on a technological revolution, integrating information and communication technologies into industrial processes. This integration required the development of methodologies to connect information systems effectively. At the industrial level, machine-to-machine communication is highly helpful for identifying production faults, facilitating continuous improvement, and simplifying information flows [1].

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The advancement of information technology enables industrial processes to reach new heights. This new development allows organizations to enhance the present environment and satisfy clients through new forms, employing new business models to create value and make cash for themselves [2].

The concept of "smart factories," which refers to manufacturing with cutting-edge technology like automation, artificial intelligence, and the Internet of Things (IoT), was introduced by Industry 4.0. This sector has elevated intelligent technology to the forefront of production. Furthermore, Industry 5.0 will promote more human-smart system collaboration. Therefore, it is crucial to understand the effects of past industrial revolutions that have occurred globally in order to comprehend how drastic changes affect industry. The fourth industrial revolution's innovations are upending industries and generating new opportunities for wealth creation. By exchanging knowledge, digital networks make the development and transportation of physical goods easier. Producing digital goods is quite cheap. Factory workers are already feeling the effects of Industry 4.0, and in order to continue to be important to their employers in the future, they will need to pick up new skills [3].

Lean 4.0 is a new iteration of Lean that has evolved as digitalization becomes the norm in this connected age. Combining Industry 4.0 technology with lean manufacturing concepts enables a thorough exploration of the advantages of both paradigms [1].

Production systems have undergone a major transformation thanks to Industry 4.0, which is defined by real-time integration in global value chains. Processes and procedures may be automated using Lean 4.0 to enable real-time analysis and intervention. Digital technologies are developing quickly, which is driving the creation of new industrial techniques to detect and eliminate waste [4].

Three key ideas come to light in this context: digitization, digital transformation, and digitalization. These concepts, while related, have distinct meanings depending on where an organization is in its digital journey. Converting manual readings to computerized ones is becoming more widespread in businesses, transferring information from analog to digital form through the process of digitization. There are several advantages to digital, including time savings, improved productivity, and higher-quality output [5].

Digital transformation involves a shift in company strategy and a customer-focused approach, which enables processes to be streamlined and automated to enhance business strategy and increase efficiency.

Digitalization is the process of using digitalization to enhance corporate processes and provide chances for value creation. It encompasses more than simply digital technology and data. Organizations have the ability to lower lead times, boost internal efficiency, connect value chains, and provide improved operational control. In the area of industrial manufacturing, digitalization has garnered more attention than digitization [6].

The Bosch group is one of those that relies on the most cutting-edge and inventive techniques, hoping to position itself as the market leader in innovation regarding both its goods and operations, given the technological competition felt amongst organizations.

In information technologies it is thought that smart working practices depend on utilizing state-of-the-art technology to support business intelligence, communication, and product and service delivery [7].

Industry 5.0 aims to combine technology with human creativity and intuition in order to create a more flexible and collaborative manufacturing environment. Cutting-edge technology like human-cooperative robotics, augmented and virtual reality, and real-time monitoring and feedback systems make this cooperation possible. This is in contrast to Industry 4.0, which integrates, for the past several years, manufacturers experimenting with integrating digital technologies such as IoT, cloud computing, automation algorithms, and software-as-a-service into their internal production processes [8, 9].

The benefits of Industry 5.0 include increased efficiency, improved quality assurance, sustainability, increased worker safety, increased consumer happiness, affordability, a competitive advantage, increased innovation, and good social impact [10].

Musculoskeletal diseases associated with the workplace that are caused by factors such as job performance and surroundings, or that worsen or prolong the illness, are known as work-related musculoskeletal disorders (WMSD). An evaluation of the data about WMSD was released in 1997 by the National Institute for Occupational Safety and Health. They concluded that among the job situations that may develop WMSD are routine overhead lifting of large things, everyday exposure to whole-body vibration, working with the neck in a chronic flexion position, and performing repetitive, forceful activities. Employers bear significant costs from musculoskeletal problems, including reduced productivity, absenteeism, and higher medical, disability, and worker's compensation expenses [11].

