Report

UNIVERSITY OF SKÖVDE

# RESEARCH PROPOSAL

A simulation-based approach for optimization of production logistics with consideration to production layout

Enrique Ruiz Zúñiga
enrique.ruiz.zuniga@his.se

2016-09-27

# Table of Contents

Table of Contents ..... 2
1. Introduction ..... 3
1.2. Aim and Objectives ..... 3
1.3. Research School and Industrial Partner ..... 3
1.4. Problem description ..... 4
1.5. Delimitations ..... 4
2. Research background ..... 6
2.1. Production, logistics and layout ..... 6
2.2. High product mix and low-volume production ..... 6
2.3. Simulation-based Multi-objective Optimization ..... 8
3. Research methodology and plan ..... 9
3.1. Research methodology ..... 9
3.2. Research questions ..... 11
3.3. Research plan ..... 11
3.4. Expected outcome ..... 12
References ..... 14

# 1. Introduction

Manufacturing sectors in Sweden have a long tradition and represent a significant share of the national gross domestic product and the export values. Most of the Swedish manufacturing companies have gone through a modernization and adaptation process in order to be able to compete on a globalized market. Many plants, however, still have non-optimized shop floors as a consequence of adaptations over time without redesigning its production and logistics flows and with a lack of an overall strategy. To support the optimization of shop floors, this project suggests the combined use of Discrete-Event Simulation (DES) and Simulation-Based Multi-objective Optimization (SBO) under the umbrella of a design and creation research strategy. The aim of the project is to support the improvement and optimization of high product mix and a low-volume of customized products manufacturing systems by considering production and logistics flows along with the shop floor layout. The methodology is intended to contribute to significantly increase the productivity and efficiency of the Swedish manufacturing industry and help companies to survive on the globalized market. The potential results can serve for decision makers and stakeholders to apply changes and adaptations in the system considering the mid and long term goals of the company. Going through different case studies implemented in a middle-size water pumps manufacturer, this methodology will be useful in practice and it will provide a decision support system for this specific industrial partner and will serve as a guideline for other manufacturing companies.

## *1.2. Aim and Objectives*

The aim of this project is to support the improvement and optimization of production and logistics systems with consideration of the shop floor layout and a high product mix and a low-volume production middle-size manufacturer.

The main objectives of this project are:

- Investigate the state of the art of simulation and optimization for system improvement in production, logistics and layout of high product mix and a low-volume production manufacturing systems.
- Support with simulation and optimization the election, design and development of new production and logistics systems.
- Find the potential and key parameters for the improvement and optimization of production and logistics flows considering the shop floor layout.

The area is very interesting for Swedish industry because many plants in the country has a long history and are not flow-optimized. This in turn increases the cost for production, flow efficiency and the resource utilization. Addressing these issues will help Swedish industry to increase its future production capacity , competitiveness and growth.

## *1.3. Research School and Industrial Partner*

This PhD project is founded by IPSI (Industrial PhD Research School in Informatics) with the support of the Knowledge Foundation (KK-stiftelsen) and the Industrial Partner Xylem Water Solutions Sweden AB together with the University of Skövde.

The IPSI Research School focuses on illustrating how advancements within engineering and computer science can be used to implement information technology systems that are beneficial for individuals, organizations and the society in general, and how with a socio-technical and organizational perspective can be integrated to create useful system solutions. Graduate students, their supervisors and mentors are linked to the IPSI School. The Research School's work is based on the combination of the knowledge available in the partner companies and the capacity of the Information Technology and Engineering Science faculties at the University of Skövde.

Xylem Water Solutions Sweden AB is a middle-size water pumps manufacturing company under the umbrella of an International American Corporation since 2011. The American corporation has more than 12.000 employees around the world, is present in more than 150 countries and provides solutions to water supply systems all over the world. Its factory in Emmaboda is the focus of this project; it has more than 1.200 employees and their main products are middle- and big-size water pumps and mixers. Their main production at Emmaboda is around 100.000 pumps per year.

