A VIRTUAL VERIFICATION APPROACH TOWARDS EVALUATING A MULTI-PRODUCT ASSEMBLY SYSTEMS

Erik Flores [1], Mats Jackson [2], Magnus Wiktorsson [1]

[1]*School of Innovation Design and Engineering, Mälardalen University*
[2]*Volvo Construction Equipment*

erik.flores@mdh.se

Growing operational complexity and higher variety of products require flexibility in assembly. Despite its many benefits flexibility is a complex concept that requires evaluation to harness its full potential. This study uses virtual verification tools as enablers of the decision making process for production system design of a flexible multi-product assembly system. A case study approach analyses a flexible assembly concept for the earth moving equipment industry through a visual and a discrete event simulation model. The paper also discusses the challenges faced by virtual verification tools when applied to the evaluation of flexible assembly systems.

Keywords: Flexible assembly, virtual verification, simulation

1. INTRODUCTION

The manufacturing has seen a radical transformation in the way products are fabricated and assembled. Literature cites numerous reasons for this, yet one characteristic holds true: today´s manufacturing environment is both more complex and dynamic than ever before. Assembly is particularly sensitive to this issue as manufacturing practices transition from product uniformity to ever increasing diversity. Consequently, assembly is faced with the daunting challenge of accommodating product variety with the available resources.

Because of its responsiveness to effectively changing circumstances (Gerwin, 1987) flexibility has been viewed as the keystone of product assembly in the face of an ever increasing product variety and mix. Not surprisingly, the use of mixed model line balancing and sequencing were the early approaches used for handling increasing product variety (Bukchin et al., 2002). However, the mixed model assembly line approach may no longer be sufficient as current market needs as well as aggressive competition force companies to levels of flexibility that encompass not only different models, but also different families of products in the same assembly line.

The body of literature behind flexibility in assembly is extensive and describes the needs, requirements, and challenges in this field; however, there are few studies that describe the transition from a single model assembly to a multi-product one (Comstock et al., 2004). Perhaps the reason for this is that such a change is a big risk. There is a need to know whether a proposed system will comply with operational outcomes and costs associated to its implementation. This study focuses on virtual verification to hasten the decision making process during the early phases of production system design of a flexible multi-product assembly system. The intent behind this focus is to provide a path that may confirm whether proposed ideas in flexible multi-product assembly system concept are feasible once implemented in the factory floor. Based on the wide spread use of virtual manufacturing technologies in manufacturing (Souza et al., 2006), the inclusion of such tools in a product’s life cycle (Maropoulos and Ceglarek, 2010), and the concerns in regard to product and process variety in mass customization (Daaboul et al., 2011) virtual verification is proposed as an enabler of this process.

This paper begins with a literature review on today´s challenges in flexible assembly systems, and particularly those that involve mass customized ones. A brief overview on how virtual verification may support mass customization is presented. The literature review is followed by a case study for earth moving equipment manufacturing company were the transition from a number of product dedicated assembly lines to a single multi-product line is in effect. The cost of assembly as a function of operator crew flexibility is evaluated, and conclusions are drawn on how a virtual verification approach provide insight into the effects of multi-product assembly system.

2. BACKGROUND

2.1 Flexibility

Long gone are the days when companies could thrive on a single product. Today´s manufacturing environment is both complex and highly dynamic, the reasons for such radical transformation are manifold. Instability and unpredictability of the manufacturer’s operation environment (Slack, 1987) and changes in product life cycle and lead times (Chambers, 1995) are but a few of the challenges that have contributed to the leap from manufacturing lines driven by economies of scale to a concept where greater responsiveness to changes in products, production technology, and markets are prioritized (ElMaraghy, 2005). Flexibility has emerged as one of the key enablers in the abovementioned transformation of manufacturing practices.

Flexibility is a multi-dimensional concept (Gerwin, 1993), as can be exemplified in a number of studies (De Toni and Tonchia, 1998, Dangayach and Deshmukh, 2001, Kara and Kayis, 2004) where many forms of flexibility within a firm´s structure are identified. Despite the vastness of literature in the field, and perhaps as a consequence of the many faces of flexibility, there exists ambiguity and confusion about a concept that often represents a critical competitive capability (Upton, 1994). The above justifies cautious judgment when flexibility is to be assessed.

Notwithstanding the difficulties in terminology and definition there is a consensus in as much as flexibility’s ability to respond to change and accommodate uncertainty (Beach et al., 2000). Manufacturing flexibility has been acknowledged as one of the primary dimensions of both competitive business (Hayes and Wheelwright, 1984), and manufacturing strategy (Boyer and Leong, 1996) as a result of its competence to accommodate external perturbations. Within manufacturing, Assembly is considered an area of high relevance to flexibility particularly in the face of complex operations where manual assembly is necessary.

