Proceedings in MANUFACTURING SYSTEMS Proceedings in Manufacturing Systems, Volume 13, Issue 3, 2018, 127-132 ISSN 2067-9238

THE DEVELOPMENT OF A LABORATORY SYSTEM TO EXPERIMENT METHODS TO IMPROVE THE PRODUCTION FLOWS

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Abstract: *Globalization of production and strong competition in the automotive industry requires manufacturers to offer their customers a wide range of products, of the best quality and at lower prices. This requires uniform production flow, increase the flexibility of the production system and its responsiveness to customer requests. To achieve these goals, it is necessary to use in the layout planning, work organization and production management the most modern methods, techniques and tools of production management, such as modeling and simulating production flows and Lean manufacturing. In this context, the present paper describes the developing of a laboratory system that allows, the research in laboratory conditions of modern manufacturing methods and their transfer to factories from automotive industry. The laboratory system is made of integrated research platforms, specific to layout design, modeling and simulation flows and Lean manufacturing and include also elements of digitalization (Industry 4.0). In this paper are described briefly the main characteristics of the research platforms made until now and the ways in which these can be used.*

Key words: *layout design, flow simulation, Lean manufacturing, production flows.*

1. INTRODUCTION

The Learning Factory concept wants to bring together the research from the academic and economic environment. Learning Factory represent an effective and efficient concept for the transfer of knowledge and conveying concepts [1]. In the area of manufacturing process amelioration, Learning Factory offer a well-suited hands-on approach for competences development [2, 3].

To organize a Learning Factory one most consider 3 directions of development. The first direction is a research-based learning environment named *experiences lab.* The experiences lab focuses on practice – oriented application of methods and tools on a physical small scaled modular production system. In the experiences lab the learners are free to modify and rearrange process and production equipment and to apply organisational measures to experience the dynamic response from the production system with all systemic interdependencies. The *research lab* is the second direction and focuses on the dissemination of research project results by implementing developed platforms in factory environments. The third direction is *education lab* – focuses on the transfer of knowledge on predefined learning paths directed at a rather less research-based learning experiences but a more application-oriented one [4].

The Learning Platforms number from the University Level institutions, other institutions and production companies is in continuous growth. They are mainly concentrated on mechanical engineering and economic studies. According to a recent study, the focus is more and more on Lean Manufacturing production [5].

In a competitive environment, companies have the challenge of developing continuously new and more complex strategies, in order to keep or enhance their performance. The layout design and Lean Manufacturing can be a way to reduce costs and to increase the profit [6].

To integrate the system analysis with the help of modelling and dynamic simulation, can be also, an important step to increase the efficiency and agility of an organization as part of a complex production system. The simulation brings a very important insight in the impact of changes, identifying the vulnerabilities and the opportunities. In a more ambitious perspective, adding the three aspects: Layout Design, Lean Manufacturing and the dynamic simulation, as proposed in this project, can bring flexibility and competitiveness to companies.

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2. RESEARCH PROBLEM

This study is part of a research project of the authors that has as aim to develop new methodologies of improvement for the production flows of automotive industry, by integrating modern methods, techniques and tools of production management. The starting conceptual model is appreciated as having Technology Readiness Level 2 – TRL2 [7] and is presented in Fig. 1.

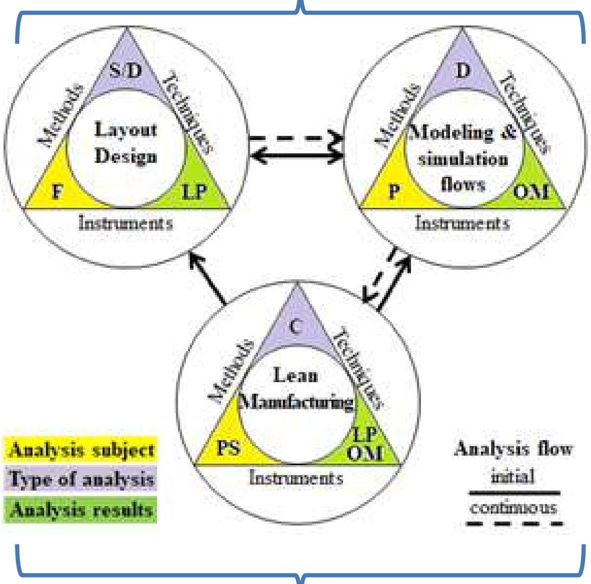
The proposed model has 3 interrelated investigations areas: layout design, in which the subject of analysis are the facilities (F), and the result is the plant layout (LP); modelling and simulation flows, in which the subject of analysis is production (P), and the result is the operating mode of the system (OM); Lean manufacturing, in which the subject of analysis is the production system (SP), and the results are the improved layout plan (LP) and operating mode of the system (OM).

