COLLECTION OF PAPERS
NEW ECONOMY
Volume 1, No. 1, 2023

BLENDING ONE-PIECE FLOW AND LAYOUT OPTIMIZATION IN AUTOMOTIVE INDUSTRY. A CASE STUDY.

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Received 23.02.2023. | Send to review 06.03.2023. | Accepted 31.05.2023.

Original Article

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JEL Classification:
C61, L16, L23, L62

Doi: 10.61432/CPNE0101234c

UDK: 669.017:[629.3:621.43

ABSTRACT

This paperwork presents a case study from automotive industry, of applying One-Piece Flow methodology, under Layout optimization program with a unique and personalized approach to company needs. A systemic outlook and appropriate involvement support the company's continuous improvement efforts. Layout optimization through One-Piece Flow implementation is an elementary key to efficiencies sand to ensure the success. Should be present in any production industry, but extra attention is paid to the automotive field. The described case study methodology demonstrates the relevance of One-Piece Flow and layout optimization in an automotive company. It offers a practical perspective from an organizational point of view, applying the different theoretical formula of OPF balancing calculation to practice. There is always a concern about improving or reducing overall production costs while being efficient. Hence, the manuscript punctualizes the relevance of production workflow, level of interphasic stocks, time, layout of production lines, balancing the production cells and resource management. The paper demonstrates with a new concept for One Pieces Flow implementation the needed steps in order to have a successful production line optimization. Major findings refer to reducing costs, reducing work in progress, quality improvements, team work benefits and freeing space so the company has room for additional projects.

Keywords: *OPF, One-Pieces flow, cycle time, cost rate, layout optimization*

1. INTRODUCTION

Lean Management represents a useful streamlining method which focuses on reducing waste. In the last 3 decades, Lean Management has started to be implemented in a wide variety of fields: automotive, governments, information technology, healthcare etc., having effects on the overall results. Lean thinking enables industries to optimize production, foster customer engagement, and maximize service resources to reduce waste and drive business growth (Lermen et al., 2023; Lakshmanan et al., 2023). Lean Management has a broad range of tools, such us Quality Management, Autonomation, Total Productive Maintenance, Performance Management, Just in Time, Continuous Improvement and many others, out of which we chose to focus on One-Piece Flow.

The One-Piece Flow method is a lean manufacturing approach that involves producing one product unit at a time through a series of continuous and uninterrupted steps. The basic idea for One-Piece Flow, further used as "OPF", or continuous flow is to maximize value addition and minimize losses, creating a manufacturing process where each product unit flows like a single piece of material, with no interruption or delay. This approach can be applied in various industries, including manufacturing, healthcare, and service businesses, to increase efficiency and productivity while reducing costs and waste.

In other words, OPF is the creation of added value for the customer using fewer resources (Productivity Press Development Team, 2002). Working in OPF is totally opposite to the batch production system (Protzman, McNamara, and Protzman, 2016; Baudin, 2002). Researchers consider that batch production affects productivity. Working in batches generates many negative effects, such us: increase of quality problems, repairs, longer lead-time, more storage space and monitoring efforts needed, more indirect staff required to perform the work etc. (Taylor & Francis Group, 1999).

In the One-Pieces Flow work mode, the operations are placed in sequence next to each other and each part moves smoothly from one process step to another until it is completed (Ghirann, 2012). Parts no longer have to move to different areas, wait hours or even days on the floor of the production area until the entire lot is processed (Rother and Harris, 2001). OPF implementation can only be achieved if the arrangement of machines, people, method and material is done in the cell (Sekine, 2017). Our paperwork describes the relevance and effects of One-Piece Flow and layout optimization in an automotive, offering a practical perspective from the organizational point of view, where there is focus on costs and efficiency. Besides this, a detailed six-steps model of implementing one piece flow is presented in the paperwork.

2.MATERIAL AND METHODS

The implementation of the project was carried out in an automotive company with 1,700 employees, with an available production space of 23.500 . The case study is based on real data.

The most common production model is batch production, where each step of the process is evaluated individually, as an independent island, and the transfer of the semi-finished product is done by handling, most of the time using storage boxes and different transport devices the type of pallet truck, different carts or simply pushing them on the floor. This mode of production was also encountered in the studied company, where the level of interphase stocks far exceeded 8 hours of production, in some cases even several days. The production space used in this case was high and totally inefficient (Soliman, 2022).