To solve the problem of human resource assignment, [12] highlights the use of optimization techniques. These optimization-based approaches help find the best combination of skills, availability, and costs for human resources. They aim to maximize efficiency and productivity by assigning the most appropriate professionals to the relevant tasks, considering time and cost constraints.

In addition [12] provides practical guidance for human resource management in projects, with a focus on efficient assignment of professionals. Through optimization techniques and continuous analysis, the aim is to achieve the best combination of skills, availability, and costs, ensuring project success and team efficiency.

2 Project Context and Diagnostic

This research emerged from a practical context due to the aim of the company to improve the operator's assignment to workstations, by developing a digital platform using low-code that compiles data about ergonomic limitations and skills of operators. It is a data-driven platform that enhances the decision-making process by showing detailed, relevant information with a user-friendly interface. The need comes from the increasing growth of Bosch, such as a new production line and, consequently, the hiring of new operators.

Furthermore, with the manual process, there is a high risk of assigning operators without the required training level for a given workstation, as well as of assigning operators with ergonomic limitations to an inadequate workstation, considering their ergonomic condition. It is important to understand that the risk is for both the client and the company.

Additionally, owing to the complexity of operations at the workstations, the diversity of workstations, and the usual rotation of operators, it was necessary to establish a

platform to manage them, addressing their specific needs. Associating the assignment based on facts enhances transparency in the process.

The aim of this study was to examine the potential benefits of digitalization for ordinary tasks. The overall goals were:

- Establish a platform that compiles all operator information;
- Assign operators based on data and facts;
- Provide high transparency regarding operator situations, including skills and ergonomic limitations;
- Boost productivity by allowing operators to be more flexible; and
- Decrease the capacity needed to plan and assign operators and the FTE (full-time equivalent) indicator.

It is anticipated that the creation of a digital platform will accomplish the following particular goals:

- Establish connections between operators and workstations;
- Deploy the operator assignment module on the manufacturing line;
- Test the platform in an actual working setting.

The following issues were noted:

- There is no binding assignment of operators, and they are not documented;
- Operators' assignment is not explicitly based on training level for a given job or ergonomic circumstances pertaining to the operator or workstations.

The research approach used to meet the project goals was action research. First, the research team met with the industrialization team of the boiler production line to ascertain the demands for digitalization before beginning to build the real project. The members of this team are in charge of industrial engineering, mechanical engineering, and times and methods measurement.

After that, a review of currently under-construction digital platforms was done, and it was found that the Skillinx platform was the most suitable to satisfy the demands and requirements of the industrialization team. The tool known as Skillinx was created by Bosch Terotechnology in Aveiro and is anticipated to be used in all departments and production lines inside the Aveiro factory, in addition to all other Bosch factories now in operation around the globe.

After that, a brainstorming session was held to decide which functions should be created in order to satisfy the list of prerequisites that had been previously established. The people in charge of building Skillinx and those in charge of digitalizing internal processes participated in this brainstorming session. A series of in-depth needs emerged from many brainstorming sessions and will be provided in the comprehensive project description.

Formalizing the criteria was followed by an analysis and diagnosis of the existing state of affairs. Since the operators' assignment team will be using the Skillinx platform in the future, negotiations with them were necessary at this point. Semi-structured interviews with the assigned point of contact in each of Bosch's value streams were used to diagnose the current state of affairs. Then, Outsystems low-code software was used to

construct the worker assignment to workstations and worker check-in modules that are components of the Skillinx platform.

After developing the two Skillinx platform modules, it was concluded that to evaluate the viability of the Skillinx platform and obtain reliable results, it would be better to implement it in a small production line that already has all the software required for the Skillinx platform. As a result, Skillinx was launched in the boiler production line, as a pilot project.

In order to determine whether additional recruits were required, each area manager needed to be able to view the availability of workers from other areas, their capabilities, and their ergonomic restrictions. Line managers' familiarity with the operators was the basis for the loaning. They would choose an operator for a certain task after reviewing the training records and being aware of the ergonomic constraints.

This project's development is necessary in light of the aforementioned considerations in order to reduce the possibility of placing operators at a workstation without the necessary training or ergonomic constraints.