The starting element in this general methodology is the layout design of the production system, which can be made in a static way (S) or dynamic (D). The resulting layout plant is improved, first, by the modelling and simulation of production flows, and after – in a continuous manner (C), by using the methods and techniques specific to Lean Manufacturing.

To experiment this methods of manufacturing flows improvements, in the project was designed and constructed an experimental demonstrator, of level TRL4, that contains integrated research platforms, specific for each previously mentioned study directions.

In this paper is presented the approach on developing such a laboratory and are described in brief the characteristics of research platforms developed until now.

Input data:
Products; Processes; Facilities;
Production conditions; Performance targets.



Output data:
Plant layout; Operating mode; Performance indicators of the production system.

Fig. 1. Conceptual model for improving production flows.

3. APPROACH

The TRL4 concept of an experimental demonstrator is described as [7]: "The basic technological components are integrated to establish that the pieces will work together. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function". To use this laboratory system to research the methods of manufacturing flows improvements from the automotive industry, is needed:

- to include research platforms specific for each direction of research proposed for study (layout design, modeling and simulation flows, Lean Manufacturing);
- the research platform must include elements specific to the application of research methodology in automotive industry and these must be integrated in the experimental laboratory.

The main elements of this research platforms are described in the following.

The research platforms for *layout design* must include:

- construction elements (tubes, fittings etc.), modular and flexible, to build the workstations;
- construction elements (tubes, fittings, label holders, boxes etc.) modular and flexible, to build the workstation supply equipment;
- construction elements (tubes, fittings, rollers etc.), to build the transfer between the workstations;
- support elements to design and analyze the layout of manufacturing system (writing boards – to design scale models of different layout variants).

The research platforms designed for *modeling and flow simulation* include:

- procedures to apply the modeling methods to analyze the manufacturing systems;
- design workstations equipped with discrete event simulations software;

The research platforms designed for *Lean Manufacturing* include:

- Poka-Yoke systems;
- DOJO systems;
- procedures to apply the methods of Lean Manufacturing concept: 5S, Kaizen, Standardization, Visual management etc.;
- procedures to apply the tools of analysis of manufacturing systems, from Lean Manufacturing perspective: Value Stream Mapping.

Also, considering the tendencies from the present industrial development, in the laboratory will be integrated equipment that will introduce the Industry 4.0 concept (PLC, HMI, scanner, RFID, pick to light systems, sensors, wireless communications etc.). At the end of the project, will be possible to further develop workstations, fully automated or automation-assisted, that will communicate between themselves but also with higher levels of IT systems. These equipment will allow the gathering, storage, synthesis and processing of data from the manufacturing system, in order to determine its efficiency and to develop further improvements.

Next to all the physical equipment – the research platforms of the laboratory contain also software specific to the research field. Considering that, the laboratory must be equipped with servers and computers, interconnected in a network, that have installed software from virtual factory environment: layout design, production planning, flow modeling and simulation. Obviously, an integrated software solution that allows synchronization of product engineering, manufacturing engineering, production and supply operations for research – innovation of these processes and maximize production efficiency is a must-have to be implemented.

4. ACHIEVEMENTS

To develop the research platforms, was needed, to find a range of products that imply manufacturing flows specific to automotive industry: products manufactured in a high variety, in mass production. The manufacturing flows must be complex enough to allow the use of modern methods of manufacturing management: flows with manual activities, and complex and diversified BOM.

Considering the above, it was chosen as *experimental product* a steering wheel [8], Fig. 2, and as research process, its assembly process.

So the assembly process could be as close as is possible to the industrial one, and to allow a big diversity of products, but also to need manual activities, was designed the structure seen in Fig. 3.

The diversity of product and, therefore, of the assembly process, is made by using components of different colors (components 4, 5 and 7), and by using components different as functionality (components 6).

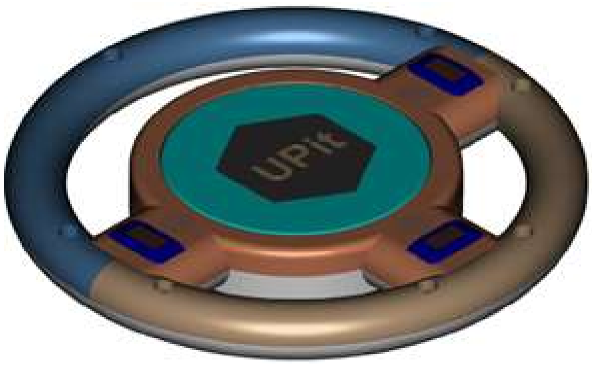


Fig. 2. The 3D model for the experimental product to be assembled (steering wheel).

