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A CONCEPT FOR IMPLEMENTATION KANBAN METHOD IN LEARNING FACTORY

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Abstract: *The KANBAN method was first developed at Toyota in 1950 as a method to manage the flow of materials on an assembly line. In the following 3 decades, the Kanban method was developed in an optimal manufacturing environment that can lead to global competitiveness. Within the POLITEHNICA Bucharest-Pitesti University Center, the Learning Factory research laboratory implemented the Kanban method on an assembly line that produces steering wheels. The influence of the Kanban method on the performance of the assembly line was studied using the Arena Rockwell discrete event simulation environment. Using the experimental simulation, the optimal number of kanban cards and operators serving the assembly line was identified.*

Keywords: *KANBAN method, assembly line, simulation, Arena.*

1. INTRODUCTION

In the last few years, companies around the world have had to find new modalities to reduce costs, improving the quality of products, and meet different customer applications. Addressing these causes is the just-in-time (JIT) manufacturing strategy, which involves a wide range of major management and operational components of a company [1].

The Kanban concept, from its debut within the Toyota Production System (TPS), has been a highly useful tool in production planning and control [2].

Kanban is a method for managing workflow to define, manage, and improve knowledge service delivery [3]. The name "Kanban" comes from a Japanese word that means visual signal. The name itself encapsulates the Kanban methodology well, which utilizes visualization to track and limit work in progress and maximize efficiency, known as "flow" [3].

The meaning of the Kanban method is signal or card [4]. It acts as a mediator between production steps and signals the demand for the various components required during product manufacturing [4].

Kanban is a concept that means a particularity of continuous change, day by day, in the sense of improving the activity of organizations [5]. Unlike the Western conception, which assumes a total change, at long intervals, with the use of a large volume of resources, Kanban therefore seeks a gradual improvement in terms of monitoring stocks and raw materials. The Japanese have demonstrated that, although the improvements achieved by applying Kanban are small when implemented, and evaluated over long periods, equivalent to those in which radical changes take place in Western organizations, the results are at least equal [5]. The improvement achieved by applying Kanban is achieved with a minimum of expenditure and is ensured by the participation of all staff of the organization [5].

To realize the JIT philosophy by initiating production or retrieving the required items in the required quantity at the right time the major means is the Kanban system [6]. Kanban aims to minimize WIP and total inventory costs. It, as a subsystem of JIT, controls inventory and production and raw material supply [6].

Kanban cards containing the production/ supply of parts information about each stage associated with containers are required in the Kanban system. The Kanban number decides the stock levels for every part at every station [6].

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According to [7] the availability of the right components for the Kanban system is when for consumption are in the right quantity and at the right time. Because the Kanban system works according to a replenishment frequency this is possible. Because of this, to reduce constant changes in production scheduling and high stock levels, increase customer numbers and customer satisfaction, the Kanban system was considered as the solution.

For [8] starting with understanding the needs of the organization's medium and then designing and implementing the Kanban system to meet those needs is an effective Kanban system. Planning, implementation, and control are the stages of implementing a Kanban system.

Using simulation, Mulissa and Kader [6] analyzed the number of ideal Kanban cards for a metal tool factory. The simulation data were tested in the real production system, thus validating the simulated model. The research examined how simulation can improve the productivity of coordinated production systems using Kanban method.

Pekarcikova et al. [9] simulated the assembly and production process in an enterprise where medical devices are manufactured. To control the material flow they proposed and analyzed the effects of implementing the Kanban method. The authors simulated, using Tecnomatix Plant Simulation software, different scenarios of material flow organization and concluded that the implementation of the Kanban method improves not only the productivity but also the utilization of the equipment used in the production system.

Pekarcikova et al [10] simulated, using TX Plant Simulation software, a production system in which solar panels are manufactured and distributed. Using the simulation bottlenecks in the logistics flow were analyzed. The bottlenecks in the logistics flow were defined in the simulated model and a method for optimizing the logistics flow by implementing the Kanban method was designed and tested. This resulted in an improvement of the total logistic flow, a reduction of interoperable stocks, and an increase in the efficiency of the production system as a whole.

