



Universitatea  
Transilvania  
din Braşov

# **HABILITATION THESIS**

## **SUMMARY**

**Title:** Research on modelling and simulation of Flexible Production Systems in the context of Industry 4.0 and Lean Management integration

**Domain:** Engineering and management

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The habilitation thesis is a synthesis of scientific and professional results, obtained and published after the completion, in 2003, of the doctoral thesis titled "*Research on the Sizing and Configuration of Flexible Manufacturing Systems for the Processing of Circular Trees*" and obtaining the title of doctor engineer in the field of Industrial Engineering, within Transilvania University of Braşov (scientific coordinator: Professor PhD. Eng Gheorghe BONCOI).

The habilitation thesis "*Research on modelling and simulation of flexible production systems in the context of Industry 4.0 and Lean Management integration*" mainly presents the achievements that attest the capabilities and performances in the field of teaching and scientific research in the field of *Engineering and management*.

The scientific research activity carried out during the entire period, in the academic environment, is focused on two major research directions:

- Theoretical and applied research on the design, optimization and management of flexible production systems. The research carried out both within the scientific research projects and through the elaboration and publication of scientific articles had a complex, interdisciplinary character and is in line with the current development trends in the field, the flexible production system being a central element of Industry 4.0. Mathematical models of dimensioning, configuration and simulation of these complex systems have been developed on a scientific basis, models that make it possible to know the behaviour and technical-economic performances as well as possible, even before their physical realization. The applied research was carried out through the simulations on graphic-analytical models and the experimental system carried out, being extended by applying the Digital Twin concept – peak simulation in Industry 4.0. The research was also carried out in the direction of optimizing the manufacturing processes, by collaborating within research teams.
- Research on production systems management and Lean management integration in Industry 4.0. Research conducted on the implementation of Lean tools and techniques in operational production management involves their knowledge and use in specific applications. Applicative research was approached, which is part of the current trend of development of production and management systems, with sensible changes on the factories, both in technology and in the socio-economic environment and in business models, digitalization and connectivity being the key elements of Industry 4.0, along with the development of the value creative chain, promoted by Lean management. The approach was also based on the promotion of the concept of sustainable development

in management, through scientific publications in the field. Also in this direction, the research was extended in related fields, towards a new approach of strategic management at the level of Destination Management Organizations by implementing Lean techniques to improve the processes of the organization, the results being disseminated together with the research team through publication in specialized journals.

The habilitation thesis is structured in 3 sections. The first section (B1) highlights the scientific and professional achievements, presenting the main original scientific results obtained by the author of the habilitation thesis after obtaining the title of doctor engineer. The second section (B2) is dedicated to presenting the evolution and career development plans (teaching, scientific and professional activity). The third section (B3) presents the references associated with this habilitation thesis.

Section **B1.1 Scientific achievements** is structured in 4 chapters, as follows:

In *Chapter 1 – New concepts regarding advanced production systems* presents the basic concepts of production systems, their evolution, the necessity and the opportunity to develop flexible structures, intelligent manufacturing systems, in order to implement cyber-physical systems in production processes and their interconnection – elements specific to Industry 4.0. A conceptual model resulting from the research is also synthetically presented, the model of flexible manufacturing system – asynchronous system, which constitutes a basis for further development through modelling and simulation.

*Chapter 2 – Research on the modelling, simulation and management of flexible manufacturing systems* presents the results of the research on the dimensioning, configuration and simulation of flexible manufacturing systems, focusing on the applicability of the research:

- Design and construction of an experimental system for the simulation of the sequential process in the manufacture of cylindrical parts, physically performed in the laboratory;
- Developing an original software package with two system management and monitoring applications: a. Controlling and configuring the technological flow in real time, based on the modelling of concurrent and asynchronous events in the flexible manufacturing system, using Grafcet techniques; b. Monitoring, control and intervention of processing. The applications were developed using the Cx Supervisor Developer license – the OMRON package.

- Dynamic modelling and simulation of the flexible manufacturing system using simulation techniques and state-of-the-art software (Plant Simulation – Tecnomatix/Siemens), specific to Industry 4.0. The structural analysis was performed, based on which the mathematical matrix model of the systems' coupling was developed, on a case study – a flexible robotic cell. Thus, it was possible to establish the interactions between the component processing subsystems and the logistic equipment, whose influences are decisive on the efficient operation of the entire system. New simulation models were developed, and the results obtained allowed the evaluation of the system's performance and the identification of bottlenecks in the production processes, knowing their negative effects on the real production lines.

**Chapter 3 – *Research on the integration of flexible production systems in Industry 4.0*** presents the scientific research, in particular, applied to make digital copies of the experimental system using the Siemens Tecnomatix – Simulate Process software. The research was carried out within the ongoing scientific research contract, and the original results obtained will be disseminated through publications in scientific articles with an impact factor and extended through collaboration with third parties. The theoretical study conducted on the Digital Twin (DT) concept laid the foundations of the developed application. The aim was to create the virtual commissioning environment of the experimental SFF system by applying another concept Virtual Commissioning (VC) perfectly integrated into the current Industry 4.0. All stages and resources of digital copy creation have been described in detail. As a result of the simulation, several complex commissioning scenarios could be tested (with collaborative robots, HMI – Human Machine Interaction interfaces and AGV – Automated Guided systems). An important benefit is to reduce the actual (physical) commissioning time and to resolve errors before connecting to the real equipment, with minimal investment and favourable implications for competitiveness. The implementation of the new technology (VC) allowed the system to test the behaviour, a high flexibility and greater precision for the simulation model, having a representation of the real process and allowing an optimal decision to be made quickly. At the same time, the model can be expanded into a real factory that wants to adapt its processes through digitalisation. The simulation also assessed the operational parameters of the system.

**Chapter 4 – *Research on the involvement of Lean instruments in production management and integration in Industry 4.0*** is structured on five subchapters in which the main results of the research are presented, disseminated through scientific articles and

presented at prestigious international conferences or obtained within scientific research projects:

- The concept, techniques and tools of Lean Management underlying the development of any applications in the field of engineering and management.
- Applying Lean techniques in production management by developing an improvement project, the results being implemented within a company, through the scientific research contract currently coordinated.
- A new conceptual approach to interdependence between Lean Management in Industry 4.0 by developing a model for correlating I4.0 solutions with Lean principles. It was based on the thorough research study on the literature in the two fields, resulting in a synthesis of "synergy".
- The integration of the Lean management concept in sustainable manufacturing provides a methodology for implementing the Lean & Green Manufacturing integrated model, based on the analysis of the two concepts.
- The extension of the Lean concept, through a new strategic management approach at the level of the Destination Management Organization (DMO) in the tourism industry, the results being published in two scientific articles elaborated as co-author and correspondence author and disseminated at an international conference by the members of the research team. As a novelty, a conceptual model of analysis of DMO processes was proposed through SIPOC analysis (Lean Six Sigma tool) applied on a case study. Based on the study and analysis of the DMO structure, the Lean implementation methodology at DMO level was developed. This direction of research will be developed in the future through collaboration within interdisciplinary teams.

Section **B1.2 Professional achievements** briefly presents the studies and professional experience of the author of the habilitation thesis, the didactic activity and the scientific research activity.

Section **B2. The career evolution and development plans** presents the development directions in the didactic activity and the scientific and professional research activity.

Section **B3. Bibliography** contains the list of bibliographic sources used in the elaboration of this habilitation thesis.

The elaboration of the habilitation thesis was based on the scientific results published in 12 scientific articles as main author (two as co-author) and obtained in two scientific research projects as project director, after obtaining the title of doctor engineer.