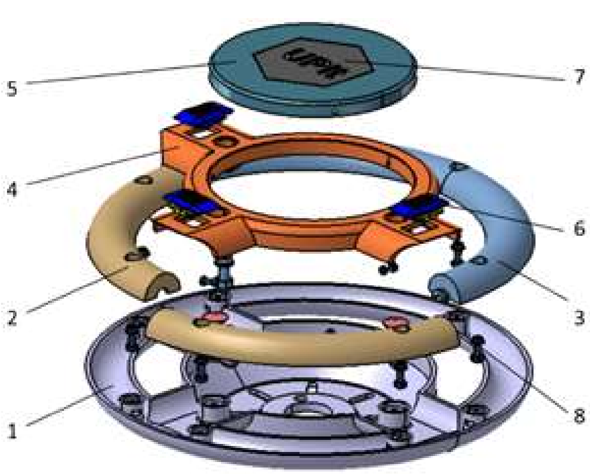


Fig. 3. The BOM of the product to be assembled (steering wheel).

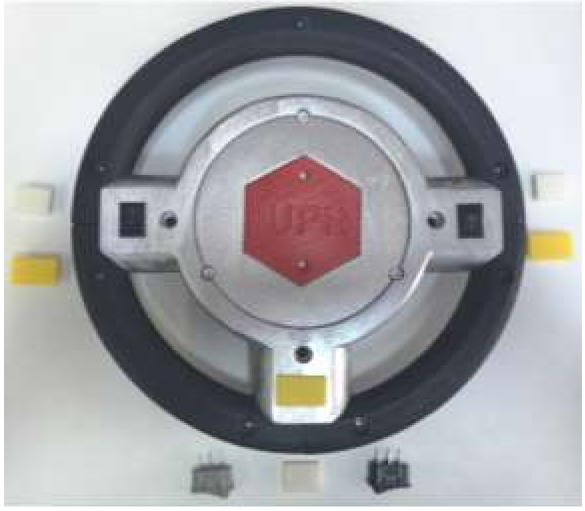


Fig. 4. The photo with the experimental product to be assembled (steering wheel).

To ensure the relevancy of the manufacturing process for the research (including repeatability of process), is needed to make a relevant number of products. For this were purchased a number of components (screws, switches) and other components were made in laboratory (by 3D printing FDM and casting of duroplastic resin) for a number of 30 products (steering wheels). A photo of this components is presented in Fig. 4. Another experimental product that will be included in the studies is a car wiring.

For the purpose of the research on the models used in *layout design* was designed an assembly line [8] that allows the integration of Lean manufacturing principles:

- a high flexibility for the workstations, so a higher diversity of products can be made with minimum of changeover;
- a modular structures - built into modular workstations, in order to decrease the costs of design and manufacture of the industrial system, and also to decrease the impact of reconfiguration of layout and process flexibility;
- the possibility to adapt the process to the clients demand – manufacture on an „one piece flow" to increase the reactivity to client demand, this needing "zero setup" for workstation;
- minimizing the activities with non-added value (mainly, movements and handlings), in order to achieve the target of "NonVA = 0".

The 3D models of the modular and flexible workstations and the modular and flexible supply and transport systems, are presented in Fig. 5, and respectively, in Fig. 6.

The photos of the modular and flexible workstations and the modular and flexible supply and transport systems, are presented in Fig. 7, and respectively, in Fig. 8.

To integrate in the study concepts of *Industry 4.0*, for one of the workstations was developed a digital structure, Fig. 9, that can be extended in the future to the all assembly line. This digital starting structure, which is in developing phase, allows the researchers to further build on it and to study easy to use and implement digital solutions with their advantages.