Kumar et al [11] analyzed, with the help of simulation, what are the effects of implementing VSM and Kanban methods in a production system manufacturing butterfly valve products. The study revealed that Kanban method significantly boosts the reduction in WIP inventory.

Today's production and logistics systems are highly sophisticated and need to focus on increasing system efficiency. For decision-makers to achieve the desired level of efficiency, techniques and tools are needed to help identify improvement solutions. A discrete event simulation is a powerful tool that can be used to evaluate the performance of a production system.

Simulation is a broad collection of methods and applications that copy a real system with the help of dedicated discrete event simulation software, but it also has limits. Here are some of them:

- Creating an accurate and detailed model is a complex and time-consuming process. Building such a model requires a deep understanding of production systems and the interactions between the different components within the system.
- Developing and running the simulated models involves significant costs, both in terms of human resources and in terms of the equipment and software used.
- Validation and verification of simulated models is essential but can be difficult. Validation and verification require accurate data and may involve extensive testing.
- The quality and availability of data input to a simulated model affects the accuracy of the simulation results. Incomplete or inaccurate data may lead to erroneous results.
- Simulation results must be interpreted correctly in order to be implemented in production systems.

These limitations do not diminish the usefulness of the simulation, but it is important to take them into account when planning and implementing such simulations.

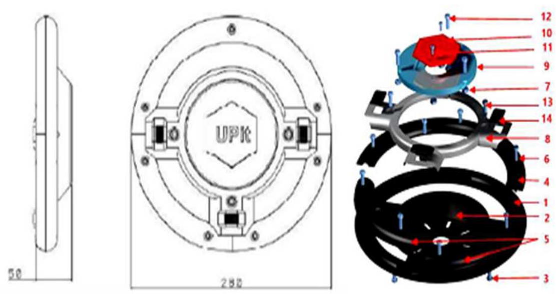
In this context, this article will analyze, with the help of simulation, the influence of the implementation of the Kanban method and the variation of the number of operators on the performance of the assembly line.

2. RESEARCH PROBLEM

This study was conducted within the Lean Learning Factory - LLF laboratory at the National University of Sciences and Technology POLITEHNICA Bucharest, Pitești University Center. This laboratory was developed according to the principle of a "learning factory" [12], [13] and consists of several learning platforms of Lean Manufacturing methods and tools, as well as a methodology for using simulation in analyzing the performance of production systems, Fig 1. As a result of this study in the LLF learning factory, students understand and apply the operation of the Kanban method in combination with the use of the discrete event simulation method.

A modular and flexible assembly line has been built in the LLF laboratory within which the experimental steering wheel product is assembled, the bill of materials of which is shown in Fig. 2.

Fig. 1. Research Laboratory – "Lean learning factory" LLF.



1. Lower body
2. Bottom cover
3. M5x10 screw
4. Large toroidal component
5. Small toroidal components
6. M4x20 screw
7. M3 nut
8. Top cover holder
9. Horn Support
10. Horn
11. ScrewM4x15
12. ScrewM3x10
13. ScrewM5x20
14.Switch

Fig. 2. Bill of materials of the experimental product - steering wheel.

The assembly line layout is presented in Fig. 3.

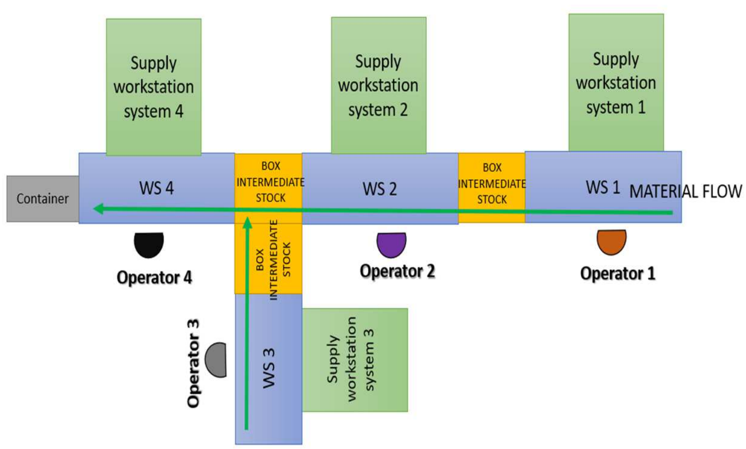


Fig. 3. Variants of assembly line layout.