## 1.4. Problem description

Many middle-size manufacturing facilities of the Swedish industrial sector have been adapted along decades to meet the requirements and evolution demand of global companies. Many times this results in different extensions of several shop floor buildings with aggregated installations mainly due to continuous expansion, adaptation and modernization of the production systems. In order to be able to support decision makers to increase the productivity and efficiency and to have a better defined long term perspective when adapting this kind of middle-size manufacturing facilities, simulation studies to find potential improvements and feasibility of different parts of the systems should to be analyzed, designed and built.

There are several limitations that have to be addressed for the improvement processes, some of them are the lack of enough free space on the shop floor, the excessive amount of traffic inside the factories, the coexistence of persons and heavy transport vehicles in concentrated areas, the extensive amount of manpower needed to produce different variants of products and the difficulties of stopping production at certain levels, all these problems should be considered when analyzing and proposing alternatives for system improvement.

## 1.5. Delimitations

Due to the wide coverture and the different entities involved in this project, boundaries have to be established in order to avoid an excess of simplification, generalization or specification. Moreover, this project will include changes in the existing facilities of the industrial partner generating some timing difficulties in the case study planning.

The aim of the project concerns a long term approach including both short and long term perspectives. This means that the systems to be taken into consideration in the development of this project should have some relations with the long term perspective of the improvement methodology. In this way minors systems, changes or improvements that will not be included in a long term thinking or affected by it should be excluded from the methodology unless strictly necessary.

Similarly, the possible planning problems due to layout changes and operational modifications in the facilities, should be addressed by the industrial partner so that the long term research aims are supported despite short term system changes. A high risk of focusing too much in coordination, technical problems, local planning, costs or development should be considered when implementing changes in the existing facilities.

To establish some boundaries of this project regarding the scope of the production flow, a prior consideration is to include the main material flows from the production site entry dock of goods until the final products are ready to be shipped out of the factory. Regarding the production lines, all the processes that add value to the products, starting when the material is delivered to the lines until it leaves the production lines should be included. In the specific case of the industrial partner, the painting and packing processes are not being considered as part of the production lines (due to that they are clearly differentiated and separated from the production processes). Some other delimitations that have to be defined more specifically and related to the industrial partner, are usually included in a list of assumptions delivered at different stages of this project together with the different simulation models or sub-assignments of this research. Finally, the scope of this project is limited to middle-size manufacturers with a high product mix and customized low volume products.

# 2. Research background

In this chapter a brief summary of the content of this project, some of the problems to confront and the literature review of the main topics of this project are addressed. These topics are production, logistics and layout; high product mix and low volume production; and simulation-based multi-objective optimization.

## *2.1. Production, logistics and layout*

The main research application of this project with the industrial partner is to try to solve the part feeding problem at the main shop floor of their factory in Emmaboda. This is known as the problem of delivering the necessary parts, at the right time, to different production lines with the appropriate transportation methods through the shop floor layout. This problem has been widely studied, mainly in some specific manufacturing sectors. For example part logistics in the automotive industry has been deeply studied and analysed by Boysen [1] and an extensive literature review and description of the different logistics types by Ziarnetzky [2] analyses aircraft assembly line models using DES. Some other papers are focused in more specific aspects of the internal logistics aspects. For example an heuristic solution procedure is developed by Golz [3] to minimize the required number of drivers for in-house shuttle tours between part storage and delivery areas in the automotive sector. Emde [4] develops an exact solution for the optimal scheduling and routing problems of the transportation method with tow-trains between a central supermarket storage and the assembly lines in the automotive industry. Many authors have analysed the in-house transportation methods from the parts storage area to the production lines [5, 6]. However the topic considering the part feeding problem has been analysed by these authors [3]. Golz [3] divides this problem into the planning of the transportation orders and the assignment of those orders to the shuttle system considering the transportation capacity restrictions. They mention that the main objective in feeding the parts to the production line is to ensure the efficiency of the logistics processes; stating that one of the key problems according to the just-in-time principle is to retrieve the parts in their respective unit loads from a central storage system until they are assigned to the designated assembly locations, with the proper transportation tour. They state that the exact timing in the material supply is of utmost important to avoid interruptions in the production line.

