View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Repositório Científico do Instituto Politécnico do Porto

Available online at www.sciencedirect.com
ScienceDirect
Procedia Manufacturing 38 (2019) 965–974
Procedia MANUFACTURING
www.elsevier.com/locate/procedia

29th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2019), June 24-28, 2019, Limerick, Ireland.

Improving In-Plant Logistics Flow by Physical and Digital Pathways

T. Tellini, F. J. G. Silva*, T. Pereira, L. Morgado, R. D. S. G. Campilho, L. P. Ferreira

ISEP – School of Engineering, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 431, Porto 4200-072, Portugal

Abstract

The automotive industry is constantly using continuous improvement to leverage its growth and sustainability. The improvement of the intralogistics of component companies for the automotive industry is based on the same principles. The Milk-Run System (MRS) allows the inbound transportation of the raw materials containers to the production lines, as well as the return of finished product containers. Thus, it is important to improve the performance of existing vehicle routing system, according to customer demand orders and the assignment of the production line. The present study identified and examined the existing constraints and proposes the improvements to increase the performance of the existing inbound milk-run system. The system capacity and the routing have been redefined as well as the information need to an efficient management system. Since the production is not standardized, the software was developed to assist the management of the milk-run system. Its implementation showed that with one vehicle and four wagons all the production lines are properly assisted. The contributions of this study were the reduction in 15% of the milk-run lap time, the decrease of the number of milk-run laps, allowing the increase of the number of lines assisted by this intralogistics system, permitting the assignment of new tasks to the MRS operator during the idle time. Moreover, unnecessary laps, unwanted stops and exchange of packaging were eliminated.

© 2019 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)
Peer-review under responsibility of the scientific committee of the Flexible Automation and Intelligent Manufacturing 2019 (FAIM 2019)

Keywords: Milk-run system; Optimization; In-Plant Logistics; Intralogistics; Continuous improvement; Industrial management; Automotive industry.

* Corresponding author. Tel.: +351 228340500; fax: +351 228321159.
E-mail address: fgs@isep.ipp.pt

2351-9789 © 2019 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)
Peer-review under responsibility of the scientific committee of the Flexible Automation and Intelligent Manufacturing 2019 (FAIM 2019)
10.1016/j.promfg.2020.01.180

1. Introduction

The automotive sector is one of the most important sectors for the world economy. The industry that has faced many obstacles faces a ceaseless pursuit of quality (relying on internationally certified standards), application of new technologies, innovations and customization that attract more customers to brands and become loyal to them. One of the requirements to optimize the operation of large companies in this sector is to make use of continuous improvement methodologies and lean tools, such as the milk-run or *mizusumashi* system. Milk-run follows a programmed route for inventory replenishment, being responsible for supplying raw material, packaging and collect finished product. This system makes the intralogistics of a manufacturing company more efficient and effective through the integration of the flow of materials and information.

This work was developed based on an industrial environment of a worldwide automotive components manufacturer, in which production is focused specifically on air conditioning and power steering pipes. Its main objective was to analyze and improve the performance of the existing inbound physical logistics process. This need is based on the increased production capacity and production of new products. Thus, new assembling production lines were implemented and the layout was redesigned and adapted. Then, the MRS presents some drawbacks. The proposal was to analyze the current MRS and implement optimization actions. This meant to analyze the existing vehicle routings, the dimension of the MRS in terms of a number of wagons, by eliminating unnecessary laps or empty wagons, unnecessary packaging movements, unwanted stops, and improved/reduced communication between operators. From the identification of these points, and the reality of the company, it was suggested to develop a digital system to transmit in real time the information related to the need of a production line to the packaging preparer in the finished product warehouse. The assumptions underlying the implementation of the initial milk-run were as follows: the company does not have a standard production pace, each line produces different references of the finished product and the products present different cycle times. However, based on these assumptions, a fixed route was established to be followed by the MRS. Regarding the increase in the production, the MRS installed was not enough to cover all needs, triggering this study. After the implementation of the improvements achieves by this work, it was concluded that a train would be enough to supply all existing lines in the company, doing laps with thirty minutes duration. The communication between the production lines and the finished product warehouse was optimized, avoiding failures in the delivery time, as well as the type of packaging to be delivered. In addition, it promoted a better use of the workforce of the milk-run operator.