Through the conducted case study, the efficiency of the cost per hour of production, called "Cost Rate", was pursued.

$$C_r = \frac{C_v + C_f}{H_p} \tag{1}$$

Where: C_r = production cost rate [€/hours]

H_p= production hours, booked by the direct personnel [hours]

C_v= variable cost, meaning the salary cost for direct personnel (operators/ blue colors) [€]

C_f= fix cost (e.g., salary cost with indirect, personnel transport, facility cost, energy/ gas cost, etc.) [€]

In order to succeed in reducing the Cost Rate, there are three directions of work. The most common is increasing the productivity of operators, thus obtaining a lower cost for , the second option is the efficiency of indirect staff activities and the reduction of costs in general, obtaining a lower cost for the fixed cost . The third element with a high potential is the increase in the number of production hours in the same production space, thus the costs of transport, building, heating, electricity has a better distribution and thus achieving a lower production rate cost per production hour.

In order to succeed in increasing the production hours on the same production space, it is necessary to optimize and reduce the production space, thus new projects can be hosted in the newly created free space, thus increasing the production hours. Efficiency is based on the principle that every additional square meter represents a cost, as it must be heated, enlightened, equipped, cared for, cleaned, etc.

The main objectives pursued by the case study were:

- increasing the productivity of direct personnel, that is, reducing variable costs ();

- optimizing the production space, freeing up space for new projects, thus increasing the number of production hours ().

The chosen optimization method of the production lines was One-Pieces Flow, the implementation concept being developed within the case study.

In Figure 1 we have developed a model of implementing the OPF concept, and in the following sub-chapters we will present and detail each stage of this implementation.

Figure 1. One-Piece Flow implementation steps

Source: Developed by the authors

The process started with understanding the OPF method, done through defining the team and ensuring training for it. The second step involves collecting and preparing the data regarding the process to improve. The third step consists of an evaluation of each production line with the product portfolio, by using a special calculation tool, and the spaghetti diagram method to create the process flow. The next step involves developing an optimization layout plan for OPF implementation, using a Gantt diagram, followed by the evaluation and validation of the obtained results, considering specific factors. Finally, the improved situation becomes a standard, which is constantly monitored and improved.

2.1. UNDERSTANDING OPF CONCEPT IN ORGANIZATION

In the first stage of implementation, a standard knowledge and understanding is needed within the organization, especially among the members of the implementation teams, for example for the Process Technology, Production & Quality departments. This was achieved within the case study through:

- defining the Project Manager and the team;
- organizing an opening meeting of the project;
- presenting the objectives and the main time plan;
- staff training on the application of the OPF implementation concept;
- practical and theoretical training of the OPF production method.

2.2. DATA PREPARATION / COLLECTION

As the team was focused on reducing variable costs and optimizing the production space, to improve the indicators they needed to collect and evaluate the following elements:

- List of part numbers on each production line;

- Demand for the next 2 years;
- Identifying High Runners;
- Level of equipment loading capacity;
- Layout evaluation.

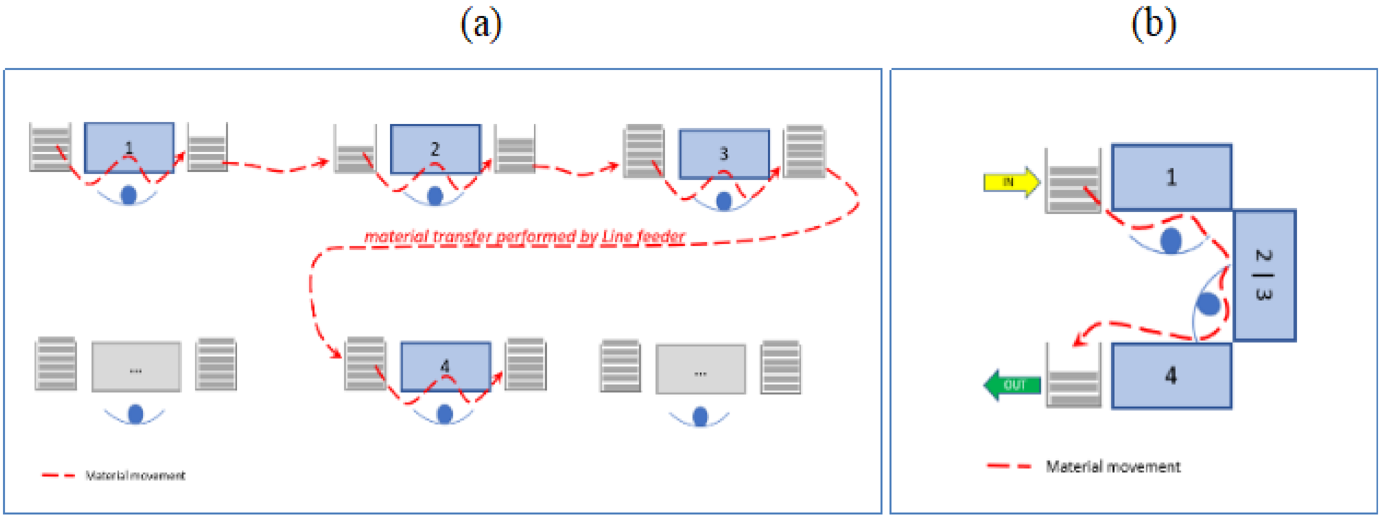
2.3. PRODUCTION LINE POTENTIAL EVALUATION