3 Improvement Proposals

The platform that was chosen, called Skillinx, enables operators to integrate pertinent data models and data sourcing across various dimensions. This allows managers and manufacturing support teams to have a new management tool that will likely improve operator engagement and well-being, in addition to enhancing performance.

A multidisciplinary team's knowledge was considered when developing the requirements. During this time, it became clear that an ergonomic assessment was necessary, taking into account the tasks performed at the workstation and the limitations of the operators, given the heavy and large nature of the product that needed to be assembled. Process leaders, suggestions made it necessary to design a check-in procedure that guarantees flexibility across workstations. The assignment manager can see who is at the workstation thanks to the check-in system, and employees may be informed of any changes that may occur during the process, such as a reference change, thanks to flexibility.

3.1 Requirements

The team as a whole recommended the inclusion of the training requirement since it is necessary to have access to and stay up-to-date with all information pertaining to each employee's training and skills. The fulfillment of these conditions was created using the Outsystems low-code platform, which subsequently prompted the development of modules that were included in Bosch Aveiro's in-house platform, Skillinx.

Table 1 gives a summary of the compliance with these requirements.

A compilation of all the requirements used in the construction of the modules may be seen in Table 2. Note that the focus of this research is on the addition of new functionalities to the already existing Skillinx platform, namely regarding workers assignment to workstations and workers check-in.

Table 1. Requirements definition to digitalize the process.

Digitalization Requirement	Description
Training support	Due the line dimension (quantity of workers) and the fluctuation of associates it is important to digitalize this part
Ergonomics evaluation	Representation of ergonomic limitations per worker
Check-in	Tool that allows to map operations/workstations that each worker has already done and develop a matrix of competencies that support the rotation
Flexibility	To make it possible to make changes quickly and easily in the process, whether it is the Exchange of references or Exchange of tasks. This change should be easily perceived by workers

Table. 2. Requirements resume board.

Requirement	When used	Skillinx Status
Introduce data about lines and workstations of each work center	System startup	Functionality already providedin Skilinx (Augmanity)
Make ergonomic evaluation of each workstation (ergonomic profile)		Functionality already providedin Skilinx (Augmanity)
Define necessary skills per workstation		Functionality already providedin Skilinx (Augmanity)
Introduce workers data into the system (name, number, medical and ergonomic evalutation, and skills)		Functionality already providedin Skilinx (Augmanity)
Assign workers for each workstation, on each line	Previously Friday's	New: adjustments to the allocation of people to workstations
Workers begin to arrive, do the "Plant Check-in" and are directed to the respective work center/line/workstation	Monday's 05:45	New: Plant Check-in
Last minute absence management	Monday's 05:46	New: adjustments to the allocation of people to workstations
Workstation check-in - last validation that this worker was assign to this workstation	Monday's 05:47	Functionality already providedin Skilinx (Augmanity)
Update worker skills	"Master Data" Update	
Updating of the medical assessment or ergonomics evaluation		

The subsequent procedure for the future was conceived when the criteria were put into practice. The design of the future worker assignment process is shown in Fig. 1, and it has been defined by using the BPMN notation.

3.2 Skillinx

The development of the modules in Outsystems to integrate into Bosch's internal platform, Skillinx, consisted of the process of designing, programming, and configuring the

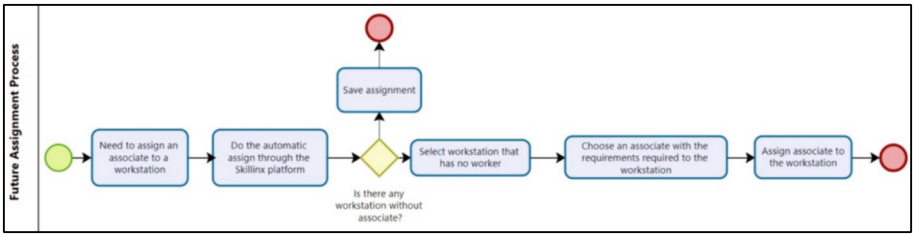

Fig. 1. New process: Future worker assignment.

platform according to the established requirements and objectives. On the other hand, the physical implementation of the Skillinx platform on the gas boiler production line aimed to ensure the proper functioning of the platform on the physical computers of the line. This involved hardware installation and integration with existing systems necessary for the platform to work correctly. These two phases, platform development and physical implementation, are interconnected processes and depend on each other to achieve a complete, functional and optimized solution.