The process for working on this assembly line is as follows:

- All operations shall be carried out on the workstation workbench.
- The subassemblies made at each workstation are stored in boxes comprising 4 subassemblies each.
- Boxes with the 4 sub-assemblies represent intermediate stocks.
- These boxes are transferred from one workstation to another.

The assembly process of the experimental product involves going through 4 operations, Fig. 4, with the help of specific orientation elements, the phases of this process being of the type: semi-finished product ordering and fixation, screws positioning and tightening, assembly and product packaging, most of these activities being done manually by operators.

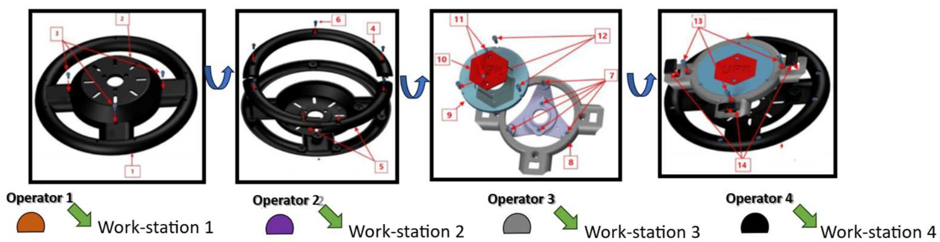


Fig. 4. Assembly operations.

This article will analyze, with the help of simulation, the performance of the assembly line managed in two ways: push system - without the Kanban method and pull system - using the Kanban method.

The working principle of the managed assembly line without the Kanban method is the classic one, when a workstation finishes manufacturing a product it will send it to the intermediate stock corresponding to the next workstation.

The working principle of a workstation managed using the Kanban method is shown in Fig. 5. A workstation when it has finished manufacturing a container of products, is sent to stock with a Kanban card attached. When a container is taken out of stock, the kan„ban card returns to the workstation, thus authorizing the workstation to work. All 4 workstations operate according to the same principle.

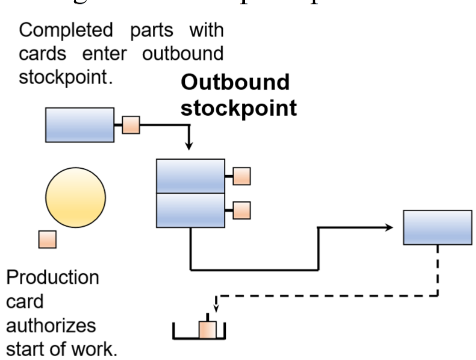


Fig. 5. Kanban method.

Information on the 4 assembly operations corresponding to the two assembly line management methods is presented in Table 1.

Table 1

Duration of operations (sec.)

	Work station	**Product development time in WS**	**Component handling time in WS**	**Interoperable product transfer time between WS**	**Total duration of the operation**
Without Kanban	WS1	14.5	11.5	4.33	30.33
	WS2	32.98	18.85	1.96	53.79
	WS3	23.61	27.58	1.84	53.03
	WS4	13.93	17.25	5.74	36.92
With Kanban	WS1	14.32	10.82	4.33	29.47
	WS2	32.98	18.85	1.63	53.46
	WS3	23.61	27.58	1.44	52.63
	WS4	13.93	18.69	5.74	38.36

3. BUILDING SIMULATION MODELS OF ASSEMBLY LINES

Arena software was used to build simulation models. Arena is one of the most widely used simulation software with discrete events [14]. ARENA is a process modeling and simulation software that combines the ease of use found in high-level simulators with the adaptability offered by simulation languages. It manages to achieve these performances through a range of elementary modular elements with which systems of particular complexity can be created, after a good understanding of logical mechanisms.