One of the closest articles to the research topics addressed in this project but more focused in tow-trains sizing and supermarket design, [7], presents the line feeding problem and models the logistics between a central supermarket area and the production lines of an Italian automotive company considering different alternatives.

## *2.2. High product mix and low-volume production*

Low-volume assembly lines with a high amount of product variants are characterized by a large amount of manual processes, buffer space constrains, specialized resources and external suppliers [2]. As stated by Ziarnetzky, low-volume serial production is usually characterized by a small number of typically large-sized objects with a big number of necessary processing steps. The characteristics of the products usually need a high level of customization, often including a complex bill of materials, multiple routes and a high degree of parallelism. The processing times usually rely on the amount and skills of the necessary workers; the degree of automation is often low mainly due to many labor-intensive processes. The major sources of complexity of this kind of production are the high customization, the high amount of involved suppliers, the necessary highly skilled workforce, the learning curve of the staff and the spatial constrains for systems objects. The resources are usually mobile and workers and auxiliary resources are important. Finally buffers are also a major constrain due to the size of the system objects. Golz [3] states that the main problems related to production systems with a high product mix in the automotive sector are: to determine a proper configuration of the production lines regarding the equipment and processes of the different stations, to have the production lines balanced according to the expected production and the master production schedule for individual models over a short-term planning, and the production sequencing and resequencing in case of disruption and the material flow control.

The related literature to this kind of high product mix and low-volume production systems regarding the layout, production lines and logistics has been deeply studied. In most of analyzed papers some of the problems mentioned above are addressed specifically, sometimes analyzed from an overall perspective but few of them including the layout, logistics and production lines of these high product low-volume production systems. Most of the relevant papers analyzed are related to the automotive sector. Several authors focus mainly on the balancing problem of the different process involved in the production lines and many others mainly focus on the production sequencing [1, 8-11]. Due to the specific case of this project, it is not easy to find related papers on similar production systems, hence, the ones found related to the automotive sector have been utilized as a reference due to the similarities in high product mix and low-volume production.

The main characteristics and limitations of different automation, production and logistics methods in the manufacturing sector have been deeply analyzed by Groover [12]. A complete study in the automotive sector of a mixed-model assembly line focused in the logistics including an optimization is presented by Wenping [10]. Battini [6] defines an interesting integrated approach to parts and components management to optimize the centralization degree of warehouses to minimize storage costs and to choose the right feeding policies. Ende and Boysen [13] summarized the problem of locating the logistics areas optimally to facilitate just-in-time supply of mixed-model assembly lines. According to these authors, in modern-day production systems there is an increasing challenge to feed mixed-models production lines due to the ever rising product variety. They propose a mathematical model with an exact dynamic algorithm to discuss the pros and cons of the supermarket-concept.

The concept of supermarket can be defined as a decentralized in-house logistics area close to the assembly lines that serves as immediate storage for parts delivered with a just-in-time approach [13]. Faccio [7] provides a framework to design the supermarket and feeding system to automotive mixed-model assembly lines. In this case the decision of choosing a central kitting area to supply all the production lines was based on the amount of required place on the shop floor. Both possibilities of having the storage areas needed to feed the lines located in a dispersed manner by every production line or having a central storage supermarket area were analysed. It was demonstrated that the second option, the central area supermarket, would free much more space especially by the production lines and would reduce drastically the traffic around the production lines where usually operators have to walk around. Many manufactures around the globe are adopting this supermarket concept to supply parts to the assembly lines.

In the field of the line feeding problem including the proper in-house transportation method and route as well as considering different types of production lines (with different automation levels) not much literature has been found. One of the closest articles involving these three principles is presented by Battini [6], who introduces the line feeding problem and analyses different solutions of optimally locating in house logistics areas to facilitate JIT-supply of mixed-model assembly lines but without considering different production methods for different lines neither the shop floor layout.

Summarizing, even though there is an extensive literature in production (especially in the automotive sector), in the field of production logistics including different types of in-house transportation methods and routing, as well as considering the layout and different types of production lines, not much literature has been found beside the analysed here.

