Improvement in Planning and Resource Management for an Automotive Company's Parts Feeding System

Teresa Pereira
Institute of Mechanical Engineering and Industrial Management (INEGI), Porto School of Engineering, Polytechnic of Porto
Rua Dr. António Bernardino de Almeida, 431, 4200-072, Porto, Portugal
mtp@isep.ipp.pt

Mariana Xavier
Porto School of Engineering, ISEP/P.PORTO
Rua Dr. António Bernardino de Almeida, 431, 4200-072, Porto, Portugal
mariana.xavier@live.com.pt

Fernanda A. Ferreira
School of Hospitality and Tourism of Polytechnic Institute of Porto,
Applied Management Research Unit (UNIAG),
Rua D. Sancho I, 981 4480-876, Vila do Conde, Portugal
faf@esht.ipp.pt

Marisa Oliveira
Porto School of Engineering, ISEP/P.PORTO
Rua Dr. António Bernardino de Almeida, 431, 4200-072, Porto, Portugal
mjo@isep.ipp.pt

Abstract

The increasing sophistication of the automotive market and the constant change in customer requirements increases companies' concern to ensure efficient internal logistic flows in line with Just-In-Time philosophy and Lean principles, to deal with wastes and variability. Variability arises from the growing differentiation of products, from the adoption of multi and mixed model assembly lines, and from the uncertainty in customer demand resulting from the worldwide outbreak of COVID-19. Considering the automotive supplier company as research subject, several problems were found to be compromising the efficiency of one of its in-plant parts' feeding systems, the most critical problem being the lack of planning and management of resources (human and material) needed to perform the logistic service. Through Action-Research methodology stages, the actions taken culminated in the development of a simulation and decision-support tool for the component supply system resource management and efficiency improvement. The simulations made revealed reliable and adjusted results of workload and workforce to face the variations in customer demand and the existing product mix. After the tool creation, resource planning and balancing was no longer based on managers experience and empirical knowledge only but based on scientific knowledge: concise and reliable data from information systems, measurements, study of times, and literature review on in-plant milk run systems, lean, just-in-time and continuous improvement techniques.

Keywords
Parts feeding systems, efficiency, workforce, workload, variability

1. Introduction

The automotive industry plays an important role in manufacturing sector and makes up a large share in country's economy. Whether in production, sales, and consumption stages, it is an important source of revenue and an employer generator (Belhadi et al., 2021; Brar & Saini, 2011). The competition in this industry has intensified such that auto manufacturers had to improve their means to manage and minimize its wastes, production times and costs (Brar & Saini, 2011; Macduffie et al., 1996). To manage costs, and align with Lean and Continuous Improvement techniques, either internal or external part's supply to the point of use on the assembly line must be assured by adopting or reinforcing just-in-time (JIT) philosophy in the organizations and eliminating *muda* (wasted resources in non-value-adding work), muri (people overburden) or mura (workload variation) (Fortuny-Santos et al., 2020; Patel et al., 2017; Silva et al., 2021).

In the automotive sector, companies need to offer a wide range of different products (Faccio, Gamberi, Persona, et al., 2013a). According to Clark & Fujimoto (1991) this increase on product variety arises from such factors as changes in energy prices and trade structures, internationalization of the market, and the growing sophistication of customers. Regarding production systems, the consequence is the adoption of multi or mixed-model assembly line configurations in organizations where the workstations continue to be dedicated to a product family but are also able to produce several different models (Battini et al., 2009; Emde & Boysen, 2012a).

Another factor influencing production systems is the recent outbreak of a novel coronavirus, named COVID-19 by the World Health Organization, which has pushed the global economy and humanity into a disaster, with the automotive sector being one of the most affected industries (Nayak et al., 2021). Its propagation alongside successive lockdowns created immense uncertainties in demands and disruptions in global supply chains (Belhadi et al., 2021).
In this context, according to Battini et al. (2009) and Emde & Boysen (2012a), one significant challenge is to establish a reliable, flexible, and efficient parts feeding system to the assembly stations since on the one hand component shortages lead to line stops and assembly station idleness, and on the other hand enlarged stocks near the lines increase inventory costs and obstruct the assembly process in the plant (Emde & Boysen, 2012b).

