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APPLICATION PROPOSAL OF A FLEXIBLE SUPPLY SYSTEM ON AN ASSEMBLY LINE: A CASE STUDY TO OPTIMIZE FLOWS IN THE MANUFACTURE OF TRUCK CABINS

Carolina Sacramento Vieira
Maira Silva Andrade
Centro Universitário Senai Cimatec
carolinavieira265@gmail.com; maira.andrade@fieb.org.br

Vitório Donato
Centro Universitário Senai Cimatec
vitorio@fieb.org.br

Abstract. *It is becoming increasingly pressing, the need for the supply networks of assembly lines to be more flexible, due to the need to reduce production costs of companies, to become more productive. In this context, the Flexible Logistics Manufacturing Support System - SLFAM was proposed, which is a simplified adaptation of the generic concept called Flexible Manufacturing System (FMS). In this sense, the present work aims to propose a new approach for production line supply systems that are more flexible and agile in assemblers that operate in the CKD (Completely Knock-Down) regime. Thus, this research is a case study based on a quantitative approach, developed in a car manufacturer, with twelve workstations as sample field. The developed model uses the Sushi Box Crab - SBC supply system, which is composed of transport modules (sushi box cars) towed by a towing vehicle. These cars, when coupled to the truck cab assembly support rack, change the operation direction. To validate the proposed implementation of the SBC system in the Trim Shop line (cabin assembly) of trucks, simulations and computer modeling was performed with the FlexSim software. This way, it was possible to perform tests and analyses about the future scenario considering the new supply model developed. With the simulations, it was possible to dimension the necessary movement resources for the supply of the assembly line, as well as to identify the intensity of the flows in the roads. The main results obtained indicate that the system applies to the production demands and shows to be a simple implementation process, which dispenses with the need for large investments.*

Keywords: *Logistics Processes, Manufacturing Support Systems, Production Line Supply.*

1. INTRODUCTION

According to Vieira and Donato (2021), it is becoming increasingly pressing the need for the supply network to be flexible, due to the need for companies to more efficiently manage costs and productive resources. A supply network must be agile, adaptable, and demand-driven, so if this same network becomes flexible, it will respond quickly to short-term changes and can evolve and improve over time to meet changing production conditions.

In light of this context, this article aims to analyze the performance, after implementation, of a Flexible Logistics Manufacturing Support System - SLFAM applied to a truck production line. One of the premises adopted was the possibility of the system adapting the line supply process to the entry of new truck models, maintaining the economic performance, and minimizing production costs. In addition, this system should meet the production line supply efficiency requirements.

In order to meet the supply needs of the truck line, a flexible logistics support system for manufacturing was developed. The flexibility of the logistical support system (FLSS) should be derived from the strategy planned for the entire internal supply chain, since only from the appropriate strategic alignment along the supply chain can one obtain a level of flexibility that is systemic.

The study is conducted in the Trim Shop of the Truck line, where the assembly of the vehicle cabins occurs. The medium-sized parts are pre-selected and stored in a supermarket that is then selected and sent to the assembly line, through the logistics process of supply called sushi box supply system that uses supply carts limited by range. The range limit is the available space for transporting parts.

This project begins with the study of the current process of supplying the Truck assembly line parts, with measurements of supply and storage times. Then, in possession of this data and the research conducted, it was possible to plan new supply methods, analyzing the impacts, and evaluating the necessary investments to be made for the deployment and operation of SLFAM.

Logistic studies were carried out that focused on substantiate the development of the new supply and storage method for the truck line. contemplating the receipt of national and imported parts, the temporary storage, and the sending of these to the line side.

The expected benefits of the project were evaluated using FlexSim software that allows modeling future scenarios through simulations. Thus, it was possible to estimate the resources needed and study the physical arrangement of the storage system used in the parts supermarket.

1.1 Flexible Logistics Manufacturing Support System – SLFAM

Manufacturing support, as a distinct operational area, is a relatively new concept in logistics management. The justification for dealing with activity cycles, in the sense of supporting production, is related to the constraints of the operational needs of production. Production support logistics is usually dealt with in three dimensions. The first is physically limited to the area of the company, while the other two deal with the behavioral uncertainty of external suppliers. To provide maximum flexibility, traditional paradigms related to economies of scale are being re-evaluated to accommodate shorter production cycles and faster process adjustments (Caccalano *et al*., 2015).