In order to identify the production lines and process steps where the OPF method can be implemented, the entire production area was evaluated, specifically each production line with the product portfolio. The possibility of implementation is conditioned by few elements, one of which is ensuring a continuous flow of production, thus considering the process steps with the involved equipment, e.g., for injection the OPF cells are more difficult to integrate.

For the implementation of OPF cells, an extra capacity is required among the equipment. In classic production, each machine, workstation has an operator assigned to it for the entire production time, so the degree of loading of the equipment is very high. Instead, in the OPF working mode, the operator moves from one station to another with the product in hand, thus the used capacity of the equipment is much lower (Chiarini, 2013).

Figure 2 (a) describes the way of working in classical batch production, where the operator does not move from one station to another, performing only ergonomic movements at the workstation, for that processing phase. In comparison, in figure 2 (b) we find described the OPF way of working, where the operator or operators move from one station to another with the product in hand so that it can be processed (Takeuchi, 2022). Their movement is streamlined and reduced to a minimum due to the use of U-shape working cell.

Figure 2. (a) Production in a classical Batch approach (b) Production in One-Piece Flow approach



Source: Developed by the authors

In the project, two options were evaluated: moving the operator with only one product in hand or with a bundle of products (approximately 50 pieces). A calculation was performed in this regard, it was found that the most efficient way of working in the detailed case study is moving with a bundle of products, as the achieved cycle time was lower.

In order to identify the areas and the process steps where the OPF cells may be implemented, a calculation tool developed for the case study was used. The methodology implies monitoring and collecting process data in a table. Thus, the sequence of process steps is recorded on the first column, the type of process step (machine, equipment or manual), the number of parts that can be produced in an 8-hour shift, and the tool calculates: the cycle time on the part in seconds, the number of operators per shift required (Liker and Hoseus, 2008).

Figure 3. OPF cell potential - calculation tool

Production line process steps	Type of the process	pcs/ shift	C/T [sec]	Nr. of operators needed /shift	pcs/ 8h	Nr. op allocated	OPF cell potential
Molding Vel grommet 148	machine	1500	19.2	0.09	1500	0.1	
Splitting wires	manual	1700	16.9	0.08	668	0.2	1 OPF cell
Molding verbinden 255	machine	1100	26.2	0.13			
Cleaning long side of the wire	manual	300	96.0	0.47	120	1.0	1 OPF cell
Tube mounting long wire	equipment	400	72.0	0.36			
Tube molding big wire	manual	400	72.0	0.36			
Molding grommet W - schib 113	machine	450	64.0	0.32	450	0.3	
Long wire length adjusting*	equipment	600	48.0	0.24	84	2.0	1 OPF cell
Crimping long wire***	equipment	300	96.0	0.47			
Assembly connect 6 pols**	equipment	250	115.2	0.57			
Assembly safety lock 6 pols	manual	350	82.3	0.41			
Long and big wire length adjusting*	equipment	500	57.6	0.28	143	1.0	1 OPF cell
Assembly safety lock 1 pol	manual	1000	28.8	0.14			
Crimping long and big wire***	equipment	500	57.6	0.28			
Assembly long and big wires**	equipment	500	57.6	0.28			
Molding 6 pols 148/255	machine	1500	19.2	0.09	1500	0.5	
Molding connector 1 pol	machine	750	38.4	0.19	750		
Molding connector 1 pol	machine	750	38.4	0.19	750		
Dismantling short wires	equipment	800	36.0	0.18	70	2.0	1 OPF cell
Cleaning short wires	manual	400	72.0	0.36			
Crimping short wires	equipment	400	72.0	0.36			
Crimping short and big wires	equipment	600	48.0	0.24			
Assembly short wires - 6 pols	manual	350	82.3	0.41			
Shrinking	equipment	850	33.9	0.17			
Leak test	equipment	100	67.0	1.42			
Electrical test	equipment	350	82.3	0.41	350	0.4	
		C/T	1498.9				
		pcs/8h	19				
		Avg order/week	2,000				
		Avg order/shift	142				
		Calcul op/shift	7.40				