In order to achieve efficiency whilst following the JIT approach, a growing number of manufacturers are therefore adopting Total Flow Management (TFM) tools that aim to achieve smooth flow of materials and information throughout the processes inside supply chains such as Supermarkets, In-plant milk run and *Kanban* to improve efficiency (Alnahhal et al., 2014; Faccio, Gamberi, Persona, et al., 2013a). Being decentralized logistics areas, supermarkets allow the delivery of frequent small batches, producing inventory reductions near the lines and avoiding long distance trips to production systems. The connection between storage areas and workstations is made through the in-plan milk run, operated by a *Mizusumashi* handler, who drives a tow-train (vehicle towing small wagons) to deliver the required components to consumption points and to collect empty handling units to be refilled for the next trip in the inventory position (Droste & Deuse, 2011; Gamberi et al., 2008; Gil Vilda et al., 2020).

The automotive company under research is currently raising its concern on continuous improvement aiming to reduce inefficiencies within the internal logistic processes. Some actions were already concluded in this regard such as the elimination of the forklifts in the welding department of the company and the implementation of an in-plant milk run system to perform the parts supply service to the assembly lines. This action was followed by the creation of a supermarket of components and by the introduction of the *kanban* concept. Being aware that a good system of milk runs can significantly increase the efficiency of the overall production logistics, the company wants to take full advantage of the investment made.

The existing setting, characterized by great variability, has called for a need to understand whether the existing parts feeding system to the welding department of the company is now operating in an efficient way. When analyzing the internal logistic flows of the welding area, several problems were identified that could compromise the performance of the system. More importantly, a methodology for resource management, either human or material, was identified as an imperative to efficiently conduct and adjust the internal supply of components to the different production sequences deriving from demand variations.

1.1 Objectives

Considering the presented background, the general objective of this work was defined: To improve the efficiency and performance of the parts feeding system to the welding department of an automotive company. In order to achieve the general objective, the following specific objective was established:

- Develop a resource management system that allows for the planning and balancing the workload and workforce needed in the performance of the welding parts feeding system considering different production scenarios in the company.

2. Literature Review

2.1 Problem of Materials Supply to Assembly Lines

According to Zhu et al. (2008), traditional mass production systems were based on assembly lines dedicated to one product or model being produced in large quantities. These same authors mention that today's marketplace does not works like that anymore. Nowadays, customers demand high product variety and short lead times, thus companies that understand these new circumstances and respond to them quickly, with appropriate products, can gain a significant competitive advantage (Macduffie et al., 1996). Zhu et al. (2008) believe that, as a result of this paradigm, assembly lines must be designed to be responsive to customer needs while at the same time accomplish mass production quality and productivity. Baudin (2004), Becker and Scholl (2006) and Mohammadi-Khashouie (2003), in their research, identified and explained three types of assembly lines designs that exist in industries:

- Single-Model: Assembly lines that have been only used in a single type or model production. In these lines, there are large quantities of products which have the same physical design. Here, operators execute the same amount of work when the parts arrive at the workstation.

- Multi-Model: An assembly line where different products are manufactured in batches. These lines are often used when there are significant differences in the production process between the products. This requires a rearrangement of the workstation equipment (considerable setups).

- Mixed-Model: Assembly lines where produced items keep changing from model to model continuously, that is, more than one product or model is manufactured. The models at a mixed-model assembly line may differ from each other with respect to some physical attributes such that their production requires different tasks, times and/or precedence relations. However, the setup time is almost zero between models.

An example of growth of product variety is the automotive sector. This industry needs to offer a wide range of different products and to quickly respond to customer demands that change every day leading to the necessity of a daily variation in the production sequences. As a result, in these cases, the typical configuration of the production system is the Mixed and/or Multi-Model assembly lines (Faccio, Gamberi, Persona, et al., 2013b). These lines have an enormous hunger for a very diverse range of parts, making the organization of a well-run logistics network one of the most vital tasks to ensure that final assembly runs smoothly and efficiently (Emde & Boysen, 2012a). Within this context, Emde and Boysen (2012a) underline as a significant challenge, the feeding of parts to the productive stations in the assembly lines, once non-reliable and non-flexible parts supply can lead to components shortages and assembly station idleness, harming the correct internal logistic flow.

2.2 In-Plant Milk Run Decision Problems

Through the studies carried out by Alnahhal et al. (2014) it was possible to understand the great importance on studying the decision problems related to the adoption of in-plant milk run systems in organizations. According to the same author, the main decisions regarding in-plant milk run using tow-trains are: Routing and Scheduling problems; Frequency of routing; Loading problem; Determining the number of *kanbans* required in the system; the number of tow-trains; and the number of handling operators.