There is information about the workstations and operators available on the newly created platform. The information that was accessible about the workstation included an ergonomic assessment of the workstations and a description of the necessary responsibilities and abilities.

The information that was accessible to operators included: endorsement; physical and psychological impairments; and completed training. The Skillinx platform further facilitates the scheduling and administration of absences. Therefore, two modules were made in order to gather the information mentioned: Worker Assignment and Check-in.

The two platforms, Outsystems and Skillinx, are described here in order to set the tools used in project development in perspective and the potential optimized results.

A software development methodology known as low-code helps programmers create apps with minimal human coding. With low-code, Outsystems programmers utilize a graphical language that is model-driven and has a drag-and-drop interface instead of typing code by hand, like in a traditional coding environment, to create software.

Skillinx is a cutting-edge, all-encompassing platform that integrates pertinent data models and sources from operators across multiple dimensions. Succinctly, Skillinx provides new tools to engage operators, provide them with personalized context assistance, and facilitate new procedures and interactive tools to enhance operator well-being. By utilizing modern digital technology to create a healthier and better industrial environment and by optimizing conventional human resource management techniques, these tools increase worker productivity.

Skillinx is an innovative holistic platform that integrates workers' relevant data models and data sources across multiple dimensions in order to provide managers and manufacturing support teams with new management tools that enable optimize worker well-being and engagement, among other things, which are likely to improve performance and attrition rates.

These tools increase human productivity by creating a better and healthier production environment using new digital technology and enhancing basic human resource management procedures.

Furthermore, Skillinx integrates non-structured data into a structure management decision platform, allowing for current situation analysis, future scenario planning, and assistance for both preventative and corrective measures. Skillinx also encourages workers to collaborate in decision-making and communicate more effectively using digital technologies.

Skillinx has six main modules, presented in Fig. 2.

The modules functionalities are:

- The workstation is responsible for ergonomic evaluation and digital work instructions;
- Skills Requirements (Workstation Level), Roles and Skills Definition, and Chemical Handling;
- Organizational modules are responsible for survey definition and communication management;
- Machine Interface is responsible for guaranteeing the software used to show the check-in modules in the machines;
- Worker skills is responsible for skills management, endorsement, and role definition required from operators;
- Worker physical evaluation is responsible for operator limitations regarding ergonomic evaluation and chemical intolerances.

The introduction of smart, connected, and autonomous digital and physical technologies such as IoT and robotics has had, and will continue to have, a significant impact on shop floor operations. As a result, in order to build action plans that clarify performance and HR well-being, we must first understand the technology underlying Industry 4.0 and how it impacts the work environment as well as the workers themselves.

3.3 Worker Assignment Module

The objective to developing this module was to facilitate the process of assignment of the workers to the workstations in a production line context. This module is intended to assist managers in managing their teams by enabling them to assign their workers to the multiple workstations of the lines they are responsible for. As already mentioned, this assignment is based on factual considerations such as ergonomic limitations and training conditions.

This module allows managers to assess which workers are most suitable for specific workstations, considering the skills level required to operate them, as well as the MARZC evaluation, a risk assessment methodology by corporal zone.

The left side of interface configuration developed in Outsystems can be seen in Fig. 3, and the right side in Fig. 4.

Regarding to the workers, it is possible to filter them according to area, sub-area, work center, line and shift or search by worker name. Once selected the filters for the working area, it is possible to filter the list of workers by those who have already been assigned to a workstation, therefore closing the gap for errors within the process of worker assignment. Also, it is possible to filter by those who have already done area