## *2.3. Simulation-based Multi-objective Optimization*

Simulation is an analytical tool to create, maintain, evaluate or improve a system or process. It is the imitation of the operation of a real-world process or system over time and presents a huge potential for manufacturing process development and improvement [14, 15].

It has been demonstrated that simulation techniques are the most suitable approach for process improvement of complex systems with high variability. The variability and difficulty of the processes within complex systems demand the analytic power of DES. One of the more highlighted characteristics of DES studies is the possibility to apply "what-if" questions or scenarios to the existing systems without disturbing them. Within these scenarios new alternatives, ideas, systems and work proceedings can be tried out without disturbing the real system, or be developed even before a system is constructed [16].

Since simulation is not an optimization tool by itself, a step that combines simulation and optimization is required when several possible combinations of the system are analysed. Traditionally, simulation and optimization have been considered as different approaches in the operational research domain, but they are many times integrated and finally the concept is to use the detail system behaviour of simulation in combination with the ability of optimization to reach an optimal or close to optimal solutions [16]. It has been demonstrated that the combination of optimization and simulation tools allows decision makers to quickly determine optimal system configurations, even for complex integrated facilities [17]. When multiple objectives are simultaneously considered, Simulation-based Multi-objective Optimization (SBO) is the most promising approach. SBO facilitates the search for trade-offs between several conflicting objectives [18].

Depending on the type of problem to analyse, there are different optimization methods that can be used in combination with simulation, of which several are presented by Figueira and Almada-Lobo [16]. Different authors have described how simulation and optimization techniques applied together have improved production or material handling systems. Nevertheless, there are not many cases found in the literature where DES and SBO are applied together to support the design and/or development of production and logistics systems of high product mix and low volume production.

# 3. Research methodology and plan

In this chapter the proposed methodology for the development of this project followed by the research questions and the research plan are presented.

## *3.1. Research methodology*

The proposed methodology of this research is based on the Design and Creation research strategy [19, 20]. The election of this research strategy is based on the creation aspect of the aim of this project, to create a guideline to support the improvement and optimization of middle size manufacturing systems with high product mix and a low-volume of customized products, addressing different kinds of production and logistics systems and considering the configuration of the shop floor layout. Another reason to base the election of this research strategy is the need of a methodical documentation of the procedures implemented in the different steps of this project, in order to produce a properly defined and evaluated artefact.

The proposed artefact to be created as part of this methodology is the mentioned guideline for system improvement of high product mix and a low-volume of customized products manufacturing systems. This artefact will be also based on the simulation methodology presented by Banks [21] that relays on DES and SBO tools to address the analysis and improvement of different logistics and production system considering the shop floor layout. For showing the industrial applicability of the methodology, it will be implemented in different case studies together with the industrial partner. The main principles of the proposed research strategy are presented here:

- Design as an artefact
- Problem relevance
- Design evaluation
- Research contributions
- Research rigour
- Research as a search process
- Communication of research

Going through these principles and deeply analyzing the problem description of this project, this research strategy should be the research framework for the application of simulation and optimization approaches for the system improvement presented. In the following Figure 1, the research framework is defined by its interrelations of the three main bodies that can be included in this research (Environment, Design Science and Knowledge Base):