A critical part of flexibility in assembly is that of worker flexibility. One such definition for the term is that flexible workers will have overlapping skills and, therefore, will be able to move to a bottleneck task, to replace one another in case of absenteeism, to assist an overloaded colleague, or to share workloads, which all will contribute to efficiency and performance (Molleman and van den Beukel, 2007). In this case operator flexibility is crucial for the success of the system thus the focus of this paper.

Assembly is one of the most cost-effective approaches to high product variety, and therefore the need for flexibility is highly relevant in this area (Hu et al., 2011). Traditional single-model assembly lines have been subjected to a transformation where the inclusion of a broader product mix, or a high number of options assembled in the same line take effect in the form of mixed-model ones as exemplified in cases performed in the German automotive industry (Meyr, 2009). Despite the growing inclusion of automation, manual assembly is pervasive in a wide range of industries. The multi-skilled workers’ ability to work in a number of different workstations and to perform several assembly tasks is also a way of their handling the increasing demand for larger product variability where operators with the right amount and type of information are expected to boost flexibility and efficiency (Michalos et al., 2010).

2.2 Challenges of Evaluating Flexibility

Literature provides ample evidence on the cautions that need be taken when flexibility is implemented. There are critical decision problems associated to execution of this systems such as the design of the production system and the associated expensive machinery as both compromise long-time investments that are not readily reversible (Boysen et al., 2007). Concern has also been voiced in regard to the initial capabilities of flexible systems as systems are built with all the flexibility, functionality, and capacity available, even, as in some cases, with those that may not be needed at installation time (Mehrabi et al., 2002).

Studies have shown that adopting a flexible manufacturing system will not guarantee improvements in performance, and that the adoption of such systems call for caution against the defence of flexible manufacturing systems as universally efficient solutions (Camisón and López, 2010). Closely associated to the latter is the balance that exists between effective and economical solutions. Flexibility is often viewed as a counter balance to uncertainty, manufacturers are confronted with the creation of production lines that are prepared to predict demand and at the same time easily and profitably adapt to other demand scenarios (Weyand and Bley, 2010). As described above, multi-skilled worker´s ability to comply with flexibility is an important part of its implementation; hence, the importance of verifying a flexible assembly concept before any resources are committed to it.

2.3 Virtual Verification

Virtual verification makes extended use of digital tools. Where the use of digital tools means to reach shortened planning times and the flexible configuration of the planning process, which in turn influence the production towards a quicker adaptation to changing circumstances and shortened time to bring a product onto the market (Zülch and Stowasser, 2005). The vision of the Digital Factory is to provide end-to-end transparency in real time, allowing early verification of design decisions in the sphere of engineering and both more flexible responses to disruption and optimisation across a company’s production site (Americon and Antonio, 2011).

Hence, the importance of verification and validation in a digital factory. On the one hand verification is used to evaluate whether compliance with regulations, specifications, or conditions exist when compared to the development phase (Babuska and Oden, 2004). On the other hand validation provides a high degree of assurance that a product, service, or system accomplishes its intended requirements (Plant and Gamble, 2003).

The early design phases have been identified as offering the best opportunities to enhance the performance of a new product or process. The same is true in terms of realising the benefits of early verification of complex assemblies (Maropoulos et al., 2011). Benefits of an early approach and the use of virtual tools for verification include: reduction of time and cost, as virtual verification leads to better decision making early on; robust and high quality systems, as alternative solutions are tested earlier; and a continuous process verification, where all modifications to a system are verified with simulation before approval (Klingstam and Olsson, 2000).

A virtual verification approach to manufacturing benefits companies with both a high degree of automation and a manual assembly process is wide spread. Since virtual production system hasten the production ramp-up, operators know the planned system better and can study the parameters and features of the new system before anything is installed on the factory floor (Heilala and Voho, 2001) that provide a direct impact on the factory floor.

3. MULTI-PRODUCT ASSEMBLY SYSTEM CASE STUDY

3.1 Traditional Assembly

A case study approach was carried out to investigate the transition from a traditional assembly line of earth moving equipment to a multi-product one with the use of virtual verification tools as enablers of the study. The study focused on the assessment of the effects of operator flexibility in the face of a multi-product assembly system with high work content variation between different assembly steps where not only different models but altogether different products were to be assembled. Discrete event simulation (DES) was used as a virtual verification tool in the study.

Earth moving equipment assembly is a labour intensive process with low production volumes, high work content at each stage of the assembly process, and where assembly lines are dedicated to a single product type. Each assembly station in the line is assigned a set of operations to perform in a defined sequence. Products remain in a station until the set of operations is completed.