The article's structure is divided into five sections: the first corresponds to this Introduction; Section 2 consists of a literature review based on the theoretical research regarding the article's issues; Section 3 refers to the methodology used in this study; Section 4 describes the work develop according to the adopted methodology and, finally, Section 5 contains the discussion of the general results and conclusions of this work.

2. Literature Review

Over the years, there has been population growth and the development of cities, which has made the need for transport and freight increase even more [1]. From the initial idea, later, in century XIX, would arise the first car, conferring another freedom to the man. Ford created a new production line concept, which enabled the mass production of standardized products, favouring a significant increase in demand [2]. In this way, it was possible to reduce the sale value of the car and make it more accessible to a larger part of the population [3]. Since then, the production of cars and the modernization of production systems has not stopped growing, adopting the most advanced technologies and science knowledge. Facilitating purchase, and with the positive evolution of the economy, the production of cars has been growing year after year since 2010.

The strong development of the automotive components industry is based on three main pillars: competitiveness, quality of the final product and deadline for response to orders received [4]. Always based on new technologies and in the market, the company ends up standing out and increasing its competitiveness among stakeholders [5]. Therefore, the creation of a new industrial model, the so-called Industry 4.0, has brought benefits to companies and their customers, establishing new business opportunities, such as cost reduction, more sophisticated communication systems and customized customer requests served in a more agile way [6]. In this industry, it becomes possible to produce highly customized products, not necessarily mass-produced, efficiently and cost-effectively, reducing the failure rate and improving quality control without losing quality and achieving cost savings [7-9].

These days, business needs to be properly maintained, performing processes of continuous improvement, to the elimination of waste and inducing the evolution of the company [10]. After optimization of mass production, Lean production was employed [11], lead times were reduced, always seeking to have better quality and with a low cost, through the improvement of the productive flow, through the elimination of wastes [12]. The engineer Taiichi Ohno identified seven wastes in this type of production, they are: handling, repair, processing, waiting, stock, transportation and overproduction [13]. Through Lean production, Taiichi Ohno identified that such waste did not add value to the final product and needed to be immediately eliminated from the production line [14]. Transport is considered one of the seven wastes since it does not add value to the final product [15]. In the industrial environment, eliminating all transport is an impossible task [16]. Therefore, for the good functioning of a company, it is important to organize what and when it will be transported so that there are no failures or interruptions in production [17]. Once the need for each component has been calculated, it is necessary to elaborate on how the packages will be transported. Through the MRS, the quantity of inventory to be transported is higher, if compared to a stacker. Thus, it is possible to minimize part of the waste transportation and improve it [18].

In any industry, the supply and collection of the finished product can be carried out manually or through an automated system [19]. The automated system almost always requires high investments and has low flexibility, since both the supply and the collection are performed by automatic vehicles or equipment, often in a rigid way [20]. In the manual system, there is a resource called *mizusumashi* or an inbound MRS tool. The use of this feature is beneficial since it presents a higher versatility [21]. The MRS is a system that requires only one vehicle, a set (variable) of wagons, usually between one and five, concerning the cargo to be transported, raw materials demand/ finished product output, run time, and one operator for its operation. The distribution done in this way ensures that the product arrives on time and in the desired quantity [22]. This tool, especially in the automotive sector, is more interesting than the use of a forklift truck, because, when it connects several wagons, the MRS in a single lap following the route can supply and lift packages from more than one line [23], optimizing logistics, since they are generally bulky materials in containers [24]. A considerable gain for the company is that milk-run makes the process more organized [25].

3. Problem Characterization and Methodology

The approach performed in this work is the usual regarding any case study. Hence, it was very important to understand the environment where the work was developed as well as the corresponding goals and constraints. Furthermore, it was very important to collect literature about the current issue to find the best practices, methods and tools applied in a similar context. The development of the work was divided into five steps: data collection and processing, decision making, improvement implementation, monitoring and future proposals, which are described in Table 1.

3.1. The Company

The company where this study was developed produces twenty-seven production lines using six production lines assigned to produce systems for power steering and twenty-one lines for air conditioning (Fig. 1), both for motor vehicles. There are lines where production is continuous, and there are lines where the process happens five days a week. All lines work in shifts of 8 hours daily. Each of the twenty-seven production lines makes different references to the same type of product, according to the specifications of each customer. There are lines in which production reaches almost thirty references, where there is approximately ten references FTL type (*Flux Tiré Lissé*), i.e., they are often produced, others are called MTO (Make To Order), or are only produced according to the customer's request.