The materials to be consumed in the assembly lines are supplied along the lines or by the edges of the work cells and are individually removed from their packaging, to be added to sub-assemblies or the final product. In the specific case of the automotive industry, due to the high volume of parts to assemble a vehicle (about 4,000 items, depending on the model) and the need to maintain increasingly smaller inventories on the line side, the containers used for supply may have their content fully consumed in a matter of a few hours.

The shapes of these materials vary from a plastic clip of a few grams to a stamped part a few meters long. Thus, the bulkiest and heavy items must be supplied through industrial handling equipment (forklifts, pallet trucks, towing vehicles, etc.), defined for ergonomic reasons and supply speed.

Thus, when finishing the components of a container, the assembly operator expects an immediate replacement of the empty container with another full one. Replenishment can be provided by signaling the need (Kanban system), by scheduling according to production, or simply pushing batches to the line side.

The justification for giving a highlight to production support logistics is related to the constraints and operational needs particular to production strategies. The goal of the manufacturing support system is to efficiently support all production needs.

Manufacturing support is quite different when compared with physical distribution service or traditional supply. Production support logistics is usually limited to the internal area of the company, while the other two activity areas deal with the behavioral uncertainty of external customers and suppliers. When the company has several production units, each specialized in specific activities, the production support system may require a wide network of activity cycles. Therefore, in certain situations, it may exceed the complexity of physical distribution or supply (Machado *et al*., 2004).

The basic difference between physical distribution and manufacturing support is that the former is concerned with reconciling consumer uncertainty with industrial demand while manufacturing support focuses on the material needs of production, ie, storage, material flow, line supply, and flow device management.

The main areas of support for manufacturing are material flow, storage systems, stock replenishment systems, line supply systems, packaging systems. The main concern of manufacturing support is not how production takes place, but what is manufactured, as well as when and where it is manufactured. (Bowersox and Closs, 2010).

There are two forms of supply chain flexibility: micro flexibility and macro flexibility. Micro-flexibility essentially refers to how quickly a supply chain can detect and respond to any type of short-term problem. On the other hand, the macro refers to the company's broader strategies, programs, and policies that, by having a flexible macro system in the supply chain, can easily change the configurations of the existing chain or develop new supply chains to accommodate the demands, that is, it has more agility and adaptability.

2. DEVELOPMENT

With the purpose to obtain data that would guide the development of a flexible logistical system to support manufacturing, it was necessary to observe, in loco, the peculiarities of the production process. Thus, performance analyzes of the supply of the truck cabins line were carried out, which can be observed in the topic called Diagnostic.

2.1 Diagnostic

The Assembly Line is composed of an assembly flow line (subdivided into 8 cells). For the study in question, the behavior of Line T was observed, which composes the beginning of the assembly and is divided into 2 ranges. The line edge is composed of flow racks, where the parts are positioned according to the assembly job. The Supply System is the hourly system that works with the push logic.

At this step, three analyzes were carried out, namely, the analysis of displacements, the analysis of added value, and the study of resistance to logistical flows.

In the analysis of the displacements, the times of four supply teams (T01, T02, T05, T06) were taken, see Table 1. It is observed that the T06 team shows a critical scenario, in which it travels 2,284 *km/year* to supply the line, that is, in the analyzed process the operator has an excessive displacement.

Table 1. Analysis of the displacements of four samples of the line supply team.

Flow analysis	**T01**	**T02**	**T05**	**T06**
Without sushi car	951 *km/year*	894 *km/year*	836 *km/year*	2,284 *km/year*

To analyze the added value of these teams, observations of 10 minutes duration were used as standard. Sample T01 shows that only 33.3% of the time is spent on work that adds value, sample T02 - 62%, sample T05 - 68% and T06 - 33.4%. In all samples, adding the activities that do not add value, there is 66.7%; 38%; 32% and 66.6% wasted time in each of the teams (T01, T02, T05 and T06), respectively.