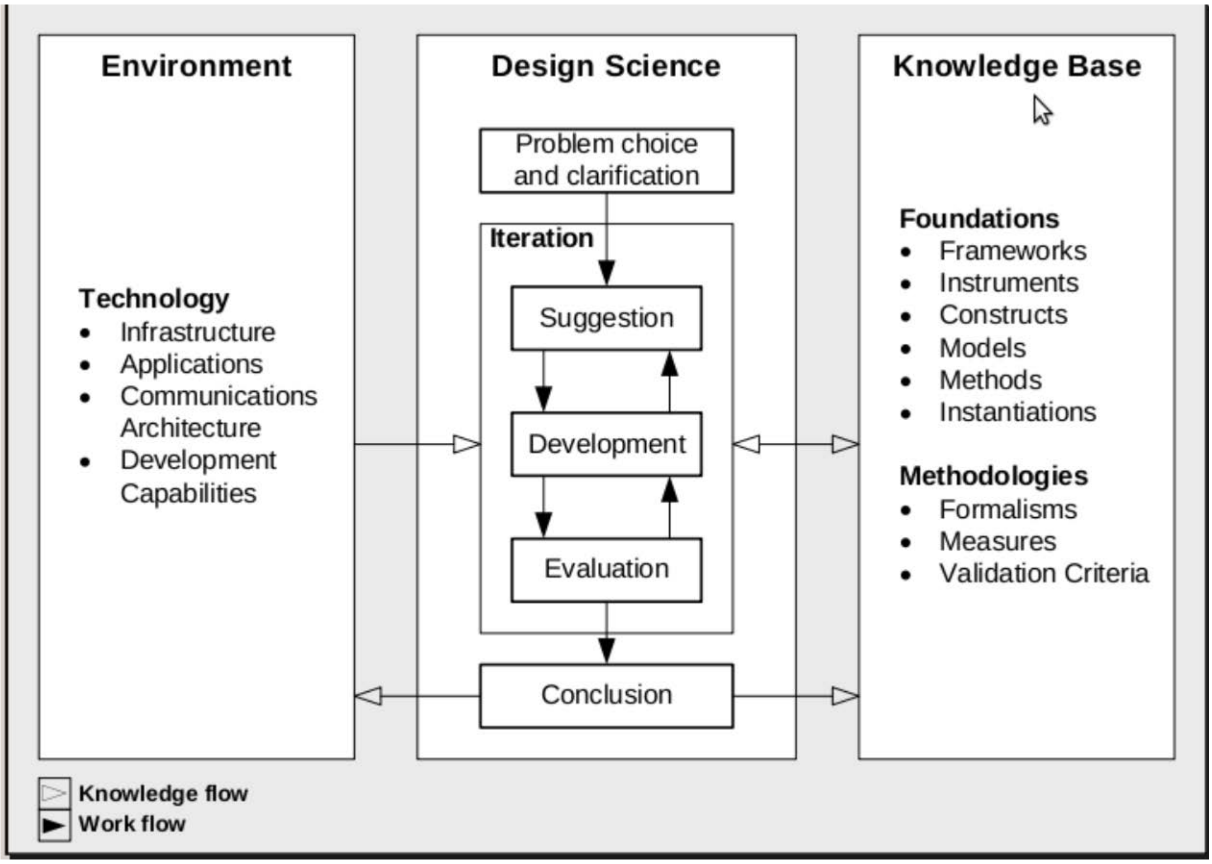


***Figure 1:*** *Information systems research framework [22]*

The first main body to consider in this research strategy is the environment, which in this case it is the existing technology present in the manufacturing sector and its evolution to new systems and capabilities. This actual and potential environment is the main input to the development phase of the project together with existing knowledge base and the previously defined problem description. The knowledge base is mainly compounded by foundations and methodologies; within the foundations, all the explicit research and industrial material and information should be considered; within the methodologies, the different measures to evaluate the base of the implementation, the formalisms and the validation of the analyzed knowledge should be addressed. After that, during the development phase, iteration between new suggestions to be implemented, the development phase, experimentation and its evaluation should be performed until the achievement of a solid conclusion. If the achievement of the conclusion is satisfactory enough, that knowledge should return to the knowledge base and to the environment bodies to enrich them, closing the cycle of the base of research and design science.

To finalize, a proper evaluation of the overall project should be performed to address the fulfillment of its purpose. Consequently the documentation and data generation phases could be implemented, including in this case, case study implementations and real result data, useful for the industrial partner and used for the assessment and evaluation of the research project.

## *3.2. Research questions*

The related research questions this project is aiming to address are:

- How can an efficient continuous flow production be achieved having a high product mix and low-volume production?
- Which production logistic concepts are more advantageous considering production layout and throughput when having a high product mix and low-volume production?
- How can we achieve an optimal combination of production and production logistic systems for different product family?
- Which combination of production and production logistic systems is the best trade-off solution for a high product mix and low-volume production considering production layout, high flow efficiency and resource utilization?