The group of operations that occur within a station are known as work content. Work content is constant in a station, as assembly operations are standardized to build a product, but work content length, that is the time it takes for work content to be performed, varies from one station to another as different sets of operations are required for product build up. Work content is comparable to machine cycle time as it defines the pace of work and the length of time a product has to spend in every assembly station.

There exists a relationship between the length of work content, and quantity of operators in an assembly station. The number of operators in a station will vary based on the work content assigned to a station. The quantity of operators in a station is defined by the relationship between work content in that station and line takt time as shown in Equation (1) where O equals the number of operators assigned to station, WC is the work content assigned, and T is the takt time in the line. Equation (1) assumes an operator utilization of 100% at all times.

$$\text{Operator assignment according to work content and takt time:} \quad O = \frac{WC}{T} \qquad (1)$$

3.2 Proposed Alternative to Assembly

A multi-product assembly concept was developed as an alternative assembly system. Flexibility was core to the development of the concept and included the fabrication of different products in the same assembly line, as a result the need for flexible personnel was deemed critical. A multi-product approach to assembly required a new system of operator assignment based on flexibility.

Three different products were selected for assembly in the multi-product assembly concept. Products were to be fabricated in a nine station assembly through an entirely manual process. A consequence of this multi-product approach was the difference in work content at every stage of the process. Work content length was modified when compared to that of the traditional assembly system as a result of both modules being assigned to specific assembly stations, and an increase in the number of products being assembled. Difference in work content length varied from station to station and between products.

Figure 1 shows the variation in work content length for each module of assembly for all products considered in the conceptual line. It follows that with variation in assembly time between stations there exists an inefficient utilization of labour in the form of line balance loss. A product with a high fabrication time will require a long time to transfer into the next stage of the process and it will also constraint the assembly flow. Opposite to the above, a product with a short fabrication time will wait idle until subsequent resources become available.

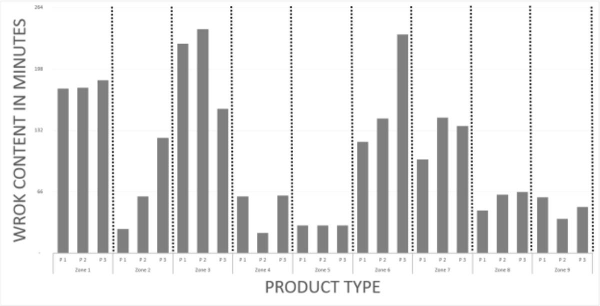

Fig. 1. Work content variation for products 1 – 3.

As opposed to the traditional approach of their being operators fixed to a station, the new method of operator assignment envisioned moveable operators who would be reassigned to assembly zones depending on the length of work content, and trained to assemble different product types in the same assembly line. Operator assignment has a double impact in the concept´s process.

Firstly, operators and their ability to carry out tasks at different ends of an assembly line in the same production cycle has been associated with the increase in the degrees of freedom of the balancing decision considerably (Boysen et al., 2008). Furthermore, as the demand of production models is likely to undergo remarkable changes over time, any assembly line configuration may stop meeting the production requirements after some time. This entails having a flexible workforce and easily reconfigurable lines, so that assembly can often be moved forward from one station to another with low costs (Merengo et al., 1999).

Secondly, the processing times at each station are significant decision variables that can be used to minimize production costs (Schweitzer and Seidmann, 1991). Traditional assembly of earth moving equipment supports the above statement. When a stage of high work content strangles the flow, additional operators are reassigned to distribute the work content and reduce the processing time. This principle was carried over into the multi-product assembly system as different levels of operator flexibility were tested.

3.3 Virtual Verification Approach

The multi-product assembly system described presents a completely different approach from the traditional earth moving equipment assembly systems. There is a need to confirm whether the proposed concept is feasible, and although physical prototyping and testing are industrial requirements it is also desirable to gain insight into the concept without indiscriminate use of resources. Verification of digital processes ensures the throughput feasibility of the production system by building the simulation model of the production line, analysing and optimizing production system layout, logistics bottleneck, the utilization rate of resource, etc., which are based on digital product, tools, resource, process, and production creed (Jia et al., 2009). DES is one such tool in virtual verification that allows the dynamics of complex manufacturing systems to be verified without physical implementation.

4. MODEL DESCRIPTIONS

4.1 Discrete Event Model

A DES model was built with the software platform ExtendSim to evaluate the effect of operator flexibility in the context of a multi-product assembly system. Three different types of operator crews were established with varying degrees of flexibility. The objective of the simulation model was to determine the assembly cost associated to each operator crew and its corresponding level of flexibility.