Source: Company's internal documentation

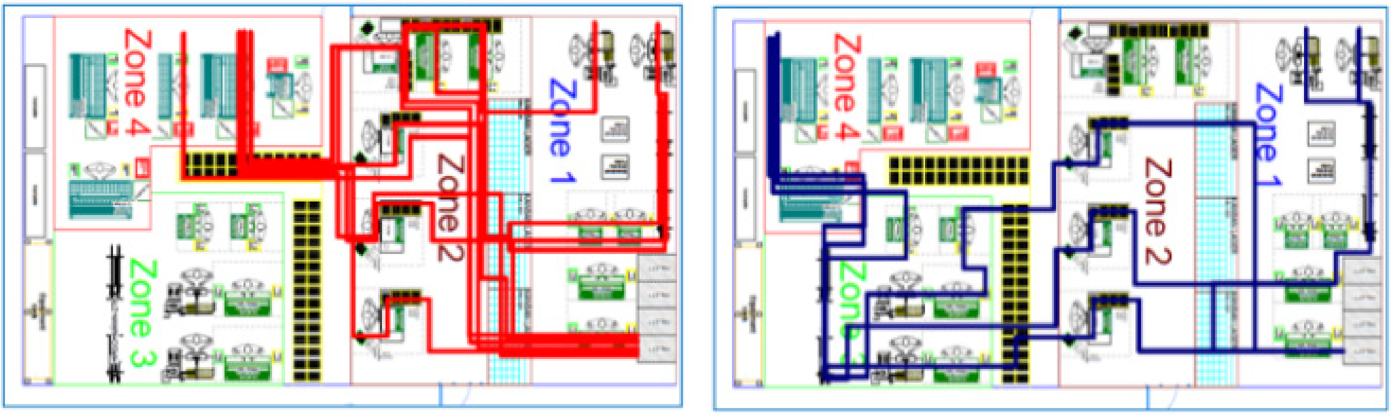
Based on the information available, several areas were identified where the capacity of the equipment was sufficient. As well, the possibility of re-arranging the layout allowed the reconfiguration of the steps and the elimination of several worktables, by placing the equipment on the same table, thus they were implemented 5 OPF cells on the studied pilot line:

1. By merging Splitting wires with Molding;
2. By merging Cleaning long side of the wire with Tube mounting long wire and with Tube molding big wire;
3. By merging 4 process steps: Long wire length adjusting, with Crimping long wire, with Assembly connect and with Assembly safety;
4. By merging 4 process steps: Long and big wire length adjusting, Assembly safety lock 1 pol, Crimping long and big wire and Assembly long and big wires;

5. By merging 7 process steps: Dismantling short wires, Cleaning short wires, Crimping short wires, Crimping short and big wires, Assembly short wires - 6 pols, Shrinking, and Leak test.

In order to correctly integrate the OPF cells within the flow and to reduce the interphase transport as much as possible, the production flow was evaluated using the Spaghetti diagram method. Using the production layout, for a better visualization, the existing routes of the products on the production line were marked, looking within the team for solutions to shorten the routes, by rearranging and or eliminating worktables and by implementing OPF cells (see the last column).

Figure 4. Spaghetti diagram Before & After



Source: Company's internal documentation

Figure 4 presents the routes before and after the implementation of the OPF projects. We can easily notice that the walked distance was reduced, the flow was simplified, which led to the reduction of waste caused by product handling, to increased productivity and shorter production times.

2.4. TIME PLAN AND ROLLOUT

For a good organization of the project and the inclusion of all areas and production lines within the company, a Gantt-type planning was carried out, allocating responsible people and a release deadline. Within the project, 56 areas/lines were evaluated with the objective of optimizing the layout and implementing OPF cells where possible.