The simulation in the Arena software is based on modules. These modules are used to define dynamic processes and process elements in the software. The modules are of 2 types:

- Flowchart: modules that can be considered nodes where entities enter and exit.
- Data: modules that set variables or numeric values and expressions.

To accurately mimic the functioning of the models, the simulation was performed using logic modules. These modules can be divided into two categories:

- General modules – valid in all 2 models: semi-finished input module, customer order entry module, process module - used to render assembly operations, order shipping module.
- Specific modules to the Kanban method – refer to how to manage the material and informational flow according to the Kanban method. To simulate the kanban loop, the Match module was used to join the kanban card with the product and the Separate module to separate the part from the kanban card, which is returned in the kanban loop.

The representation of the model began with the creation of the 13 components necessary for assembly with the *Create* module. The Create modules were also used to introduce Kanban cards into the system. The steering wheel assembly consists of 3 assemblies that are made on this line. The components needed for each assembly are joined into a Match so you can assemble them. They are assembled with the help of the Process module where we assign a resource–operator and assembly time. In Fig. 7 we have highlighted all these modules with different colors such as: the create module with green, the match module with blue and the process module with purple.

In Fig. 6 shows the assembly line model managed without the Kanban method and in fig. 7 the assembly line model managed with the Kanban method.

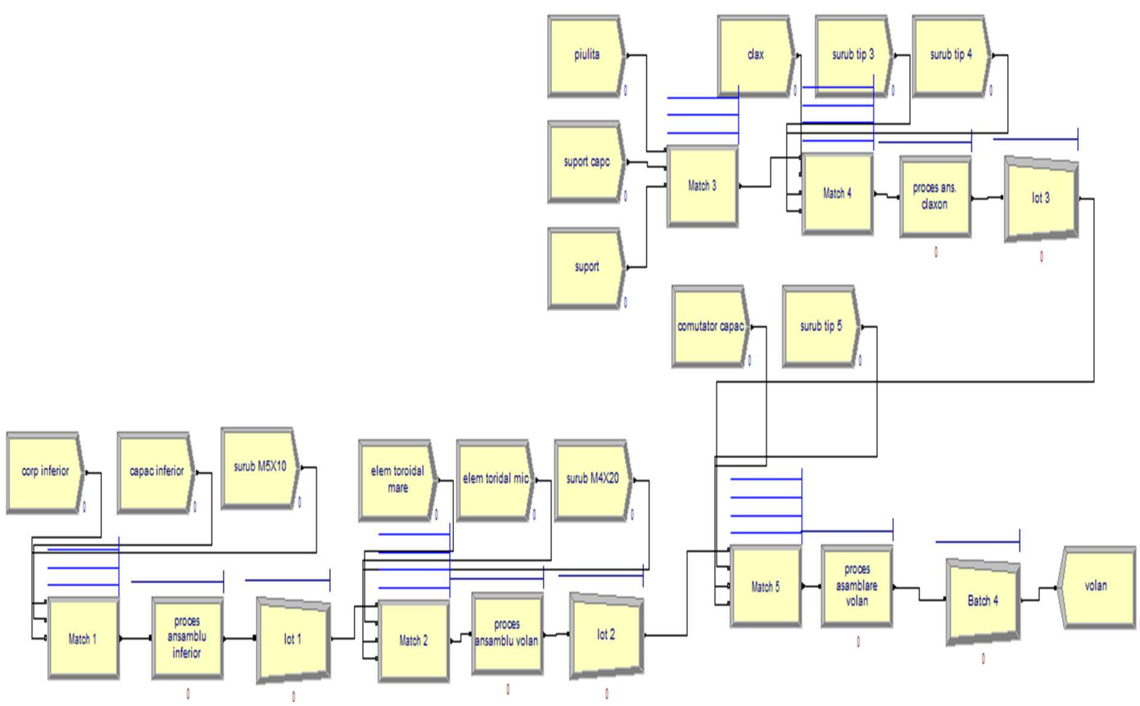


Fig. 6. Model in Arena without Kanban.