3.2. The Production

Each line knows the reference and the quantity to be produced because the company works with a digital system integrated between production and logistics, called FTL Digital. This digital tool provides quick and efficient information about:

- The day and time when the production order enters in the system;
- The product reference to be produced;
- The planned quantity to be produced, according to the customer's need;
- The time required for production;
- The date when the production batch needs to be started to produce;
- If there was any stop during the production process;
- The number of operators assigned to the line in charge;
- The number of products that are missing to complete the order.

Table 1. Practical activities developed during each work stage

Data Collection and Processing	• Data were obtained as: cycle time, seasonality of production, number of kanban cartons, number of parts per package and type of packaging related to each reference produced, in all production lines.
Decision Making	• The feasible proposal to implement was the creation of software able to transmit the information to the milk-run, through which lines he/she should pass and the respective packages that he/she needs to supply.
Improvement Implementation	• Due to the difficulties found in elaboration of the proposal, certain rules were added, for example, which lines should be met initially and which is the minimum time required for a line to be considered as urgent.
Monitoring	• The results of the proposed improvements were evaluated by means of a monitoring of the milk-run operator. The previous and current scenarios were compared to verify which parameters were improved and which ones could be optimized.
Future Proposals	• In the future, new production lines will be added to the current production, changing the layout of the company. In this way, the rules to be added to the current signaling panel have been established, allowing further development.

Fig. 1. Examples of finished products of power steering and air conditioning

Lines are daily informed about the assigned production through the system and there is no sequencing of production. In this way, the lines do not present a productive pattern, and they produce exactly according to the need and in the order in which the references appear in the system. This order may not be respected when there is a lack of raw material to continue the production batch, or when there is a need to produce an order regarding some customer's emergency. After production, to allocate the final products, each customer provides a specific type of packaging, which can be a bac or a container (Fig. 2).

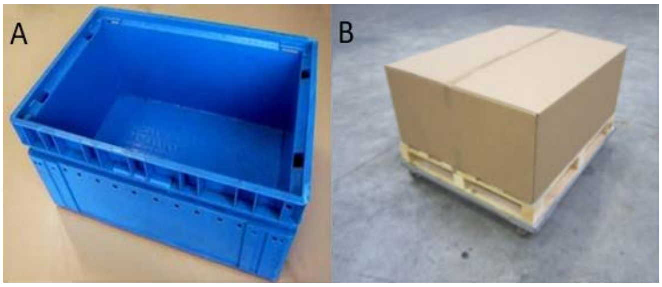

Fig. 2. Packaging made available to accommodate final products: (a) bac and (b) container

3.3. The packages

The volumes of the final packages are: 300 x 400 x 600 [mm] for the bacs and 900 x 1000 x 1200 [mm] for the containers. The quantity of the finished product within each package is pointed out by the customer. In the bacs, the quantity varies from 15 to 40 units per pack. In the containers, the minimum quantity is 35 and the maximum is 120 units. Therefore, for the proper functioning of the MRS in the company under study, it was necessary to respect some rules, such as:

- The milk-run will follow just one circuit, providing the supply of raw materials and collecting the finished products;
- Permission to collect any complete package of finished products only after it has been declared to the system (by the responsible monitor);
- A maximum of four containers and four stands carrying four bacs each (totaling sixteen bacs) was established.

3.4. 3.4 Difficulties found during the operation

The difficulties found during the operation of the MRS were:

- Lack of readiness of the monitor to read the labels of the packages;
- Change of a batch in production and, consequently, of the package needed;
- The operators need to go to productive lines at all time, to request information or to wait for the monitor to declare a package;
- An excess of packaging in the lines, or in improper places, making circulation difficult, either of people and material;
- Daily, the milk-run travels empty several times. This is a waste of labour and a depreciation of the equipment;
- Sometimes the raw material convoy is ahead of the convoy of the finished product, resulting in a return almost three times slower.

The time interval between the average weighted, the minimum and maximum cycle time, on approximately 90% of the production line, is too long (Fig. 3).