When designing the delivery routes of milk run using tow-trains, routing and schedule problems use to appear. The milk run vehicle routing can be seen as a special case of the Vehicle Routing Problem (Carić et al., 2008), which in turn is a generalization of the Traveling Salesman Problem, as referred by Gyulai et al. (2013), and aims to find the optimal set of routes for a fleet of vehicles delivering goods or services to various locations. There is large research on this theme, but only a few are devoted specifically to in-plant milk run traffic problems. Most of the research in the field is focused on methods to organize transport processes in order to minimize the fleet size, the distance traveled, or the space occupied by a distribution system (Bocewicz et al., 2019). According to Carić et al. (2008), this requires updating and revision of the routing policies used, or prior planning of congestion-free vehicle routes and schedules. In this way, Bocewicz et al. (2019) conducted a study to analyze the possibility of using declarative modeling methods in solutions that provide interactive decision support for prototyping in-plant milk run traffic systems.The implemented model in a constraint programming driven solver, aimed to determine the number of transport trips and their organization in time and space needed for timely delivery of material to specific loading/unloading points and was subjected to constraints imposed by an in-plant distribution network and environment.

Emde and Boysen (2012b) identified an obvious interdependency of both problems routing and scheduling in a way that the decision variable of the routing problem serves as an input to scheduling each train once it determines the subset of stations to be served per tow-train. On the other hand, only solving the respective scheduling problem can determine whether a specific subset of stations allows for a feasible delivery schedule given the limited train capacity. Thus, this author's paper introduces an exact solution procedure which solves both problems simultaneously in polynomial runtime. The same author showed that the variable periods for milk runs are optimal for reducing inventory costs and space occupied in the workstations. However, Bozer and Ciemnoczolowski, (2013) believe that, from the point of view of lean manufacturing, it is better to standardize the system by stabilizing and fixing periods, meaning to schedule the departs at constant time intervals, which the authors define as the in-plant milk run cycle time. Marchwinski states that "determining the delivery frequency is a balancing act" (as cited in Emde & Boysen, 2012b) however, specific circumstances might call for adjusting this parameter. Karkoszka and Korytkowski (2016) adds that lengthening the cycle duration leads to lower milk runner utilization, giving him more time to handle materials to other production areas.

During the research was found a very embracing paper from Faccio, Gamberi, Persona, et al. (2013) that comprises a big number of decisions. This paper presents a framework proposing an integrated approach both for long-term (static analytical model) and short-term (dynamic simulation) problems dealing with *Kanban* and Supermarket systems and with tow-train fleet sizing and management in a complex multiple mixed-model assembly system. This framework was divided into three main phases: a Static one applying an analytical simple but robust model to design and correlate the tow-train fleet size and the *Kanban* number.

In the first phase (static), the expected trips/day and the related average supply lead time were determined as a function of the tow-trains number (equal to the number of handling operators) and the service level for the assembly station supply. Given these variables and the safety stock, the number of *kanban* as well as the number of bins per trip were derived. Thus, using the results obtained in the first phase as inputs and varying them into allowed ranges, the second phase were carried out (multi-scenario dynamic analysis) to point out the best delivery frequency from the supermarket to the lines and the vehicle capacity utilization. The last phase was the performance analysis of the long-term and short-term variables and system validation (Faccio, Gamberi, Persona, et al., 2013a).

Despite the importance of the review made about the aforementioned decision problems, there are restrictive dimensions of in-plant milk run systems which are time, capacity and ergonomics physical strain of the operators that must be considered properly in order to achieve an efficient in-plant milk run system (Droste & Deuse, 2011).

2.3 Lean and Continuous Improvement aspects in In-Plant Milk Run

According to Fortuny Santos et al. (2020), besides *muda*, also *muri* (people overburden) and *mura* (workload variation) are very common to be found in mixed and multi-model assembly lines. The author affirms that problems such as staffing and balancing multi-model lines have not been well studied. The same author points out that, in terms of Lean Management, designing efficient assembly processes requires computing the number of people necessary to accomplish a certain task or service and then assigning work elements to operators in an even and standardized manner.