Combining the aim and objectives that compound this project, these questions should be addressed. The two main approaches in which this project will be based are DES and SBO. The area is very interesting for the Swedish industry due to many plants in the country has a long history and are not flow-optimized. This fact limits the potential capacity of the production, competitiveness and growth of the Swedish industry.

## *3.3. Research plan*

The proposed plan for this PhD project is presented in the following figure 2. In the left part of the figure it is possible to see the time period that this research would preliminary take. On the headings of the upper row of the table is it possible to appreciate the main division of tasks: literature survey, case studies and experiments I and II, thesis writing and conference and journal papers. At the Ecuador line of this project the thesis proposal or licentiate is programed.

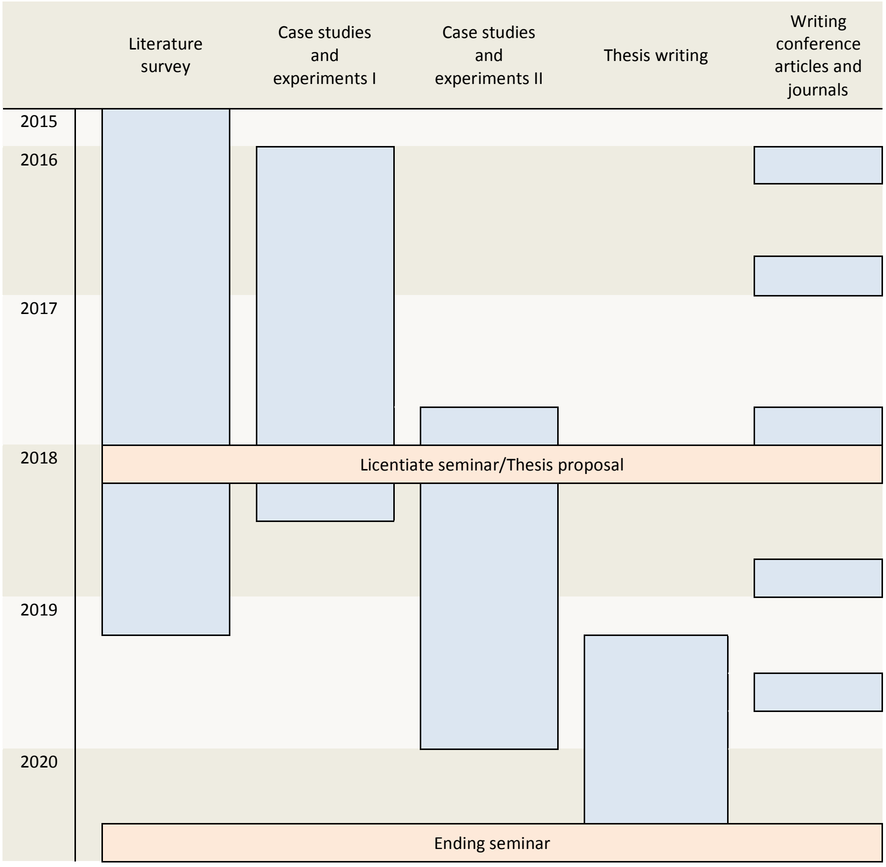


**Figure 2:** *Research plan*

## 3.4. Expected outcome

The outcome of this research should be an analysis presented in form of a guideline addressing different kinds of production and logistics systems considering the configuration of the shop floor layout to make similar middle-size manufacturing systems with high product mix and a low-volume of customized products work more efficiently. This analysis should be supported by DES and SBO techniques and should be complemented by real world case studies that support and validate it giving some benefits to the mentioned industrial partner. Besides the aim of this project, the presented objectives should also be addressed in the outcome of this project:

- Investigate the state of the art of simulation and optimization for system improvement in production, logistics and layout of high product mix and a low-volume of customized products manufacturing systems.
- Support with simulation and optimization the election, design and development of new production and logistics systems.
- Find the potential and key parameters for the improvement and optimization of production and logistics flows considering the shop floor layout.

The combination of a guideline with industrial case studies can be a really useful tool to increase the production and efficiency of similar middle-size manufacturers around the world. Supporting this guideline with simulation and optimization, the trial and validation of potential improvements of the system can be implemented without the need of interrupting it or even working in the design phase of new systems to be constructed. The potential results of this research can serve to stakeholders and decision makers to increase the productivity and efficiency of different and complex production systems with high product mix and a low-volume of customized products around the world.