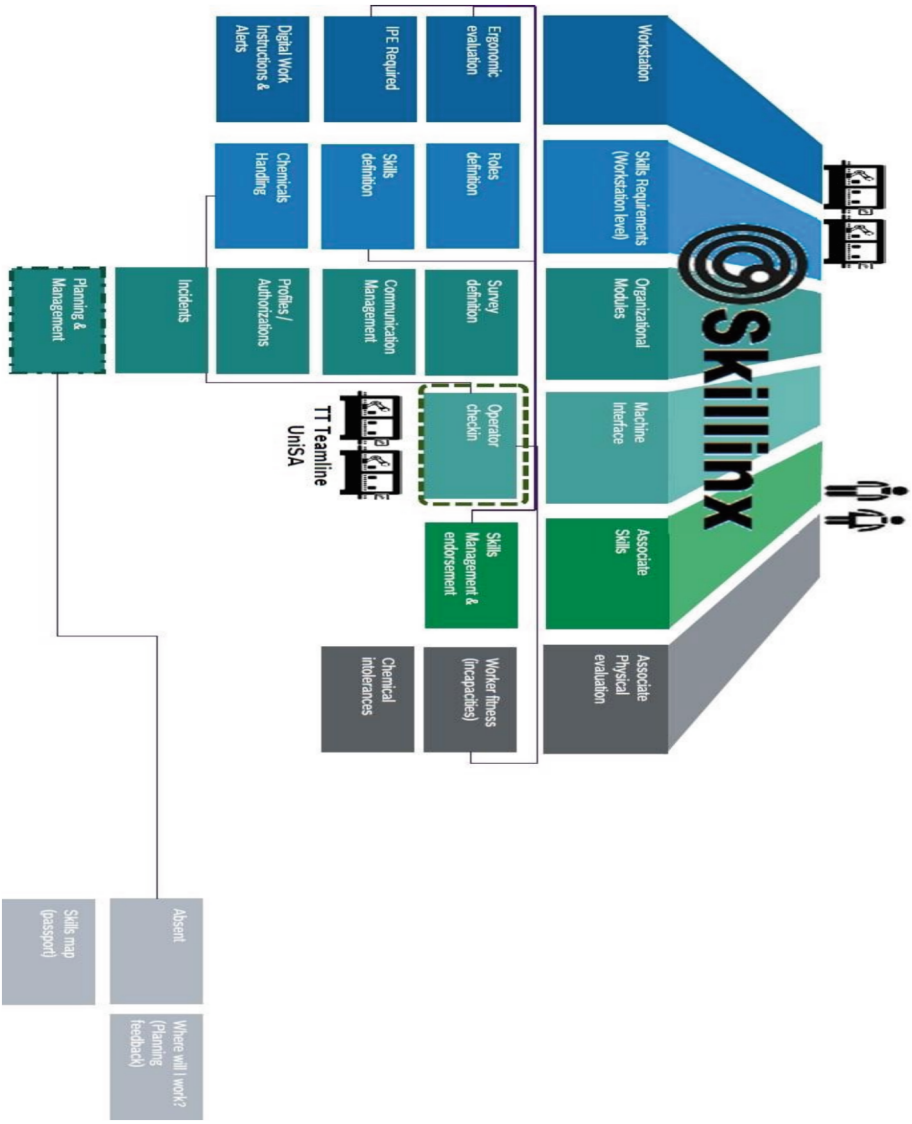

Fig. 2. The modules of Skillinx.

check-in and workstation check-in. The area check-in and workstation check-in modules allow workers to validate if they can work in that specific workstation. While the Area Check-in module was configured on a monitor at the entrance of the factory zone, the Workstation Check-in module was set up at each individual workstation. Figure 5 gives an example of the interface after filtering.

The fields "name" and "assigned workstation," which include the worker's name and the workstation to which they have been allocated by the person with responsibility, are