3.5. Tool development

From the difficulties found, and from a study of the MRS, an application tool was elaborated in which the information that the MRS operator and the milk-run preparer in the TPA (Truck Preparation Area) need, are sent for both, by installing a board table located in the TPA with the specification for each of the lines and the corresponding locations of the current production, and the subsequent batch. In addition to this information, there are proper spaces for packaging containers and trolleys. The operation was based on the following information:

- the type of packaging being used;
- the required quantity of packaging for the batch being set up;
- the type of packaging used in the subsequent batch;
- and the required quantity of packages from the next batch.

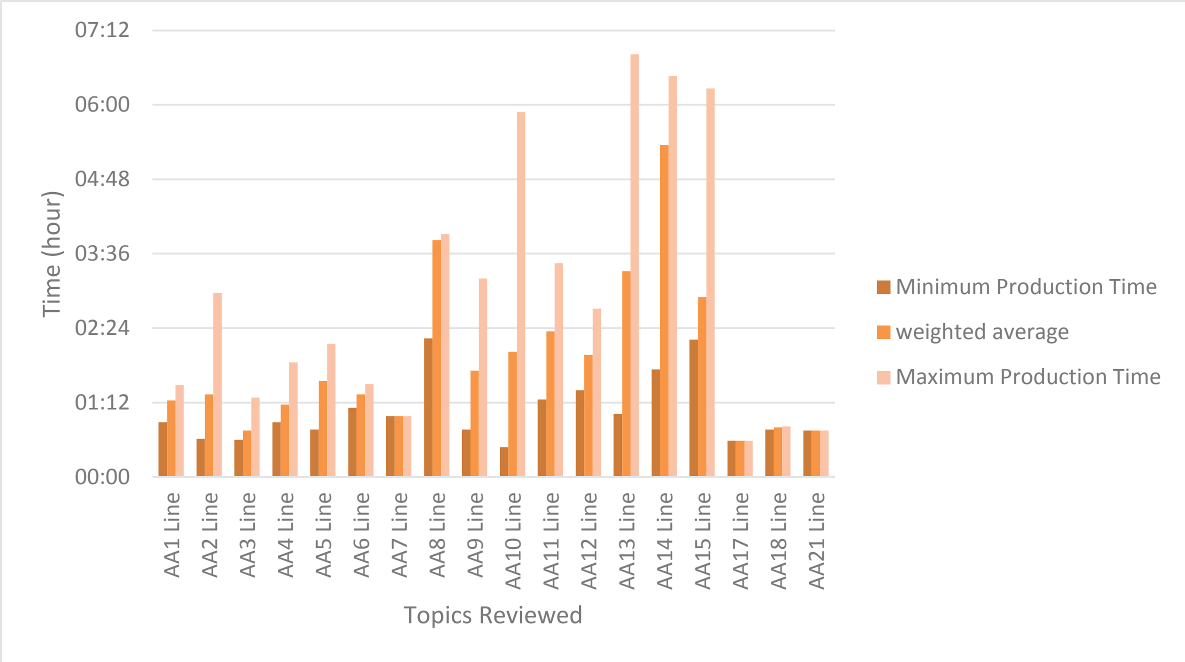

Fig. 3. Minimum, maximum and average weighted cycle time of all production lines

As described in Fig. 4, if a batch of 10 cartons is considered, the system considers essentially 8 cartons, because there is one carton that is being loaded on the line at the moment, and there is another carton that is already ready to be used, soon that the former be complete. Thus, using the Kanban system, the total number of cartons assigned to the batch also includes cartons in use or ready for use on the production line.