Some papers regarding this theme suggest that mixed and multi-model assembly lines can be balanced separately according to each model they produce (Boysen et al., 2008; Kalaoglu & Baskak, 2008). Kabir and Tabucanon (1995) introduced another option that is to study each model in an independent way and then select common configurations for all models. Roser (2016) proposed either balancing the line for only the most frequent model or computing, for each task, a weighted average performance time considering the quantities to be produced.

To solve the balancing of workload and workforce, Fortuny Santos et al. (2020) presents a procedure to staff multi/mixed model assembly lines, based on the comparison between workload and capacity. The aim of the problem is to determine the number of workstations or operators so that, given a number of models, the work elements can be assigned to workstations, when the desired daily production is known of each model assembled. Once carried out this research, it was possible to verify that these considerations have its focus usually in production environments (workstations) and that there is scarce literature review on the same topic regarding in-plant milk run or supermarket handling operators.

Regarding the same theme (balancing workload and workforce) Kumar and Kumar (2014) suggest the use of Standard work tool as a lean and continuous improvement enabler. To evaluate the application of SW on their paper, the authors carried out a study of the layout, a data collection about the environment, which consider critical steps to remove wastes and to document processes. Additionally, Lu and Yang (2015) carried out an analysis of the parts quantity and process route of the products involved as well as a measure of operations time based on breaking down activities into elements. In what is related to balancing work, the possibility to reallocate the content of worker tasks or eliminate some of them was analyzed by Kumar and Kumar (2014) with the aim of making operators available for other activities. To help this reallocation, Lu and Yang (2015) identify the use of an operating loading chart (OLC) to help balancing and eliminating wastes. Both authors aimed to achieve the right number of operator for the tasks they were evaluating and recognize that the results obtained must be frequently reviewed to implement changes required based on flexibility of demand (Kumar & Kumar, 2014; Lu & Yang, 2015).

An important topic to retain from this research is that the most of previously explored decision problems, objectives and lean approaches are being addressed by mathematical models, complex simulations models or metaheuristics like, genetic algorithm or tabu search, among others (Fortuny Santos et al., 2020), even though these methods usually require a greater degree of computational complexity.

3. Methodology Application

The conduction of the Action-Research methodology was based on five cyclical stages involving diagnosing, action planning, action taking, evaluating, and specifying learning.

3.1 Diagnosing and Action Planning

The company where this work took place is an international Spanish group dedicated to the design, development, and manufacture of metal automotive components. The present work was carried out on one of its subsidiaries in Spain. Its most prominent products are Body in White, Chassis & Platform, Bumpers, Blanks and Painted parts. The company is classified in the hierarchy of automotive suppliers, as a Tier 1, meaning that it purchases raw materials and parts from lower-level suppliers (Tier 2 and 3) and delivers finished subsystems directly to the final assembly lines of the Original Equipment Manufacturers (OEM). The company´s production philosophy is MTS (make-to-stock). It applies a push-type model that involves producing goods based on anticipated consumer's forecast demand. Products are stocked for covering the deliveries/sales forecasted, at least, for the next two days. The MRP (Material Resource Planning) can support the process of making a prognosis by analyzing per article, its current stock, costumer's gross needs and company's strategy defined on SAP's material master data. Despite this, the production accounts for a minimum batch of at least four hours of operation. The main production processes are Stamping, Welding, Cataphoresis and Blanking. The welding department is the object of the present research and is composed of twenty-two automated welding cells being the configuration of this production system a multi/mixed-model assembly line. When the welding process takes place, it is necessary to transport the components from the supermarket to the border of line at the cells. In the current system, the in-plant milk run is carried out by a logistic handler (*Mizusumashi*) who drives a tow-train that travels an established route and replaces the necessary components according to the *kanban*/leveling system full box-empty box. It means that during the route, the visualization of the order is created by the empty unit and in the next route must be replaced as many units as the orders created in the previous route for each component. It is determined, in the present status, that the time between routes (milk run cycle time) is 1 hour for all production scenarios. The picking tasks are all performed in the supermarket area, either from the KLT pallet area or from the container area with larger components. Regarding the handling units to transport the parts, these can be KLT (Packaging and Transport of Small Components) from company, KLT from supplier and kit cars called *Minomi*, depending on the components.