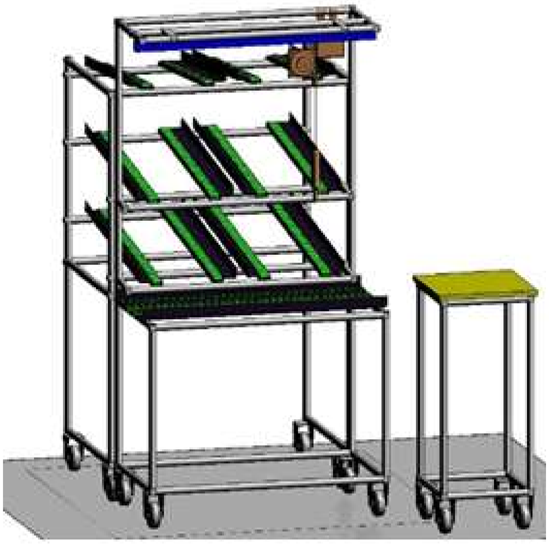


Fig. 5. The 3D model of a modular-flexible workstation.

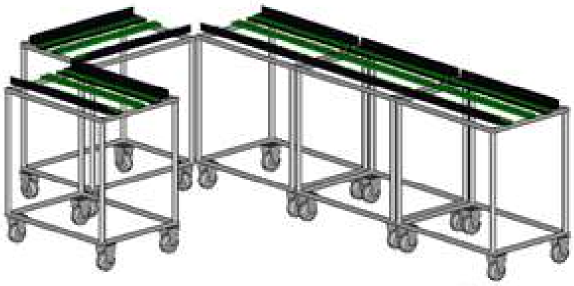


Fig. 6. The 3D model of a modular-flexible transport system.

Fig. 7. The photo of a modular-flexible workstation.

Fig. 8. The photo of the modular-flexible transport system.

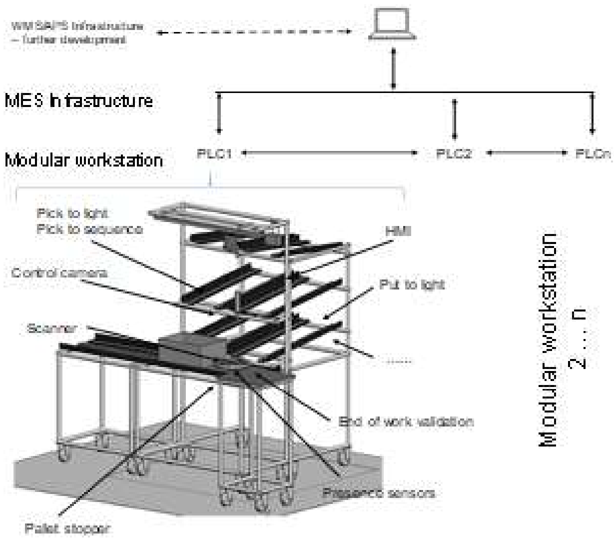


Fig. 9. The digital architecture of a workstation.

To develop and analyze different theoretical solutions of layout organization and to optimize them, will be used specific software: IMPACT, Tecnomatix FactoryCad, FactoryFlow, Jack, already purchased. The IMPACT software allows, starting from technical data on the production (articles, nomenclatures, load stations, ranges), to study possible layouts, to propose uploads or to propose an implementation minimizing the distances between machines (Fig. 10) [9].

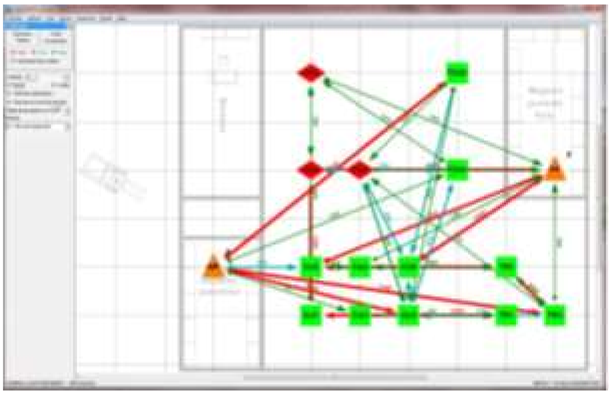


Fig. 10. Production flux optimization using. IMPACT software [9].

FactoryCAD is a software that has all the tools needed to create detailed and intelligent models of a factory. The "intelligent" objects that represent all the resources of a factory: floor, transport conveyers, cranes, storage equipment and operators, can be described and have the parameters changed according with the study conditions.

FactoryFLOW is a software that allows the design and optimization of a general layout of a factory, considering the material flow distances, frequencies and costs. This is done by the analysis and evaluation of information about routes of products, needs of storage, handling equipment specifications and information about the products assembly in the general layout of the factory (Fig. 11).

Jack is used to simulate, test, improve and fine tune the designed models and the industrial tasks, using the most complex set of human simulation tools available on the market.