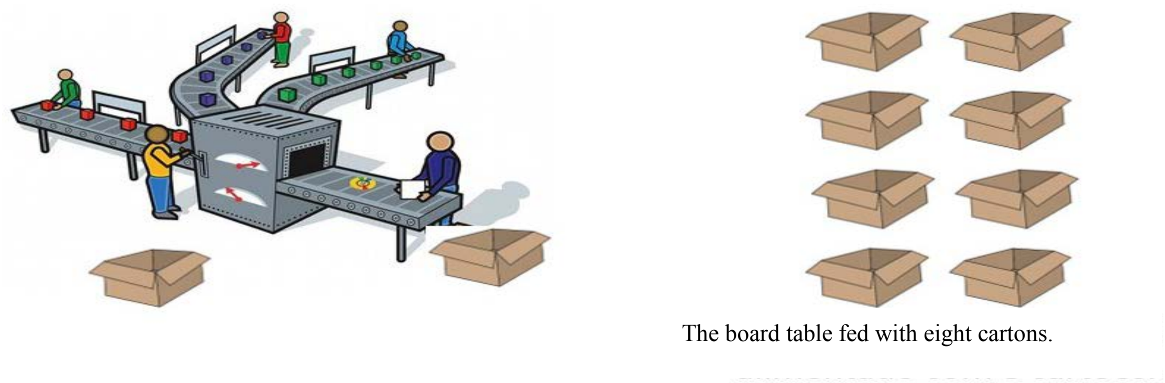

Fig. 4. Scheme representing the initial cartons supply

Upon knowing that a package is ready and declared, the information is sent to the TPA and a carton of the said production line is placed on the left side of the frame, according to its type of packaging. When the eight spaces are complete, the MRS departs from TPA with its maximum capacity of empty containers. At this moment, the system is already aware of which lines should be visited to deliver them and, consequently, to collect declared packages. As the information came to the board table, the TPA operator will use the time spent by the MRS operator during a lap to prepare the packages that will be taken in the next lap.

4. Results and Discussion

Based on the implementation of the framework previously described, many benefits have been found, such as the optimization of the working time of the MRS operator, allowing that this operator can assume more tasks, such as bringing packages whose are larger than the capacity of the milk-run to the lines. A greater control about the time spent in each lap was achieved, approximately thirteen minutes, thus eliminating wasted time to take unnecessary paths and unwanted stops. After the milk-run time optimization (approximately ten minutes reduction), the operator will have time to deal with unscheduled events while continuing to perform their main tasks.

After the improvement implementation, the next step was to implement the automation of the MRS management process, so that it did not need two people focused on this process. Thus, a decision support application was developed to integrate the information provided by each production line to the MRS management system, in which a single person could manage the information concerning the use of packaging and the number of operators and monitors involved in the project. Through this system, it is possible to provide a time for the TPA preparer to organize the packages to be carried in the next MRS lap. Figure 5 shows the sequential order to enter the information into the digital system.