In the current situation, the company has only one tow-train to allow the performance of the described service and three cars available to transport KLT boxes. In terms of human resources, it has its own workers, however depending on demand variation, it may subcontract workers. The in-plant milk run and the supermarket setup, are two of the services inside the parts feeding system to which the company allocates workers of both types (internal and subcontractors). It is determined that between 3 and 4 workers are needed in total to perform the two services depending on low or high customer demand, respectively. Of these workers, one is assigned to perform the milk run service and the rest to the setup supermarket service.

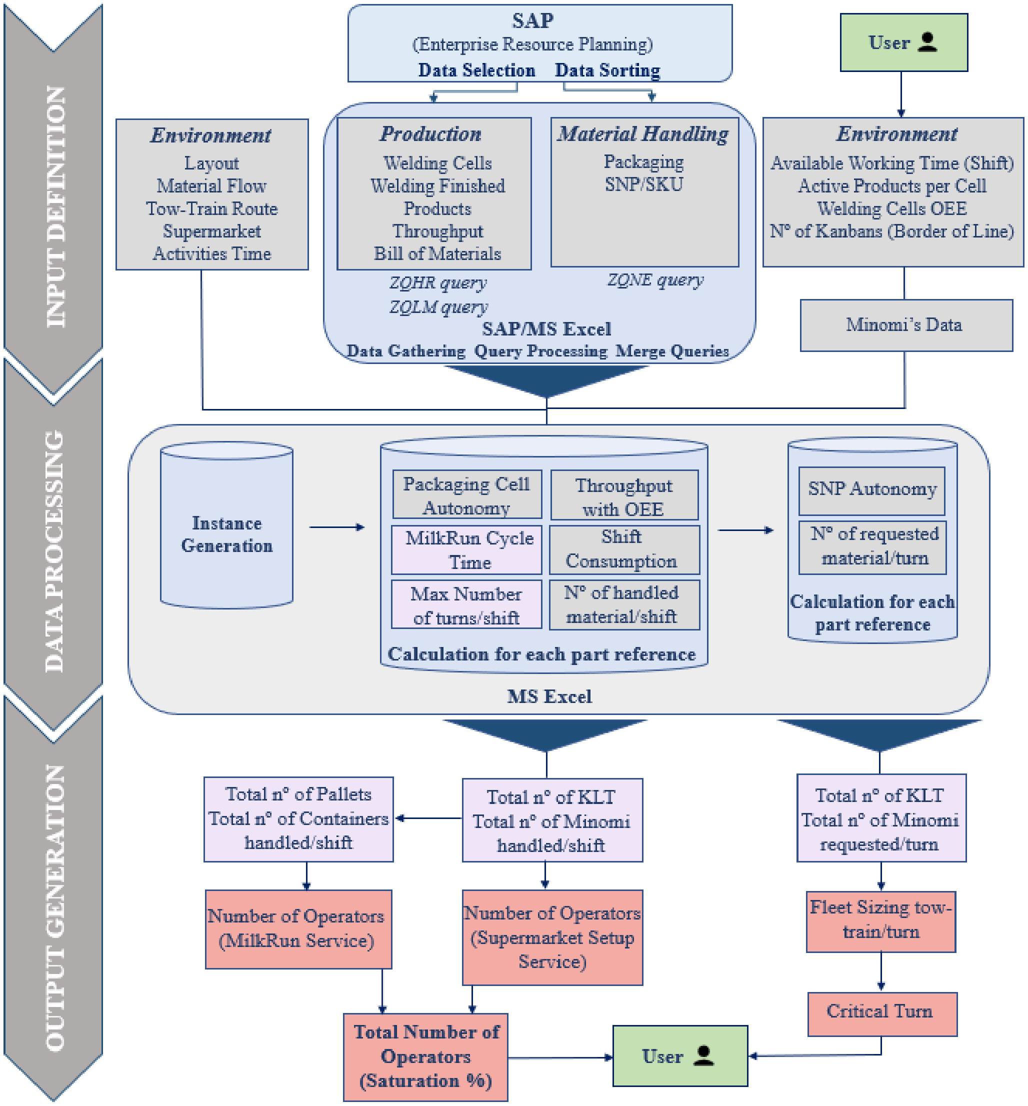

Figure 1. Tool Framework

The research problem initially identified was the lack of management, planning and control of the resources needed to perform the parts feeding system to the welding cells in an efficient way, particularly with respect to milk run and supermarket logistic services. Analytic SW actions were planned and taken in this sense. However, the present paper will focus on the improvement action planned that is the development of a simulation and decision-support tool.