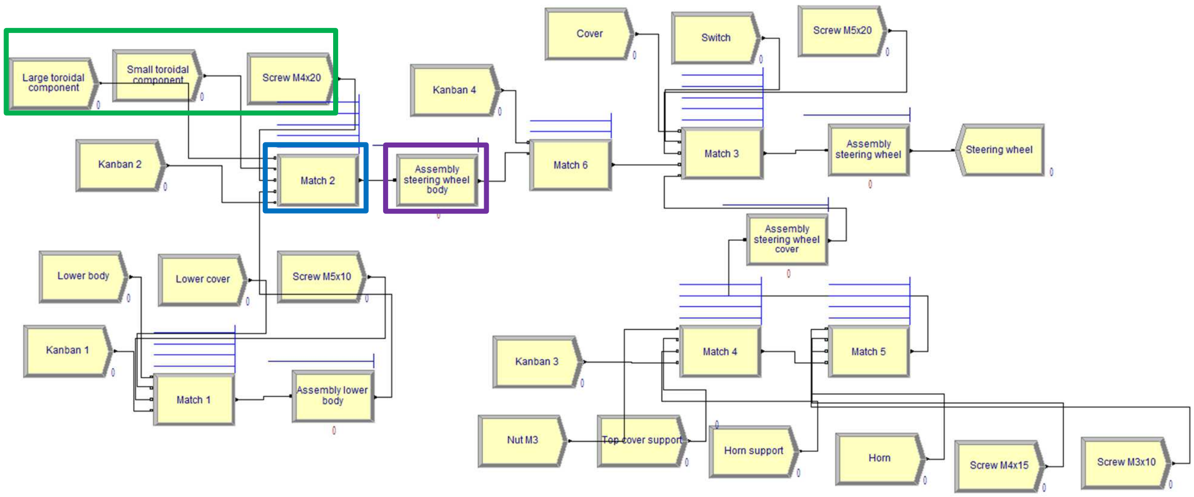


Fig. 7. Model in Arena with Kanban.

4. TEST AND MODELS VALIDATION

Test and validation involve determining the loading period with parts of the system – warm-up, determining the period to be simulated, and checking the functioning of the model.

The warm-up period is the period during which the simulation runs without recording statistical data. The part-loading period of the system is determined using Welch's method. As can be seen from Fig. 8 and Fig. 9, both models begin to stabilize after 75 hours of running.

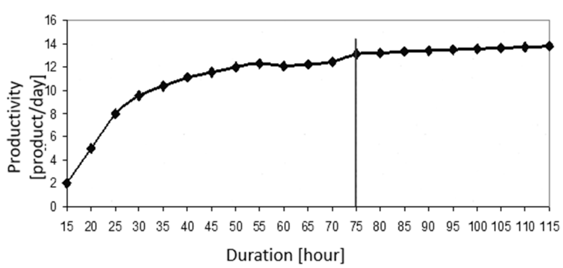


Fig. 8. Warm-up model without Kanban.

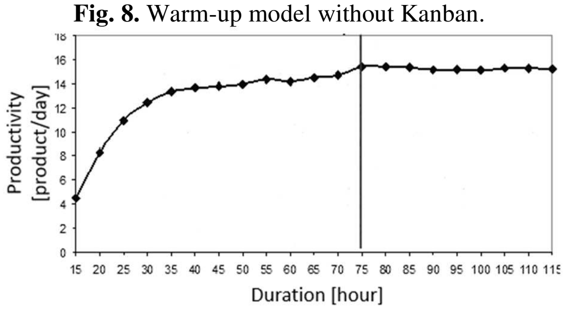


Fig. 9 Warm-up model with Kanban

The simulation period was determined by multiplying the warm-up time of the system by 10, resulting in 750 hours. The verification of the functioning mode of the models was done with the help of the ARENA animation.

5. RESULTS

After running the simulated models for 750 hours, the system automatically generates data reports, from which, for the current analysis we carry out, we will extract data on resources and entities.