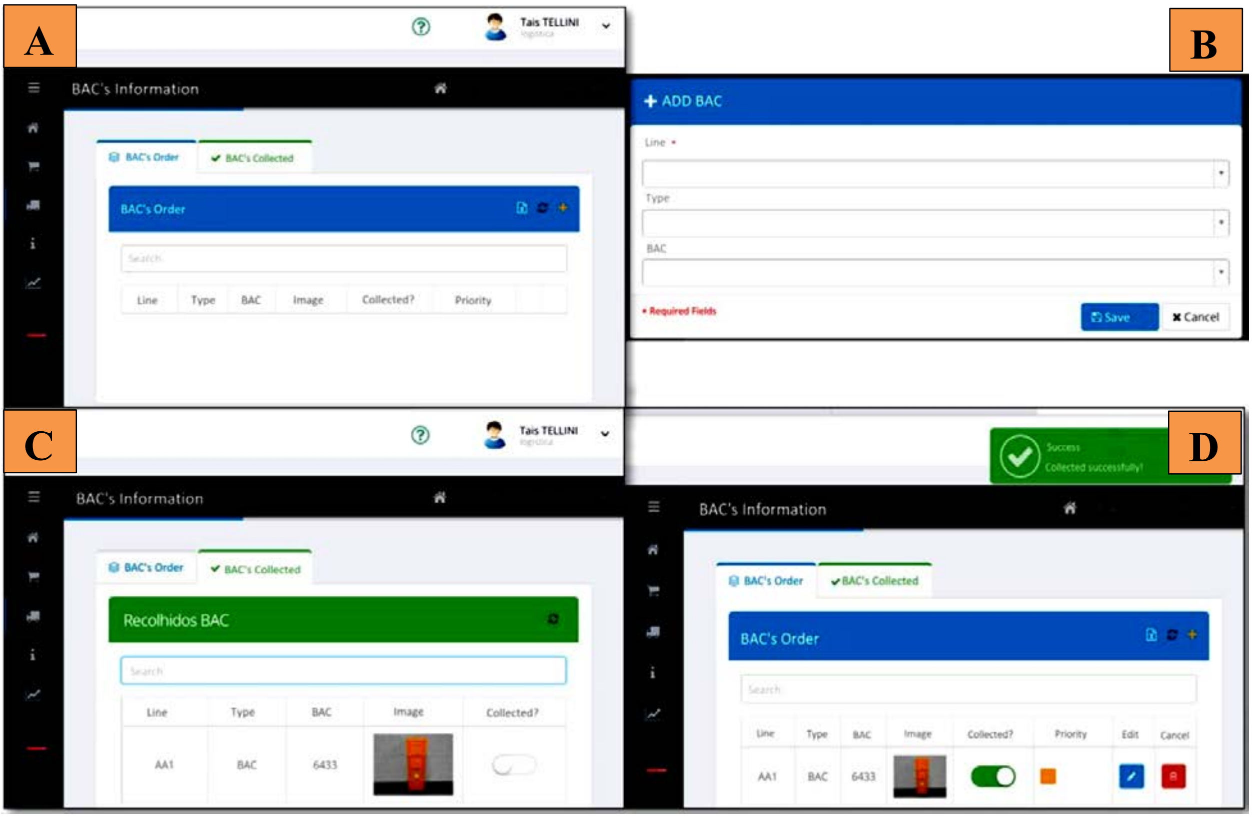

Fig. 5. Sequential order to enter information: main page (A), add the line, the type of packaging and its respective reference (B), page after the information input (C) and pass the information to the TPA (D)

Regarding the lines that presented a shorter cycle time and the need to be answered faster, the system was provided with an icon named priority, which, when it is highlighted, a specified line took precedence over all others. An example of this situation is shown in Fig. 6.

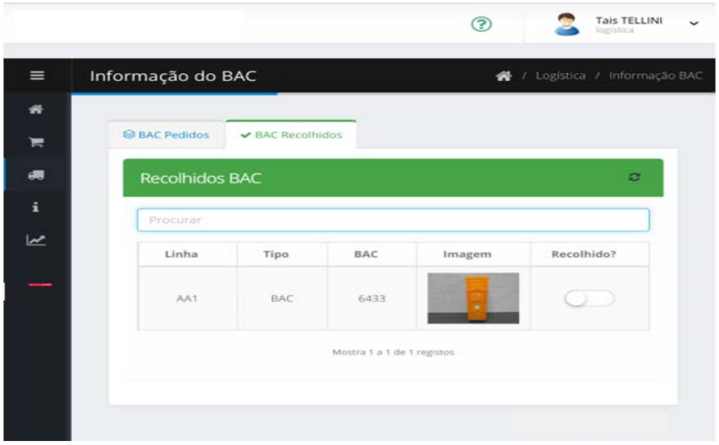

Fig. 6. List of lines and packaging on the TPA screen

The TPA preparer, upon receiving this information, arranges the packages in the order they appear on the screen so that when the milk-run operator arrives at the TPA, they can unload the packages of the finished product and load the raw material into according to the information that is available on the screen. When completing all wagons of the train, or when satisfying any priority need of a production line, the milk-run leaves the TPA. Otherwise, remain in the TPA until all eight milk-run spaces are full. In this way, the working time of both the milk-run operator and the TPA preparer is optimized, as well as the inventory close to the lines is reduced, increasing the available space in the lines, since only the packaging in use remains in the line and the one that would be used next.

In order to validate the MRS improvements, a case study has been drawn. The case study will be tested under three different scenarios, regarding the different stages of this project. The first is the way the MRS was used before this study, the second is considered with the optimization done manually, with the implementation of the project with cartons (Kanban methodology), and finally, the last scenario is considering the implementation of the semi-automated project with the implemented application tool. It was necessary to compare the average time between the three functions of the MRS operator (Fig. 7). The three functions average time represents:

- the time needed for the milk-run operator take an entire lap, supplying/collecting the packages of the lines;
- period that the operator takes to set up, i.e., to empty the train and to supply it with empty packages, and,
- the time when the milk-run is stopped because there are times when all the lines are producing simultaneously and consequently there is nothing to be collected or there are few packages with a finished product that needs to be collected.