3.2 Action Taking

In the context in which this work was done, the tool was created in Microsoft Excel, since the use of other type of software would require a high computational complexity and the acquisition of another software that is currently not part of the resources available in the company. A framework was created to facilitate the comprehension of the structure and organization of the tool and it is shown in Figure 1.

Regarding the Input definition stage, data from the system in SAP was selected trough three customized transactions used in the company. These are the ZQHR, ZQLM (both provide information related to Production) and ZQNE (provides information related to Material Handling) and both variants and layouts were created to each one of them to easy sort the pertinent information. The delimitation of data resulted in a range of 15 welding cells and 55 products. The environmental considerations were important so the tool could reflect the most reliable outputs in accordance with the real situation. These considerations were obtained through *gemba* walks, corridor talks, data collection and through the analytical standard work actions taken before the tool development such as the material flow mapping of the welding area, the identification of tasks, activities and technical actions of the milk run and supermarket services and its temporal quantification (study of times).

To gather the data selected from SAP to the MS Excel, queries of each one of the transactions were created and the "Merge" feature was used for the construction of the database. This query combination presented in Figure 2 is the base for all calculations of the Data Processing and Output Generation Stages represented in the framework from Figure 1.

ZQHR | ZQLM | ZQNE

Fixed Data

Welding Cell	Output Reference	Throughput (Pieces/h)	Input Reference	BOM Quantity	Original Packaging	Original SNP
S020	V0012S00990	34	V0012E00990	1	C994322ESB	42
S020	V0012S00990	34	V0012E05990	1	C994322ESB	25
S020	V0012S00990	34	V0012K02990	2	C99CARTON	800
S020	V0012S00990	34	V0012E01990	1	C994322ESB	42
S020	V0012S00990	34	V0012E02990	1	C994322ESB	42
S020	V0012S00990	34	V0012K01990	1	C99CARTON	50
S020	V0012S00990	34	V0012K00990	1	C99CICS10	102
S021	V0013S00990	22	V0013E01990	1	C994322ESB	50
S021	V0013S00990	22	V0013E00990	1	C994322ESB	50
S021	V0013S00990	22	V0013E04990	1	C994322ESB	40

Figure 2. Extraction of the Merge between ZQHR, ZQLM and ZQNE transactions

The appearance of the user interface of the tool is presented in Figure 3.

	Minutes	Hours
Rest Time	40	0.7
Available WorkingTime	438	7.3
Ideal MilkRun Cycle Time	32	0.5
Max MilkRun Cycle Time	31.0	0.5

Welding Cell	Output Reference	OEE	Active
S020	V0012S00990	0.85	1
S021	V0013S00990	0.85	1
S021	V0014S00990	0.85	
S022	V0026S00990	0.85	
S022	V0027S00990	0.85	
S022	V0083S00990	0.85	1
S022	V0090S00990	0.85	
S023	V0026S01990	0.85	1
S024	V0023S00991	0.85	
S024	V0023S01991	0.85	1
S024	V0080S00990	0.85	
S024	V0081S00990	0.85	
S025	V0023S00991	0.85	
S025	V0082S00990	0.85	1
S028	F0079S00991	0.85	
S028	F0080S00991	0.85	
S029	V0026S00990	0.85	
S029	V0027S00990	0.85	1
S029	V0090S00990	0.85	
S030	V0024S01990	0.85	1

Max N° of Turns	Total N° KLT /shift	Total N° Minomis /shift	Total Nr Containers /shift	Total N° KLT Pallet /shift
14.0	348	42	18	8

MilkRun Service		
Time KLT (h)		Time Minomi (h)
2.85		0.51
Travel Time (h)		
Get on/Get off truckie time (h)		0.002
Stop Time (h)		0.066
Normal Time (h)		0.07
Train displacement time (h)		1.8896
MilkRun Service Time (h)		5.25
Nop/Saturation		0.72

Setup Supermarket Service		
Time KLT (h)	Time Minomi (h)	Time Containers (h)
1.17	6.69	1.33
Setup Supermarket Time Service (h)		9.19
Nop/Saturation		1.259

Total Service	
Total Time (h)	14.45
Nop/Saturation	1.979

Critical Route

2

3

Figure 2. Tool Interface

Here, besides the presentation of the outputs, is presented the instance generator (underlined heading) where the user is able to create desired production scenario, taking into consideration the available working time established by the company. In the "Active" field, the user is allowed to test real or hypothetic scenarios of production through the input of a binary code 1 or 0, where 1 means that the selected product is being produced in the associated cell and 0 that is not in operation. When a product is not being produced it means that the amount of its components must not be considered for the calculations. Thus, it is the filling of this table that triggers and manages all the intermediate and final calculations. Although the tool was developed whilst considering the requirements established by the company, it was necessary to validate it. Therefore, simulations were performed, being presented in this paper the results of four of them.