So, for the model to simulate without the Kanban method, the operator workload is as follows:

- Operator 1 - 47%.
- Operator 2 - 21%.
- Operator 3 - 84%.
- Operator 4 - 3%.

For workstation workload, it is seen a similarity between the models, Fig. 10.

Within the two models of the assembly line, the number of operators is varied to identify the influence of variation of the number of operators on the performance of the line.

For both variants of the assembly line, 5 versions are proposed, resulting in 10 variants of the assembly line Fig. 11.

It is proposed as a first variant, to use in the 4 workstations 3 operators, namely: the operator from the first workstation to work the workstation number 4, and operators 2 and 3 to remain at fixed workstations. In addition to the initial version, this variant excludes the use of one of the operators but includes an additional movement, namely moving by a maximum of 2 steps to the next workstation, which can delay production by 2.58 cmin according to a MODAPTS analysis (2W5 = 12 modes = 2.58 cmin).

	Number In	Number Out
Assembly steering wheel cover	459	108
Assembly steering wheel cover	573	135
Assembly lower body	582	567
Assembly steering wheel body	110	108
Assembly steering wheel	27	27

Usage

	Inst Util	Num Busy
Operator 1	0,47	0,47
Operator 2	0,21	0,21
Operator 3	0,84	0,84
Operator 4	0,03	0,03
Workstation 1	0,47	0,47
Workstation 2	0,21	0,21
Workstation 3	0,84	0,84
Workstation 4	0,03	0,03

Fig. 10. Resource report, model without Kanban.

For this change of operators to occur, there is no need to make another form of the model, but only to modify the allocation of resources (operator resource 1 for item 4, instead of operator resource 4). Similar to the initial version, the program will run in this hypothesis in order to generate the final report.

However, there are differences in the reports regarding the percentages of workload capacities. Because we have placed an operator on two workstations, he is now more requested than before, and the operator to whom he took his place reaches 0%, because he is practically excluded from the process.

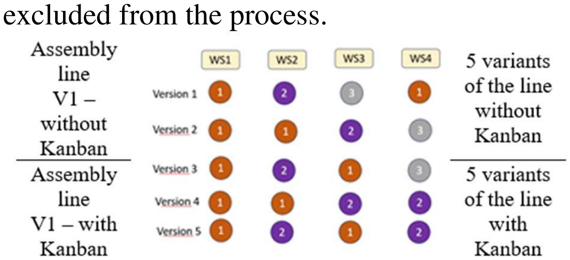


Fig. 11. Assembly line variant

In the second variant, the assembly line is served by 3 operators, it is suggested to transfer operator 3 to workstation number 4, and operators in positions 1 and 2 to remain in their initial positions. The only difference between this variant and the first proposed one is the distance that the operator is supposed to travel between workstations, this time being a maximum of 1 step, so 1.29 cmin. Similarly to the previous version, differences in operator workload are observed here, highlighting the lack of the replaced operator in the system by assigning in relation to Figure 11 for its defining characteristics.

In the third variant - if we initially started with the attempt to replace operator 4, now we will change the parameters of operator 2, to be able to observe the changes made to the system after its runs, so we will put first operator 1 and on workstation 2, and operators 2 and 3 moved by a workstation.

In the fourth variant, because no differences have been previously noticed due to the reduction in the number of operators, which would negatively influence the performance of the assembly line, we use only 2 operators. Namely, operator 1 should also serve workstation 2, and operator 3 should also serve workstation 4.

In the last proposed variant, we kept the variation of 2 operators but distributed them differently to see if there were differences. Operator 1 shall also serve workstation 3 and operator 2 shall also serve workstation 4.

To be able to visualize more accurately the changes and differences that occur according to the variants of proposals we have listed, the graph in Fig. 12 and Fig.13 was made.

For all these variants proposed in the following graph, the differences in production can be observed, the most important variable being the one allocated to the final product – steering wheel, Fig. 14.

From the graphs presented for the 5 variants, production decreased from 27 products per shift to 21 products, a decrease in production of 22.23%. From this point of view, the choice can be quite risky, because it cannot meet customer demand, which can be considered an unpredictable variable but cannot be ignored.