Table 2. Add value analysis of the supply activity in four samples.

Activity	**T01 (%)**	**T02 (%)**	**T05 (%)**	**T06 (%)**
Displacement	23,3	20	25	33,4
Parts search	3,3	16	5	-
Wait	42,5	-	1,6	46,6
Transport (Cabin displacement)	10	-	-	-
Others wastes (Talk; cell)	-	2	-	20
Works (Add the part to cabin)	33,3	62	68	100

In the study of resistance to supply flows, see Figure 1, the resistance index reached was 34.5 points out of a total of 52 points (highest resistance), classifying the flow studied as a resistant flow (Donato and Passos, 2014).

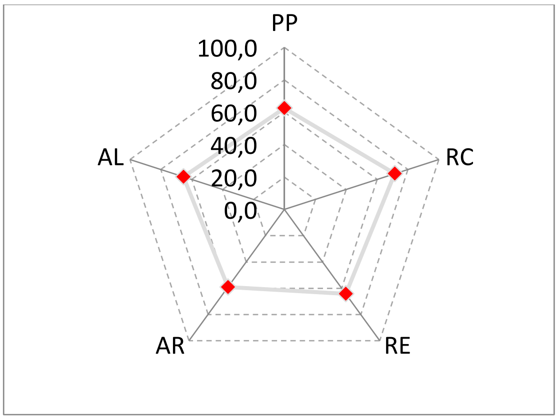

Figure 1. Resistance to T-line supply flows.

2.2 Implementation of flexible logistics system to support manufacturing

SLFAM is composed of a parts supermarket (supermarket supply subsystem and picking subsystem), a parts call system, and a parts supply system on the line.

- Parts Supermarket (supermarket supply subsystem and picking subsystem) This is a parts storage area, in which the storage sequence is a mirror image of the assembly line. The truck parts supermarket is composed of a supply street and a picking street.
- The parts call system consists of a barcode reader, zebra printer, server, and a PBS program. The booths are ordered in the buffer and registered in the PBS system that sequences the sending of the sushi box cars according to the registered order.
- The parts supply system in the line is composed of a parts transport car called sushi box crab, see Figure 2, where each part has its captive place. They are transported in trains composed of 4 cars pulled by a towing vehicle and are attached to the cabins.

Figure 2. Sushi box crab car attached to the mounting support rack.

3. RESULTS AND DISCUSSIONS

3.1 Simulation

With the help of Flexsim software, it was possible to analyze and validate the proposal for the implementation of the Sushi Box Crab system, regarding the dimensioning of the handling resources needed to supply the truck assembly line.

To perform the simulation and computational modeling, it was necessary to raise assumptions and define the production schedule to be simulated so that it was possible to relate the number of resources to the mapping of flows. The following topics summarize the validated criteria:

- JPH (Jobs per hour) of 4 trucks.
- The logistics operation is pulled so that there is no possibility of pushing unnecessary material onto the line.
- An average of 4 sushi box cars per trip (towing vehicle) was simulated, 2 from range 1 and 2 from range 2.
- The average speed of the towing vehicles is 10 *km/h.*
- It was considered 1 exclusive operator to doing the picking in the supermarket and 1 exclusive towing vehicle to transport the sushi box cars from the truck line.
- The filling of the car is done with all items of the respective range/model.
- The picking is done with 1 car at a time/per operator.
- The towing vehicle takes the full sushi box cars to the right side of the line and picks up the empty ones on the left side of the line.
- The number of items per range/model was used considering the version with the highest quantity.

The flow of the operation, as can be seen in Figure 3, has as its origin the supermarket and as destination the supply stations on the production line.

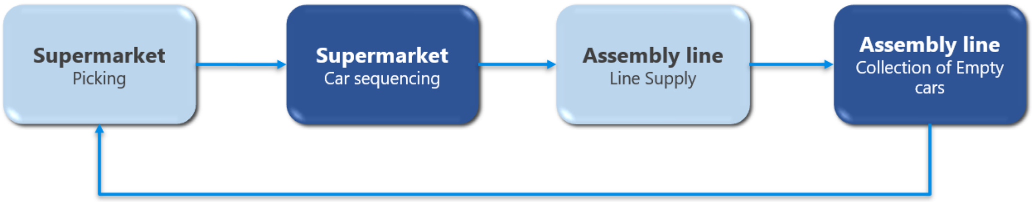

Figure 3. Flow of the operation.