4. Results Presentation

The results of the four simulations are presented in Table 1 and will be analyzed in sub-chapter 4.1.

Table 1. Summary of simulation's results

	S1 – high demand	**S2- low demand**	**S3 – high demand**	**S4 – low demand**
Ideal milk run Cycle Time (min)	66	66	32	78
Max milk run Cycle Time (min)	62	62	31	73
Max Nº of Turns	7	7	14	6
Total Nº KLT/Shift	345	232	400	120
Total Nº *Minomi* /Shift	45	29	53	23
Total Nº Containers/Shift	18	11	21	10
Total Nº KLT Pallet/Shift	7	3	9	4
Nop/Saturation milk run Service	0.61	0.42	0.83	0.26
Nop/Saturation Setup Supermarket Service	1.263	0.795	1.558	0.679
Nop/Saturation Total Service	1.872	1.216	2.387	0.941
Fleet Size (Nº KLT cars; Nº *Minomi* cars)	3;6	2;4	3;5	2;2

As it is possible to observe, in the simulation S1 was carried out an instance with the tool reflecting a usual scenario of high demand. To address this scenario, the instance generator table was activated with output references from all cells existing in the welding department supplied by tow-train, meaning all cells were operational. For those that can produce only one product, only one output reference was activated, and in those that can produce multiple products at a time, multiple output references were activated. The same was done to simulation S3 but changing the output references in operation. The tool was also tested with a reduced number of products to be assembled in S2 reflecting a low-demand situation in the company. In simulation S4 the same was tested, though with different output references activated in this case**.**

4.1 Critical analysis of the results (Evaluating)

Analyzing the results, more precisely the output Nop/Saturation Total Service, it is possible to see that the current way of defining resource needs can represent *muda* for the company in some situations of demand. In the high-demand simulations (S1 and S3) the results varied between 2 and 3 operators needed for operating the two services, with the instances considering the maximum current capacity of the welding department. In the low-demand simulations (S2 and S4), the number of operators varies between 1 and 2. This means that when the company defines that it would need 4 workers (high demand situation) or 3 (normal or low demand situation), there will be, at least one unsaturated worker. This represents efficiency losses for the company as these operators could be allocated to other tasks or departments.

Regarding the Max milk run cycle time output, in simulations S1 and S2 the result was in accordance with the 1 hour stipulated by the company, however in S3 and S4 this did not happen. Since the difference between these simulations was the activation of different output references keeping the demand situations, it was realized that this change in the output would be related to the replenishment lead time (autonomy) of certain components. Thus, the welding department milk run should not have a defined cycle time of 1 hour but an adjustment of it according to what is being produced during the available working time, since there is a risk of material shortage in certain cells or passage through them before the necessary time, not complying with the JIT principle. The tool developed can be used in this sense. The other option would be to adjust the number of *kanbans* of components in the border of line so that they all have approximate replenishment lead times and allow the establishment of a uniform cycle time. The tool can also help in this regard since the user can change and test the number of *kanbans* to achieve the required/desired lead time.

With regard to the output Fleet Size, this reflects the maximum amount in KLT and *Minomis* that the tow-train will have to transport, considering the instance created. Prior to the realization of this project, it was decided that in case of transporting KLT cars and *Minomis*, the maximum allowed amount would be between 2 KLT cars and 5 *Minomis*, and that in case of only transporting *Minomis* it could be 6 cars. Through the analysis of the output, it is understood that in the scenarios of greater demand there is at least one route in which the maximum would be exceeded. Thus, the developed tool previously exposes a possible fleet sizing problem so that it can be addressed before causing constraints in the corridors, interruption of other logistical flows or even disruption of productive activity. Physical modification of the means of transporting materials, such as increasing the capacity of KLT cars and size them according to the handling units or to make another tow-train available to carry out the supply of components in the moments when demand is expected to increase are possible ways to avoid exceeding the established fleet size. Lastly, an alternative could be to slightly reduce the milk run cycle time so that the milk run would perform more turns and the tow-train would be less saturated.