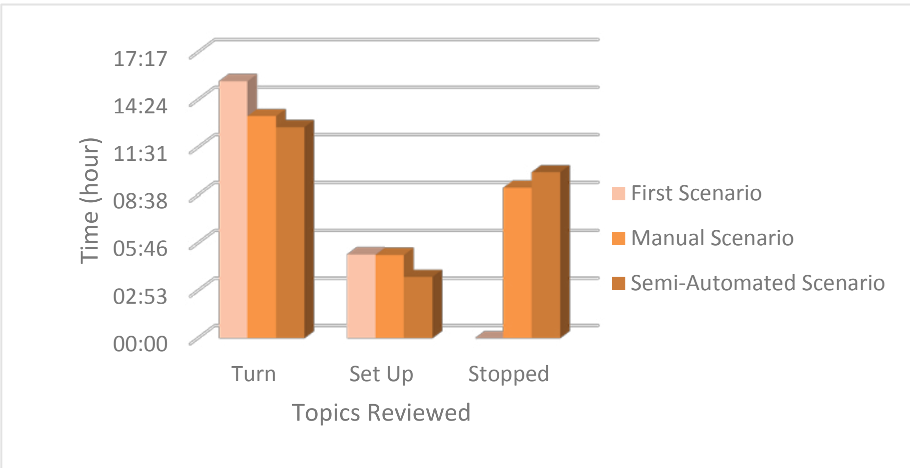

Fig. 7. Comparative chart between the three scenarios evaluated, relating the time to the functions of the MRS operator

5. Conclusions

Initially, in order to optimize the system, it was necessary to analyze the operation of the milk-run, the existing rules for its operation and the way those involved in the supply and collection of finished product packaging worked. After this analysis, it was calculated the minimum, maximum and weighted average cycle time of all production lines, through all the references that make up a line.

After this stage, it was observed that the only way to optimize the milk-run operation, while keeping the lines at the correct time, is that the information of the moment the package is declared, as well as the model of the packaging to be used, was transmitted from the lines to the TPA preparer and, consequently, to the MRS operator. In this way, the results were really positive, in order to find small gaps that had not been observed until then, such as:

- the wasted time spent by the milk-run operator;
- needless to supply excess production lines.

After the first stage has been successfully implemented, the team moved on to the next stage, which was to create a semi-automatic system with the same goal. The same success was once again recognized and highlighted. The difficulties found were the same in both scenarios. It took some time for those involved to adapt to the new way of performing their duties. For the company the contributions of this study were extremely positive because it was possible to optimize the MRS laps, allowing new production lines to be added to the lines already supplied by the milk-run, to assign new functions to the MRS operator during the idle time, suppression of unnecessary laps, unwanted stops and exchange of packaging. Finally, it was observed that the lack of standardization in the production and the type of packaging to be used prevented a better performance of the milk-run, avoiding excellent results. Thus, a study based on mathematical models such as the Vehicle Routing Problem (VRP) that is used for the optimization of the MRS tool needs to be tested in the near future.

References

[1] P. Négyesi, How The Motor Museum Saw The Automobile: Curating The Automobile As Commodity, As Design And As Social History In Germany And Austria In The 20th Century – From National Identify To Mobility, PhD Thesis, University of Leicester, Leicester, 2018.

[2] A. J. A. Magalhães, F. J. G. Silva, R. D. S. G. Campilho, A novel concept of bent wires sorting operation between workstations in the production of automotive parts, Journal of the Brazilian Society of Mechanical Sciences and Engineering 41 (2019) 25.

[3] E. Mason, Price and Production Policies of Large-Scale Enterprise, Papers and Proceedings of the Fifty-First Annual Meeting of the American Economic Association, 29(1) (1939) 61-74.

[4] W. F. S. Araújo, F. J. G. Silva, R. D. S. G. Campilho, J. A. Matos, Manufacturing cushions and suspension mats for vehicle seats: a novel cell concept, International Journal of Advanced Manufacturing Technology 90 (2017) 1539–1545.

[5] R. J. S. Costa, F. J. G. Silva, R. D. S. G. Campilho, A novel concept of agile assembly machine for sets applied in the automotive industry, The International Journal of Advanced Manufacturing Technology 91 (2017) 4043-4054.

[6] M. Barbosa, F. J. G. Silva, C. Pimentel, R. M. Gouveia, A novel concept of CNC machining center automatic feeder, Procedia Manufacturing 17 (2018) 952-959.