The simulated line is composed of 2 ranges and assembles two models (HR and HD), one of them with two different versions. So, to make possible the calculation of the quantity of demanded cars, it was necessary to start from the calculation of items per sector and per model, according to Table 3.

Table 3. Quantity of items per range and per model.

Range (T line)	HR	HD	Total
Range 1	58	47	105
Range 2	41	53	94
Total	**99**	**100**	**199**

The two resources mapped were the towing vehicles and the operators who perform picking in the supermarket. To generate, through simulation, the cycle times of the activities of these resources, it was also necessary to collect the tasks samples of coupling, uncoupling (shown in Table 4), and picking (shown in Table 5), considering the scenarios with and without the pick by light system installed in the supermarket racks.

Table 4. Towing vehicles times.

Activity	**Average time (*sec*)**	**Standard deviation (SD)**	**Coefficient of variation *(%)***
Coupling Supermarket	13	1.3	10
Uncoupling Supermarket	8	2.5	33
Coupling line	69	9.3	14
Uncoupling line	93	19.3	21

Table 5. Operator Times.

Activity	**Average time *(sec)***	**Standard deviation (SD)**	**Coefficient of variation (%)**
Picking/part (Pick by light)	4	2.11	51
Picking/part	10	0.81	8

Another important point was to define the flows and directions that each resource goes through based on the plant's floor plan and storage area.

By simulating the operation of the factory during a working day (8 hours) and considering the appropriate breaks, it was possible to generate the cycle times of the activities, as presented in Table 6.

Table 6. Simulated cycle times.

Cycle time	**Operator without Pick by Light**	**Operator with Pick by Light**	**Towing vehicle**
Min	443 *s*	92 *s*	841 *s*
Max	773 *s*	615 *s*	933 *s*
Average	586 *s*	267 *s*	891 *s*
Standard deviation (SD)	102 *s*	113 *s*	27 *s*
Coefficient of variantion	17%	42%	3%

In order to analyze whether the resources can meet the demand of trips per day, the takt time was calculated, which mathematically results from the ratio between the time available for production (7.88 *hours*) and the number of trips per day (16 for the towing vehicle and 62 for the operators).

Comparing the takt time with the simulated cycle times we identify whether or not the resource can perform the amount of trips required, allowing us to observe the behavior of different scenarios. Figure 4 shows scenario I with only one tugboat, in which it is possible to verify a large gap between the two parameters.

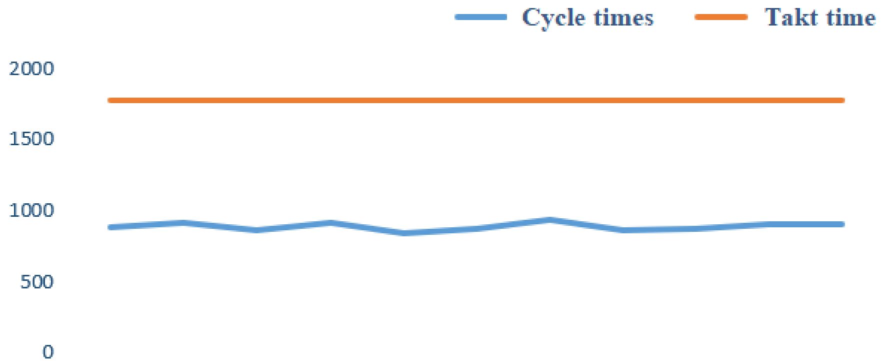

Figure 4. Scenario I – Towing vehicle.

Figure 5 shows scenario I with only one operator, in which it is possible to verify that without the pick by light the operator would not meet the demand, but that probably if they installed the pick by light, they would meet the demand.