Once the critical evaluation of the simulations results was carried out, together with the logistics department, the focus was once again given to the outputs related to the workforce. In their presentation, it was noticed that the value of the output Nop/Saturation Total Service did not always coincide with the values generated for the outputs Nop/Saturation milk run Service and Nop/Saturation Setup Supermarket Service. As an example, in S1, the workforce needed to perform the total service was about 2 operators (1.872) and the workforce needed to perform the milk run service and the supermarket service was about 1 (0.61) and 2 (1.263), respectively, thus 3 operators in total. This happens because each task or activities to be performed was, previously in the study times done, specifically assigned to one of the services, making it impossible to balance the workload. Thus, it was decided to apply an improvement in the operation of the tool that consisted in not assigning tasks to a logistic service but to a specific worker, giving to the user the possibility to allocate and balance the workload in a more flexible manner.

5. Conclusion (Specifying Learning)

As result of Action Taking completion, especially with the creation of the tool, the company has achieved an encompassing resource management system with simulation, test, and parametrization capabilities that is helpful on workload/workforce planning and balancing regarding the parts feeding system, on material and tow-train fleet sizing management and on milk run routes scheduling. All these outputs being adjusted to the required production instance whilst having considered the changes occurring in the information systems. In addition, it can be used from a short-term and long-term planning and management perspective.

In this sense, the tool was tested and verified at company with real production instances and there was consensus that the results were reliable and concise. By using the Simulation and Decision Support Tool, it is expected to increase the efficiency of the supply system to the welding cells, and by being dynamic and generating outputs according to demand it will ensure that resources are always fully utilized and properly balanced.

Finally, it is possible to conclude that both general and specific objectives established for this were approached and achieved throughout the course of this work. The output of this project contributed to the creation of a new dynamic and flexible methodology for resource management and subsequently to the improvement on the welding department parts feeding system efficiency by smoothing the impact of the variability associated with company´s business context.

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Biographies

Maria Teresa Ribeiro Pereira is a Full Professor and Coordinator of the CIDEM, research center of mechanical engineering. She is sub-director of the master course of Mechanical Engineering- branch Industrial management and of the master course of Industrial engineering & management of ISEP. She holds a Production Management Engineering degree from Minho University, a Master course in Information Management from Sheffield University and a PhD. In Operational Management from Minho University. She worked 8 years in the industry and has a 26 years' experience teaching being Professor of Operational Research, Decision Support models, Operations Research, Logistics, Supply Chain Management, Transportation in several courses of IPP. She is responsible by the Industrial management research group of LAETA/INEGI. (ORCID ID: orcid.org/0000-0003-4556-9578). She Guided/guides more than 80 master's theses, and participated in several projects/research, and national and international projects with companies, which resulted in several publications/communications. She participated in several EU projects, being the coordinator of UoF – Universities of the Future project - 2017-3364/001–001

Mariana Xavier is currently a student of the School of Engineering (ISEP) of Polytechnic Institute of Porto, Portugal, where is finishing a Master in Industrial Engineering and Management. She is already graduated in the same area by the same institution.

Fernanda A. Ferreira is a Full Professor and the Director of the Department of Mathematics at the School of Hospitality and Tourism of Polytechnic Institute of Porto, Portugal. She holds a BS in Mathematics and a PhD in Applied Mathematics from the University of Porto. She also obtained a Diploma of Advanced Studies in Statistics and Operations Research from Vigo University. A member and Coordinator of the Applied Management Research Unit (UNIAG), her publications, mostly journal and conference papers, cover the research interest areas of industrial organization, game theory and tourism (ORCID ID: orcid.org/0000-0002-1335-7821). Co-author of two books published in the field of Mathematics. Supervised many dissertations in the areas of Game Theory and Management. She also organizes Symposium on "Operational Research and Applications" in several International Conferences and has collaborated as reviewer with several journals.

Marisa Oliveira is Adjunct Professor in the Department of Mathematics at the School of Engineering (ISEP) of Polytechnic Institute of Porto, Portugal. She holds a BS in Mathematics and a PhD in Industrial Engineering and Management from Engineering Faculty of University of Porto. She is a Pedagogical Council member of ISEP and member coordinator of mentoring program. (ORCID ID: orcid.org/0000-0002-1918-0895)