Figure 5. OPF cells & Layout optimization planning

Production Area	Production Line	2020										Responsible
		Week 01	W 02	W 03	W 04	W 05	W 06	W 07	W 08	W 09	W 10	
Production 1	1B-Z		c									S.M.
	1B-Z		c									S.M.
	1B-Z		c									S.M.
	1D-Z			o								S.M.
	1E-Z			o								S.M.
	1F-Z			o								S.M.
	1G-Z			o								S.M.
	1H-Z			o								S.M.
	1J-Z			o								S.M.
	1L-Z	c										S.M.
	1M-Z	c										S.M.
Production 4	4A-Z				p							C.D.
	4A-Z	c										C.D.
	4B-Z	c										C.D.
	4C-Z	c										C.D.
	4D-Z	c										C.D.
	4E-Z	c										C.D.
	4G-Z	c										C.D.
	4J-Z	c										C.D.
Production 5	5A-Z							p				S.H.

Source: Company's internal documentation

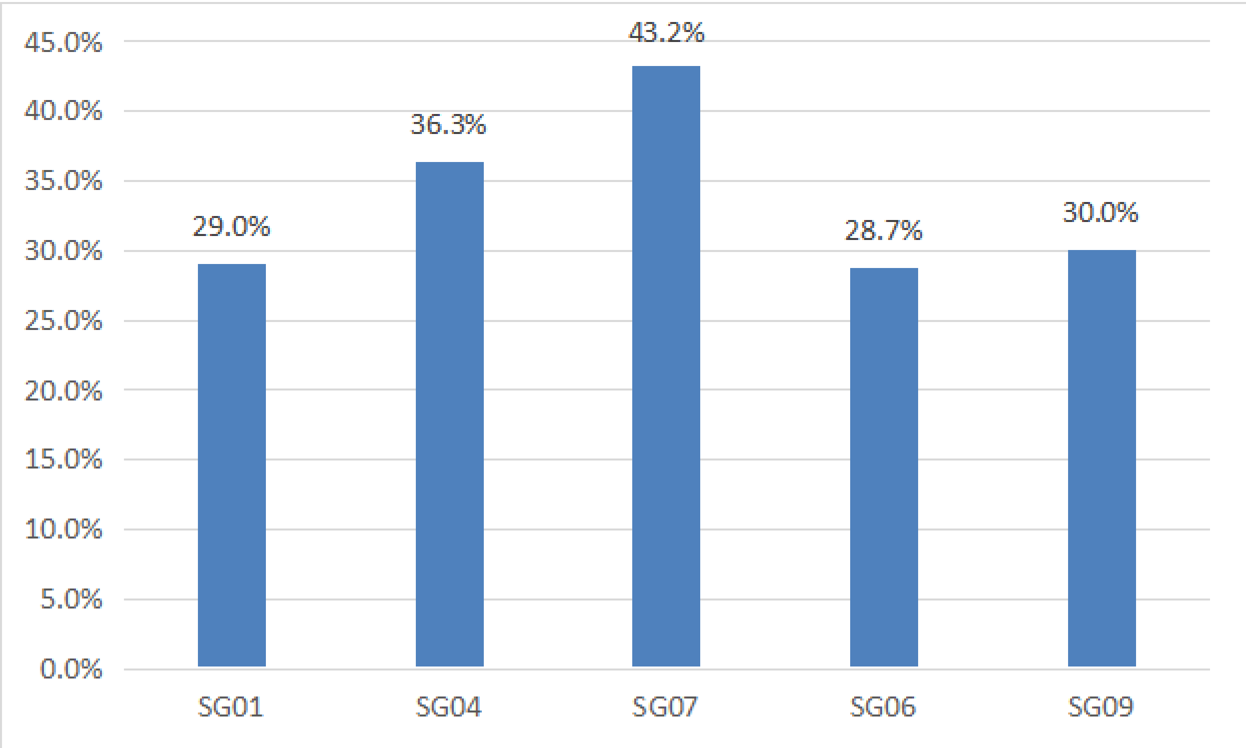
The Layout optimization planning lasted 10 weeks. A responsible has been appointed for each segment of the production area (please see figure 5).

2.5. RESULTS EVALUATION & VALIDATION

In this stage, the obtained results were monitored and evaluated by comparing them with the initial situation. The Controlling Department together with the Lean Department were coordinating this activity by evaluating the following factors: the number of operators on each line before and after optimization, the number of workstations before and after, production output releases before and after, growth potential identified in the framework of the workshops and the actual achievements (out-put) after implementation.

The team calculated productivity increases on each production segment and working stations, from 7% up to 87%. Figure 6 presents the average increase of productivity in each of the segments 01, 04, 07, 06 and 09, which mean 43 working stations.