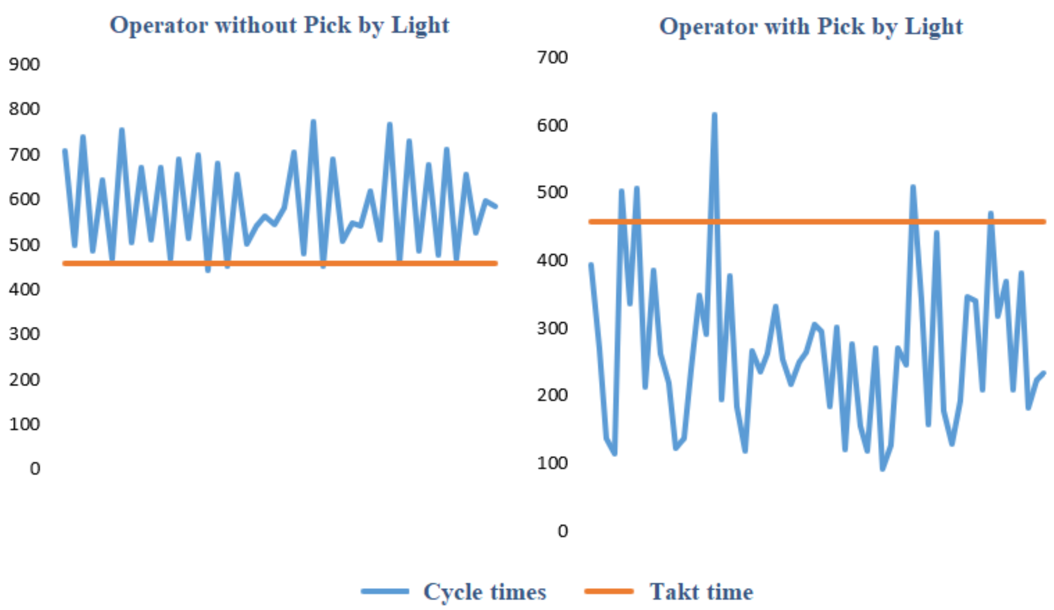

Figure 5. Scenario I – Operator.

It is important to highlight that in this study there was no flexibility to change the process with possible improvements, only changes related to the number of resources.

Figure 6 shows the scenario II with two operators considering the option without the pick by light, in which it is possible to see a significant change in relation to scenario I, meeting the demand with ease.

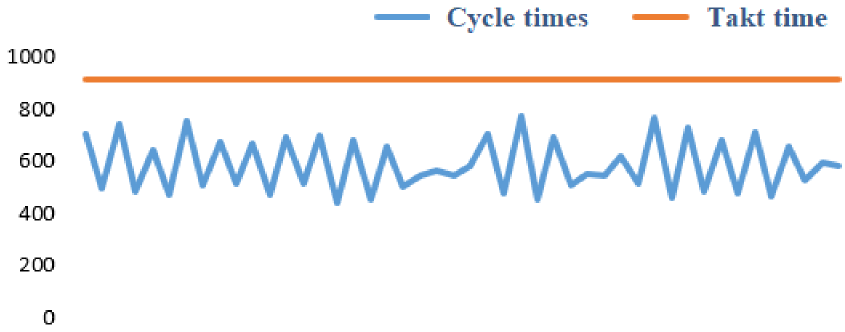

Figure 6. Scenario II – Operator.

Using these results it was also possible to observe the occupation percentage of each of the resources, generating a team sizing estimate is summarized in Tables 7, 8, and 9.

Table 7. Towing vehicle occupancy analysis.

Towing vehicle Scenario I (1 Resource)			
	Average	Median	Average + 1 SD
Cycle time	891	888	918
Occupation – Sce. I	50%	50%	52%

Table 8 – Operator occupancy analysis without pick by light.

Operator without Pick by Light: Scenario I (1 Resource) and Scenario II (2 Resources)			
	Average	Median	Average + 1 SD
Cycle time	586	556	688
Occupation – Sce. I	128%	122%	150%
Occupation – Sce. II	64%	61%	75%

Table 9 – Operator occupancy analysis with pick by light.