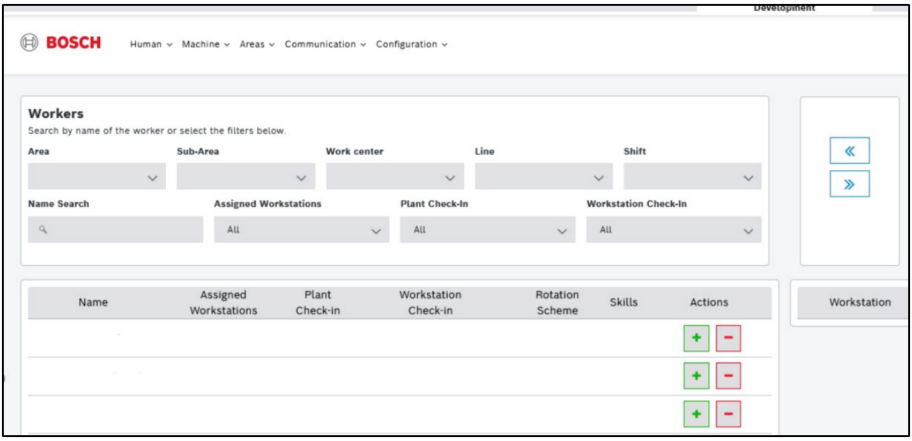

Fig. 3. Left side of the interface Worker Assignment window.

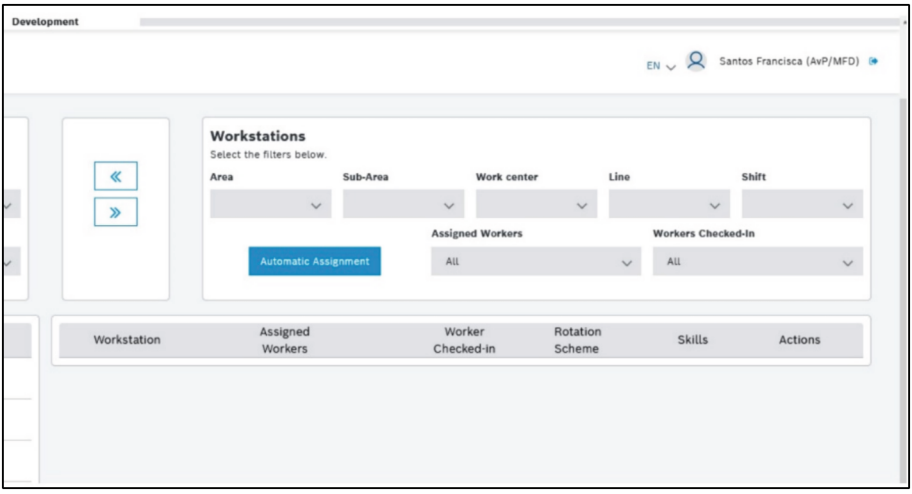

Fig. 4. Right side of the interface Worker Assignment window.

related to the workers. “Plant check-in,” which confirms if the employee has checked in before; “Workstation check-in” displays the workstation number, line number, and section number where the corresponding worker completed the check-in; Moreover, shading in either green or yellow has been used; The worker that checked in at a workstation where he/she wasn’t allocated previously is shown by the yellow shading; If the worker checks-in at the designated workstation, the result is shown in green coloring; “rotation scheme” refers to constraints related to ergonomics; When there are no restrictions, green coloring is used for a more readable indicator; When it comes to competencies, “skills” is represented by a green checkmark or a red cross, and “actions” is where the person responsible for the assignment can add or remove a worker from

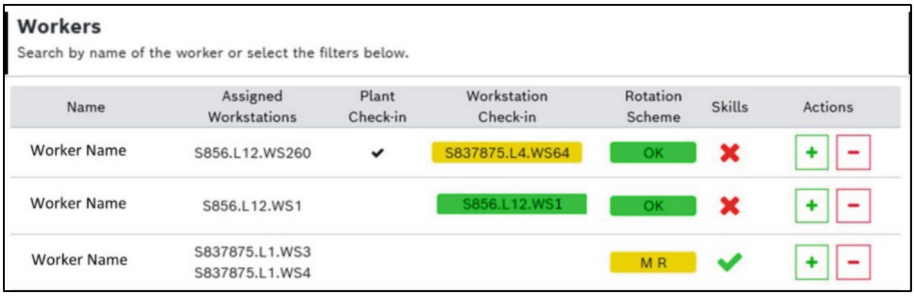

Fig. 5. Worker fields.

his/her workstation based on whether he/she is missing, by a square with a plus sign or a minus sign.

4 Main Results and Discussions

Following the implementation of the modules "Worker Assignment", "Area Check-In" and "Workstation Check-in", the Skillinx platform's Worker Assignment module has an intuitive user interface that makes it simple to understand and utilize and is prepared for integration, enabling communication with other databases, particularly the training data repository.