Also, for a better visualization, we highlighted inter-operational stocks before and after the implementation of the Kanban method. As can be seen from Fig. 12 and Fig. 13, stocks are minimized after the implementation of the Kanban method.

From all those presented, the best variant of the system is variant 4, the one that proposes that the assembly process can work with only 2 operators who will have 66% and 87% workload respectively with Kanban. As can be seen, if the process is structured using operators, they will not be overloaded in terms of working capacity.

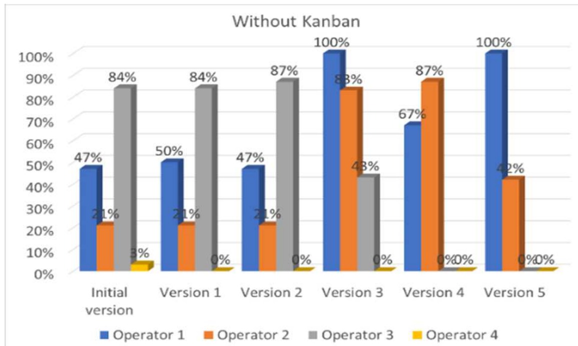


Fig. 12. Workload percentage of the assembly line without Kanban.

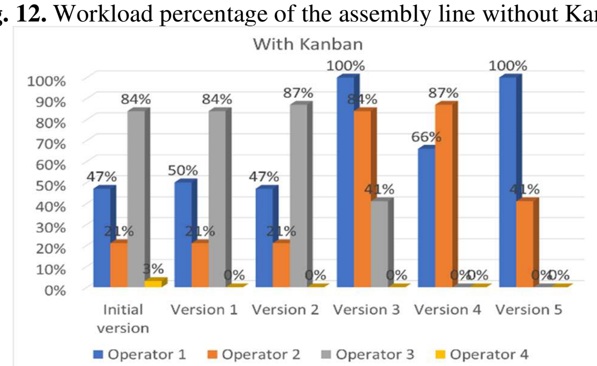


Fig. 13. Workload percentage of the assembly line with Kanban.

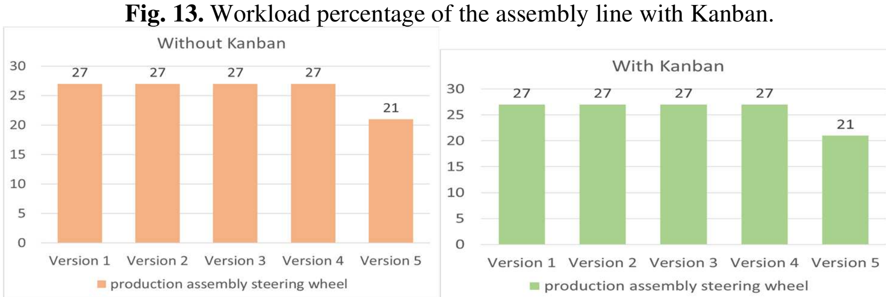


Fig. 14. Production differences for the 5 variants.

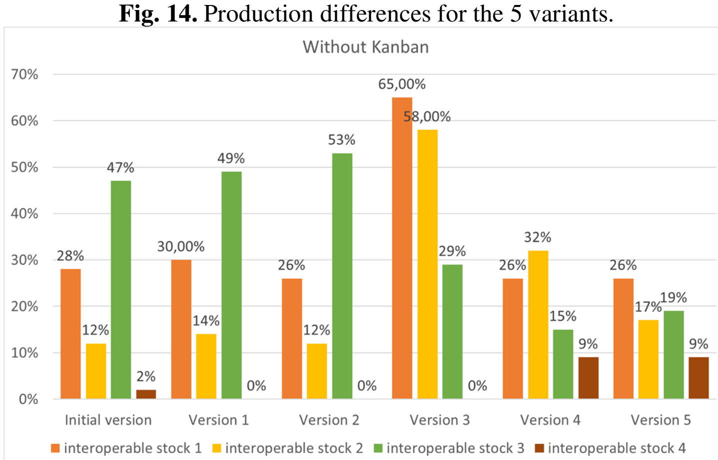


Fig. 15. Inter-operational stocks on the assembly line without Kanban.