Operator with Pick by Light: Scenario I (1 Resource)			
	Average	Median	Average + 1 SD
Cycle time	267	258	380
Occupation – Sce. I	58%	56%	83%

Therefore, the simulation results in a sizing that considers one tugboat and two operators as the ideal team, considering all the assumptions made.

3.2 Deployment

After simulation and analysis of the results, the SBC was implemented in the cabin assembly line. In addition, with the implementation of SLFAM, significant improvements were achieved on the T-line compared to the old System. Figures 7 (Production) and 8 (Logistics) show the time of the activities in the before (in December 2020) and after (in May 2021) of the implemented SLFAM.

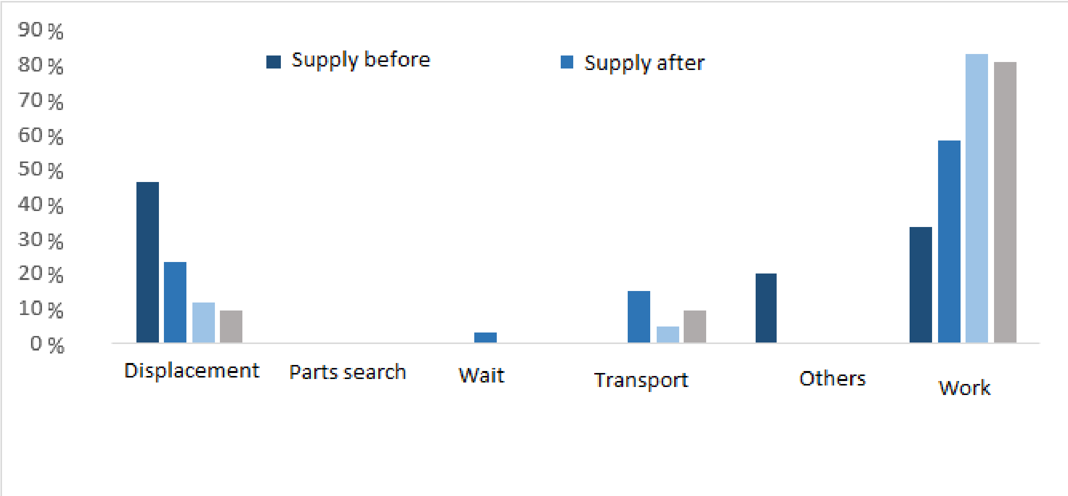

Figure 7. Production Value Added Analysis.

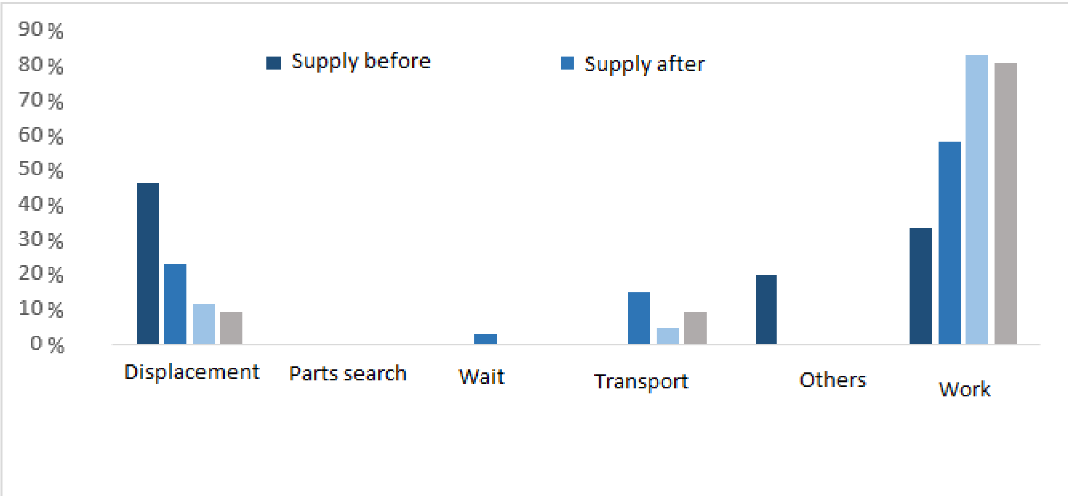

Figure 8. Logistic Value Added Analysis.