It has been possible to go from an empirically-based decision-making process to one that is data-driven to achieve as close as possible to an optimized assignment of the workers to the workstation. This involves making judgments about assignments based on ergonomic settings and actual training data. Improved transparency on the conditions of operators includes their abilities and ergonomic constraints. Also, a reduction in the necessary capacity, expressed in full-time equivalent (FTE) figures, for scheduling and allocating operators was achieved (Table 3).

Table 3. Key Performance Metrics

Performance metrics	Key Performance Indicator	Units	Current	Goal	area manager	team leader	shift supervisor
		Hours/ weekly	0.025	0.013	0.016	0.018	0.018

Because of the hold-up in getting performance indicator data, only the FTE metric was taken into consideration in order to meet the goals of efficiently managing labor capacity and maximizing operator assignment, since it is a metric that takes into consideration both full-time and part-time employees, aiding in hiring, restructuring, and downsizing decisions.

The data acquired during the research served as the foundation for calculating the FTE measure. Within a 40-h workweek, the present assignment procedure is anticipated to take one hour. Finding the number of FTEs that equal one hour was the aim, as one FTE is equivalent to forty hours per week. As a consequence, 0.025 FTE is equal to one hour. The outcomes were as follows: the area manager required around 40 min, equivalent to 0.016 FTE and both the team leader and shift supervisor used approximately 45 min, equivalent to 0.018 FTE each. The time required by each responsible party to utilize the Worker Assignment module was assessed three times, once for each assignment responsibility (e.g., area manager, shift supervisor, etc.), in order to track the metric, assess platform efficacy, and examine user-friendliness.

Furthermore, the assignment manager's experiential understanding of ergonomic limits was taken into account, even though the medical and ergonomics teams were still developing ergonomic limitation data.

In addition, an A3 problem-solving report was created to demonstrate the project's advancement throughout the whole organization, but by the time of the project, few outcomes were obtained.

5 Conclusions and Future Work

The large number of workers who needed to be assigned to their individual responsibilities made it necessary to create a platform that would optimize and fact-check the process, accounting for things like ergonomic settings and staff training. In response to these requirements, a platform was created that compiles all operator data into a single location and establishes an operator assignment procedure based on verifiable facts. This minimizes the time needed for scheduling and assigning operators while ensuring maximum transparency about skills and ergonomic restrictions.

The first step in achieving these goals was defining the conditions that the Skillinx platform had to meet. The Outsystems software was used to carry out the development of the work, following brainstorming meetings to determine the most important modules to create.

Thus, it can be said that the worker assignment module's implementation succeeded in achieving the goals of centralizing operator data and developing a fact-based assignment mechanism. The goal of guaranteeing openness in training and ergonomic constraints was accomplished by means of the worker assignment module and the workstation check-in module. These modules also resulted in a decrease in the amount of time needed for operator assignment and planning.

The creation of these modules encouraged accountability and trust among operators while also lessening the workload for those in charge of assignments. Inquiring about new product references and addressing difficulties related to ergonomic restrictions or necessary training can foster employee empowerment and dedication to their work.

In order to achieve the goal of calculating the amount of time spent on each assignment, three measurements were made, one for each operator assignment supervisor. The results showed that supervisors needed 43 min on average to do the work. After thorough investigation, it was evident that one of the main areas for improvement was cutting down on the amount of time needed to assign operators to workstations. Working together across departments during the project enabled shared decision-making and

helped to clarify the issues and challenges facing the weekly production line process at the moment.

Only the first phase of the first cycle was taken into consideration while applying the action research approach. Due to the limited time allotted for the project, it was not feasible to finish a second cycle, which precluded a thorough examination of the interaction cycles recommended by the approach. Installing the Skillinx platform required obtaining many software packages, which was a hindrance.

Future work may involve acquiring mobile devices that can support the Skillinx platform. This will provide assignment supervisors with more process flexibility and enable them to do the task from different locations within the plant, for example.

This experimental concept was validated through one production line, but it is expected that the entire facility, worldwide, would be added to the Skillinx platform. The goal of this platform is to compile all the information needed about the workers and production lines so that the plant manager and assignment supervisors may access it.

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