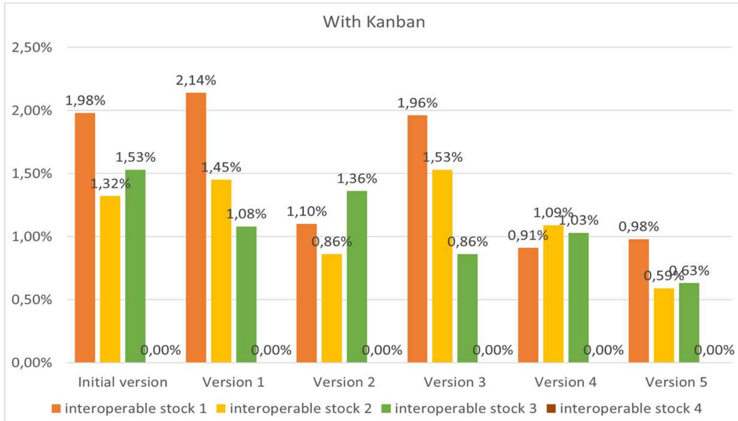


Fig. 16. Inter-operational stocks on the assembly line with Kanban.

6. CONCLUSION

In this article, we have presented a production system created in the research laboratory with the scope to improve the workload capacity without too long a waiting time for the operators participating in the assembly operations and to see if the Kanban involved regulates the production flow.

This study was carried out in the Learning Factory because it provides students with a safe and controlled space to perform theoretical concepts, such as the Kanban method, and then apply them practically through discrete event simulation methods.

Analyzing the loading percentage of the assembly line in the two variants, it was observed that in the initial variant and the first two variants the Kanban method does not influence this loading percentage, but for variant 3 operators 2 and 3 have a loading of 88% and 48% respectively without Kanban and 84% and 41% respectively with Kanban. In the fourth variant, the differences are minimal for operator 2, respectively 1%.

After the analysis performed on the influence of Kanban on the performance of the assembly line with variations in the number of operators, it results that the assembly process can operate with 2 operators having 66% and 87% loading, respectively, with Kanban.

Implementing the Kanban method resulted in a major difference in the interoperable stocks for the trim line. For the initial variant the interoperable stock 1 decreased from 28% to 1.98%, interoperable stock 2 from 12% to 1.32%, interoperable stock 3 reached 1.53% with Kanban from 47% and interoperable stock 4 reached 0 from 2%. For all 5 variants, significant decreases as shown for variant 1 are observed.

The variant that was found to be favorable does not lead to negative effects on production. Furthermore, it is kept within the initial limits without impacting the workload or production capacity of the operators.

Future research directions in analyzing the Kanban method with simulation could study how machine learning and artificial intelligence can be combined to make simulations more efficient. Also, in the future, the performance of the production system managed with the Kanban method will be compared with that of the system managed with the CONWIP method and a hybrid consisting of the two methods.

Another future direction is the implementation of Kanban, CONWIP and eKanban on the existing assembly line in the Lean Learning Factory Lab.

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Un concept pentru implementarea metodei kanban în fabrica de învățare

Metoda KANBAN a fost dezvoltată pentru prima dată la Toyota în 1950 ca metodă de gestionare a fluxului de materiale pe o linie de asamblare. În următoarele 3 decenii, metoda Kanban a fost dezvoltată într-un mediu de producție optim care poate duce la competitivitate globală. În cadrul POLITEHNICA București – Centrul Universitar Pitești, laboratorul de cercetare Learning factory, metoda Kanban a fost implementată pe o linie de asamblare care produce volane. Influența metodei Kanban asupra performanței liniei de asamblare a fost studiată utilizând mediul de simulare cu evenimente discrete Arena Rokwell. Folosind simularea experimentală, a fost identificat numărul optim de carduri Kanban și de operatori care deservesc linia de asamblare.

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