# References


1. Boysen, N., et al., *Part logistics in the automotive industry: Decision problems, literature review and research agenda.* European Journal of Operational Research, 2015. 242(1): p. 107-120.
2. Ziarnetzky, T., et al. *Simulation of low-volume mixed model assembly lines: Modeling aspects and case study*. in *Simulation Conference (WSC), 2014 Winter*. 2014.
3. Golz, J., et al., *Part feeding at high-variant mixed-model assembly lines.* Flexible Services and Manufacturing Journal, 2011. 24(2): p. 119-141.
4. Emde, S. and N. Boysen, *Optimally routing and scheduling tow trains for JIT-supply of mixed-model assembly lines.* European Journal of Operational Research, 2012. 217(2): p. 287-299.
5. Emde, S., M. Fliedner, and N. Boysen, *Optimally loading tow trains for just-in-time supply of mixed-model assembly lines.* IIE Transactions, 2012. 44(2): p. 121-135.
6. Battini, D., et al., *Design of the optimal feeding policy in an assembly system.* International Journal of Production Economics, 2009. 121(1): p. 233-254.
7. Faccio, M., et al., *Design and simulation of assembly line feeding systems in the automotive sector using supermarket, kanbans and tow trains: a general framework.* Journal of Management Control, 2013. 24(2): p. 187-208.
8. Meyr, H. and M. Mann, *A decomposition approach for the General Lotsizing and Scheduling Problem for Parallel production Lines.* European Journal of Operational Research, 2013. 229(3): p. 718-731.
9. Boysen, N., M. Fliedner, and A. Scholl, *Assembly line balancing: Which model to use when?* International Journal of Production Economics, 2008. 111(2): p. 509-528.
10. Wenping, L. and H. Yuming. *Car sequencing in mixed-model assembly lines from the perspective of logistics optimisation*. in *2008 IEEE International Conference on Automation and Logistics*. 2008.
11. Boysen, N., M. Fliedner, and A. Scholl, *Sequencing mixed-model assembly lines: Survey, classification and model critique.* European Journal of Operational Research, 2009. 192(2): p. 349-373.
12. Groover, M.P., *Automation, Production Systems, and Computer-integrated Manufacturing*. 2008: Prentice Hall.
13. Emde, S. and N. Boysen, *Optimally locating in-house logistics areas to facilitate JIT-supply of mixed-model assembly lines.* International Journal of Production Economics, 2012. 135(1): p. 393-402.
14. Tempelmeiera, H., *Practical considerations in the optimization of flow production systems.* International Journal of Production Research, 2003: p. 149-170.
15. Banks, J., *Handbook of simulation*. 1998, Atlanta, Georgia, USA: John Wiley & sons, INC.
16. Figueira, G. and B. Almada-Lobo, *Hybrid simulation–optimization methods: A taxonomy and discussion.* Simulation Modelling Practice and Theory, 2014. 46: p. 118-134.
17. Jacobson, S.H., S.N. Hall, and J.R. Swisher, *Patient Flow: Reducing Delay in Healthcare Delivery*, ed. R.W. Hall. 2006, Los Angeles, California, USA: Springer US.
18. Deb, K., *Multi-objective optimization using evolutionary algorithms*. 3rd ed. Wiley-Interscience series in systems and optimization. 2001, Wiltshire, UK: John Wiley & Sons, LTD.
19. Oates, B.J., *Researching Information Systems and Computing*. 2006: SAGE Publications.
20. Hevner, A. and S. Chatterjee, *Design Science Research in Information Systems*, in *Design Research in Information Systems: Theory and Practice*. 2010, Springer US: Boston, MA. p. 9-22.
21. Banks, J., *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice*. 1998, New York, USA: John Wiley & Sons, Inc.
22. Kuechler, B. and V. Vaishnavi, *On theory development in design science research: anatomy of a research project.* European Journal of Information Systems, 2008. 17(5): p. 489-504.