[7] M. J. R. Costa, R.M. Gouveia, F. J. G. Silva, R. D. S. G. Campilho, How to solve quality problems by advanced fully-automated manufacturing systems. The International Journal of Advanced Manufacturing Technology 94 (2018) 3041–3063.

[8] Erdogan, M., Ozkan, B., Karasan, A., Kaya, I. "Selecting the Best Strategy for Industry 4.0 Applications with a Case Study", Industrial Engineering in the Industry 4.0 Era, Springer, pp. 109-119, 2018. ISBN: 978-3-319-71224-6.

[9] T. Costa, F. J. G. Silva, L. P. Ferreira, Improve the extrusion process in tire production using Six-Sigma methodology, Procedia Manufacturing 13 (2017) 1104–1111.

[10] C. Rosa, F. J. G. Silva, L. P. Ferreira, Improving the quality and productivity of steel wire-rope assembly lines for the automotive industry, Procedia Manufacturing 11 (2017) 1035–1042.

[11] C. Rosa, F. J. G. Silva, L. P. Ferreira, T. Pereira, R. M. Gouveia, Establishing standard methodologies to improve the production rate of assembly-lines used for low added-value products, Procedia Manufacturing 17 (2018) 555-562.

[12] E. Sousa, F. J. G. Silva, L. P. Ferreira, M. T. Pereira, R. Gouveia, R. P. Silva, Applying SMED methodology in cork stopper production, Procedia Manufacturing 17 (2018) 611-622.

[13] P. Neves, F. J. G. Silva, L. P. Ferreira, T. Pereira, A. Gouveia, C. Pimentel, Implementing lean tools in the manufacturing processes of trimmings products, Procedia Manufacturing 17 (2018) 696-704.

[14] D. Correia, F. J. G Silva, R. M. Gouveia, T. Pereira, L- P. Ferreira, Improving manual assembly lines devoted to complex electronic devices by applying Lean tools, Procedia Manufacturing 17 (2018) 663-671.

[15] B. Villarreal, D. Garcia, I. Rosas, Eliminating Transportation Waste in Food Distribution: A Case Study, Transportation Journal 48(4) (2009) 72-79.

[16] ISO 9001:2015 Quality management systems. Requirements, International Organization for Standardization: Geneva, Switzerland, 2016.
[17] I. Antoniolli, P. Guariente, T. Pereira, L. P. Ferreira, F. J. G. Silva, Standardization and optimization of an automotive components production line, Procedia Manufacturing 13 (2017) 1120–1127.
[18] Â. Barreiros, F. Cavalheiro, J. Castro, M. Pinto, O Sistema Mizusumashi, Lean Supply Chain Management, Comunidade Lean Thinking, 2015. [Online]. Accessed on 15th of January 2019. URL: https://pt.slideshare.net/Comunidade_Lean_Thinking/mizusumashi-clt-2015.
[19] E. Klent, S. Galka, W. A. Gunthner, Operating strategies for In-Plant milk- run systems, IFAC Paper OnLine 48(3) (2015) 1882-1887.
[20] J. Schuhmacher, W. Baumung, V. Hummel, An intelligent bin system for decentrally controlled intralogistics systems in context of Industrie 4.0, Procedia Manufacturing 9 (2017) 135–142.
[21] J. Nomura, S. Takakuwa, Optimization of a number of containers for assembly lines: the fixed-course pick-up system, International Journal of Simulation Modelling 5(4) (2006) 155-166.
[22] A. Urru, M. Bonini, W. Echelmeyer, Planning and dimensioning of a milk-run transportation system considering the actual line consumption, IFAC PapersOnLine 51(8) (2018) 404-409.
[23] H. Mei, Y. Jingshuai, M. Teng, L. Xiuli, W. Ting, The modelling of milk-run vehicle routing problem based on improved C-W algorithm that joined time window, Transportation Research Procedia 25 (2017) 716-728.
[24] T. Nemoto, K. Hayashi, M. Hashimoto, Milk-run logistics by Japanese automobile manufacturers in Thailand, Procedia Social and Behavioral Sciences 2 (2010) 5980-5989.
[25] N. Arvidsson, The milk run revisited: A load factor paradox with economic and environmental implications for urban freight transport, Transportation Research Part A 51 (2013) 56-62.