Figure 6. One-Piece Flow Evaluation Sheet



Source: Company's internal documentation

Besides the productivity increase, the company saved space for other projects and decreased the mobility of the employees, also decreasing the stocks in progress and reducing waste, safety risks, cost rate and production lead-time.

2.6. NEW WORKING STANDARDS MONITORING

In order to ensure continuity in compliance with the new working methods, it was necessary to update the production documentation, through which the work instructions describe the way of working in the OPF cells, and also regulate the level of work in progress stocks. In addition to these aspects, a weekly audit on compliance with work instructions in the OPF cells was implemented.

This last phase ensures continuous monitoring and improvement of the One-Piece flow process, by also looking for opportunities to eliminate waste and improve efficiency. This involves regularly reviewing the production process, collecting feedback from employees, and using data to identify areas for improvement.

Within the studied project, a number of 43 OPF cells were implemented in 15 production lines, as a result of which an average of 33,4 % increase in productivity was reached strictly on these process steps and at the factory level the overall productivity increased by approx. 5%.

Following the layout optimization project and the implementation of OPF cells, a free space was obtained within the production of 3.450 , available space for attracting new projects and additional investments.

Following the improvement activities carried out, a reduction of 0.8% in the Cost Rate in 2021 compared to the previous year was reached. This means, in the event of a salary increase, through the increases in productivity, it would be possible to absorb the salary increases without a negative impact on the financial results of the company.

3. DISCUSSION

As a result of the layout optimization activities and the implementation of the cells, several positive effects were obtained.

An important to mention improvement of the project was the fact that implementing the team work, the shift manager no longer had to manage approximately 40 operators, but only 10 cells and 20 individual operators, the management in the case of cells being at team level and not individual. As well, related to the activities within the team in the OPF cells, it was observed that people with performance problems were much more supported by their colleagues, thus ensuring a high-performance result for the team.

At the beginning of the project, a high reluctance was observed in the employees' behavior, to make changes and be open to understand the benefits of the OPF concept. This is a natural phenomenon, as any new activities or procedures are accepted with reluctance in the first phase, and later, by practicing the new standards, the benefits are identified and the change is accepted.

A distinct element of the case study is the implementation of the calculation tool for identifying the potential for the implementation of OPF cells. The development of this tool was carried out within the project studied and adapted to the given conditions. By applying the described tool, a standard evaluation was obtained within the factory, being able to significantly reduce the project implementation time.

In similar cost rate reduction studies, the increase in performance and the reduction of costs were addressed. In addition to the effects listed in the scientific works, in our case study another element was addressed, too, namely the optimization of the production space. Thus, by reducing the used space, it was possible to release approximately 3,500 , space that in two years was occupied with new projects, in this way increasing the production hours on the same surface, having approximately the same fixed costs, which consisted a significant gain for the production company.

The company realized that their old /classic way of working brought several disadvantages, such us:

- High level of work in progress;
- Excessive handling of stock between workstations;
- Additional handling of the product at each workstation;
- By handling the stock, there is a higher risk of damage;
- Higher probability of having serial defects in high quantities;
- More space used in the production area;
- Static, non-ergonomic working mode of the operator;
- The work carried out is not team-based, the workstations and phases are individual;
- Increase number of safety incidents etc.

4.CONCLUSIONS

Blending one-piece flow and layout optimization in automotive industry has shown in our case study an average growth of 33,4 % in employees' productivity, by also freeing up a space of 3.450 m2. The distance traveled by the operators was significantly reduced. Moving waste lead to a reduction of waste caused by product handling, to increased productivity and shorter production times.

The OPF production method is an instrument that simplifies the way of working, eliminates manipulations and unnecessary movements, obtaining a much clearer and easier to manage production flow. Through the very low interphase stocks, a very short feedback loop between operators was obtained, so in the case of any identified quality problem, feedback to the upstream personnel is possible to be obtained immediately, resulting in an improvement in quality and productivity as effects of this new way of working.

The calculation tool developed within the project can be adapted and used in any production area, helping to evaluate and implement OPF cells.

An important element revealed in the study refers to the six-step implementation concept that helps the efficient development of the project and ensures continuity through continuous improvement activities.

In future we intend to deepen the research by measuring the long-term impact of OPF cells on productivity.

5.ACKNOWLEDGEMENT

We are very grateful to Manuela Rozalia GABOR, our professor, coordinator and colleague, for her invaluable patience and feedback. We also could not have undertaken this journey without the members from the Lean and Technology team, who generously provided knowledge and expertise.

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