As shown in Figure 7, travel time, search for parts and transport were reduced after the implementation of SLFAM, increasing workers' performance. Those times that do not appear had a result equal to 0%, as can be seen in Tables 10 (production) and 11 (logistics), which detail the percentages of time for activities and value-added analysis.

Table 10. Percentages of Value Added Production Analysis.

December/2020 x may/2021	**T01 Before (%)**	**T01 After (%)**	**T02 Before (%)**	**T02 After (%)**	**T04 Before (%)**	**T04 After (%)**
Displacement	23.30	12	20	10	25	18.30
Parts search	3.30	0	16	0	5	5
Wait	42.50	30	0	0	1.60	0
Transport	10	1.70	0	3.30	0	0
Others (Toll, offal)	0	0	2	20.30	0	3.40
Adding value	33.30	57	62	67	68	78.30

Table 11. Percentages of Value Added Logistics Analysis.

	Supply before (%)	**Supply after (%)**	***Picking* HR R1 After (%)**	***Picking* HR R2 After (%)**
Displacement	46.60	23.30	11.70	9.50
Parts search	0	0	0	0
Wait	0	3	0	0
Transport	0	15	5	9.50
Others (Toll, offal)	20	0	0	0
Adding value	33.40	58.30	83.30	81.00

4. CONCLUSIONS

The present study had its objective reached since it was able to obtain good results for the future scenario with the implementation of the Flexible Logistics Manufacturing Support System (SLFAM) in an assembly line for truck cabins.

With the implementation of SLFAM, the production line supply model was reformulated with the creation of a parts supermarket, to enable mixed service (several brands and models), which resulted in an improvement in the supply flow, reduction of line waste, such as minimizing of the movement of operators to collect parts in the line side flow racks. Another contribution of this work was the development of the sushi box crab car used to supply the production line.

Improvements in supply flows were confirmed using FlexSim software. The main results obtained show that the System applies to the production demands of assembly lines and proves to be a simple implementation process, without the need for large investments.

5. REFERENCES

Bowersox, Donald J., Closs, David J. *Business Logistics: The Supply Chain Integration Process* (Logística empresarial: o processo de integração da cadeia de suprimento). Donald J. Bowersox, David J. Closs; tradução Equipe do Centro de Estudos em Logística, Adalberto Ferreira das Neves; coordenação da revisão técnica Paulo Fernando Fleury, Cesar Lavalle. 1. ed. - 9. reimpr. - São Paulo: Atlas, 2010.

Caccalano, Luiz; Da Cunha, Claudio. *Vehicle routing for the supply of production lines* (Roteirização de veículos para o abastecimento de linhas de produção). São Carlos: Gestão e Produção, 2015.

Donato, V; Passos, F. U. *Proposal and application of a method, based on the context of least resistance transport lines, to qualify logistic distribution chains as a green chain* (Proposta e aplicação de um método, baseado no contexto das linhas de transporte de menor resistência, para qualificar cadeias logísticas de distribuição como uma cadeia verde). RECC – Revista Eletrônica Científica do CRA-PR, v. 2, n. 2, p. 47-61, Paraná, 2014.

Machado, André. *Flexibility in manufacturing systems: an exploratory study* (Flexibilidade em sistemas de manufatura: um estudo exploratório). Bauru: XI SIMPEP, 2004.

Vieira, C. S.; Donato, V. *Flexible Manufacturing Support System: A Proposal for the Automotive Industry* (Sistema Flexível de Apoio à Manufatura: Uma Proposta para a Indústria Automobilística) p. 149-156. In: Anais do XXVIII Simpósio Internacional de Engenharia Automotiva. São Paulo: Blucher, 2021. ISSN 2357-7592, DOI 10.5151/SIMEA 2021-PAP35.

6. RESPONSIBILITY NOTICE

The authors Carolina Sacramento Vieira, Maira Silva Andrade, and Vitório Donato are the only ones responsible for the printed material included in this paper.