To analyze different solutions of spatial organization, and also to visualize the manufacturing flows, a writing board with magnetic rubber sheets was purchased, Fig. 12. Using these, it can be easier to design and make analysis using working in group, a plus comparing with the software solutions where there is a more individual approach.

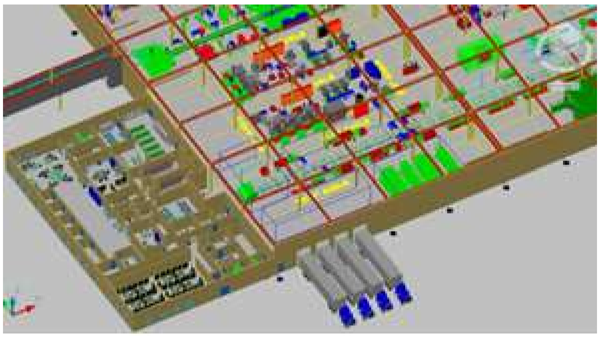


Fig. 11. Layout design optimization using FactoryFlow software [10].

To put in practice all the described above, a laboratory system, was allocated a room of 60 m^2. The 3D model of the layout of the room, with the purchased/ made equipment, is presented in Fig. 13, and a photo of it can be seen in Fig. 14.

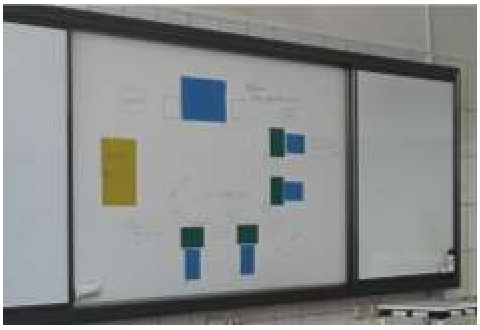


Fig. 12. The photo of the writing board.

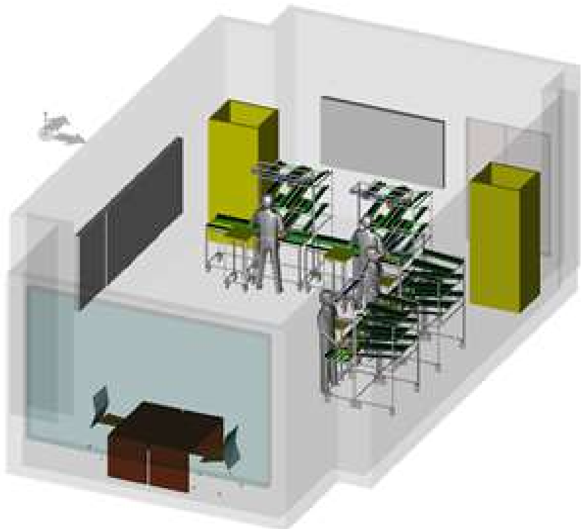


Fig. 13. The 3D model of a laboratory system.

Fig. 14. The photo of a laboratory system.

5. CONCLUSIONS

In this research project, that is the subject of this paper has started the development of a laboratory system – of TRL4 level, that includes integrated research platforms, specific for modern methods of manufacturing flows improvement, specific to automotive industry. In this paper is presented briefly the approach to develop this laboratory and were described shortly the main characteristic elements of the research platforms made until now. This platforms are specific to each direction of research considered: layout design, modeling and simulation flows, Lean Manufacturing.

Concluding, until now the following was achieved:

- the modular-flexible assembly workstations, one being equipped with a starting kit of digital equipment;
- the modular-flexible system to supply and transport parts to the workstation and between them;
- the interconnected network of servers and computers, that have installed, software of layout design (IMPACT, Tecnomatix FactoryCad, FactoryFlow, Jack) and also the software to command and control the workstations, based on the digital solution (Industry 4.0).
- support write board to design and analyze the manufacturing layout.

The development of this laboratory allowed already to experiment some layout design methods applied in the manufacturing systems, methods and models developed in this project [11].

The study will continue with the development of other research platforms, all of them in a common, integrated vision. These platforms will allow to further research different methods of manufacturing flow improvement and the experimentation of Lean manufacturing work organization models.

The possibility to experiment and validate the theoretical models, using these research platforms in the laboratory environment, is the innovative element of our study and will lead to increase the technological maturity level of the laboratory system.

Also, this laboratory system will allow the collaboration with partners from the industrial environment in order to improve the manufacturing flows from their factories.

ACKNOWLEDGMENTS: This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI-UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0446 / 82-PCCDI-2018, within PNCDI III.

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