Operator Flexibility. Operator flexibility was associated to the number of assembly stations an operator could work in. Operator flexibility was defined as an operator´s capacity of movement in the assembly line and his or her ability to perform different assembly tasks along the line. The three different schemes of operator flexibility evaluated were:

- Fixed Operators – An operator was permanently assigned to a station. Operator movement was limited to activities that occurred within the assigned station.
- Mixed Operators – Operators were assigned to a station, but operators could move into adjacent assembly areas to perform work once work at their original station concluded.
- Flexible Operators – A pool of operators was determined but no operators were assigned to any station. Operators moved freely between stations regardless of physical distance as long as there existed a need to perform work at any stage of the process.

The assignment of operators in a station determined the time a product spent in each stage of assembly. Hence a product required a certain quantity of work content to be performed in a station before it were moved down the line, and the total length of the work content was divided in equal parts by the number of operators present in the station. The relationship between work content and operator crew size is shown in Table 1. A change in the number of operators in a zone meant a shorter or higher fabrication time, and a change in the amount of time a product spent in a station. An important assumption in the model is that no loss in operator efficiency was considered as a result of worker.

Table 1. Work content vs crew size for different levels of flexibility.

	Work Content in Minutes			Crew Size		
Station Name	P1	P2	P3	Fixed	Mixed	Flexible
Station 1	177	178	186	3	3	18
Station 2	26	61	124	2	1	
Station 3	225	241	155	4	5	
Station 4	61	22	62	1	1	
Station 5	30	30	30	1	1	
Station 6	120	145	235	4	3	
Station 7	101	146	137	3	2	
Station 8	46	63	66	1	1	
Station 9	60	37	50	1	1	

Cost of Assembly. Operational status of each zone was divided into three categories as a percentage of the total available time. First, an assembly station was considered utilized if assembly work was performed by the operators. Second, a lack of assembly material in an assembly zone meant that the operation remained idle (that is with the possibility to perform work but no product to work with). Third, if a zone were to have a product but could not move the product onto the next assembly step, as result of a longer fabrication time in the subsequent process, then the zone´s status was deemed blocked.

The operational status of each zone, the number of operators assigned according to its flexibility level, and the total available time were used to quantify the total cost of assembly. The Cost of Assembly (CA) is defined in Equation (2) where the Idle (*I*) and Blocked (*B*) operational statuses for each station in the process were recorded in a length of Available time (*S*), and the number of Operators (*O*) in each station were accounted for.

$$\text{Cost of Assembly:} \quad TA = \sum_{n=1}^{m} OS(B+I) \qquad (2)$$

The model assumes that an assembly zone will consume resources regardless of whether demand is present or not. Therefore the Cost of Assembly is defined as a function of a station´s operational status: busy, idle, or blocked. The Cost of Assembly is used as a measure that relates operator flexibility with the assembly operation.

Products and Product Mix. Products P1, P2, and P3 supplied the model based on takt time established by the total working hours (T_a) in a year (3 600 hours) and the total yearly demand (*D*) of items (3 200) units according to Equation (3). The type of product entering the model was randomized based on the proportion of demand by product as shown in Table 2.

$$\text{Takt Time:} \quad T = \frac{T_a}{D} \qquad (3)$$

Table 2 Yearly demand by product type

Product Type	Yearly Demand	Demand as a Percentage
P1	1900	59%
P2	800	25%
P3	500	16%

4.2 3D Visual Model

The software 3D Create was used to develop a dynamic visual representation of the assembly line. The different types of operator flexibility: fixed, mixed, and flexible were represented in this model to showcase the movement of operators through the assembly process show in Fig. 2 Visual representation of the model served to demonstrate the interrelation between operators in a dynamic environment and depict both material and operator crew flow.

Fig. 2. Work crew assignment.

5. RESULTS AND DISCUSSION

5.1 Simulation Results

Simulation results of the DES model after Assembly Cost analysis are shown in Table 3, and the corresponding level of Idle and Blocked time of the assembly line as a percentage in Fig. 3 both charts correspond to a simulated year worth of assembly. The results show that a higher degree of operator flexibility correlates to a lower level of assembly cost. More importantly, the results indicate that despite the existence of a unevenness in Blocked and Idle time at every stage of the process there is a potential for the reduction of Assembly Cost as a function of operator crew assignment situation that could further increase as a result of a reduction in the variation of work content in the assembly process. Additionally the results show a decrease in the yearly wasted hours (idle or blocked hours) as operator flexibility increases.

Table 3. Assembly Cost as a Function of Crew Flexibility per Year.

Crew Flexibility	Assembly Cost in hours
Fixed	18 800
Mixed	14 900
Flexible	8 500

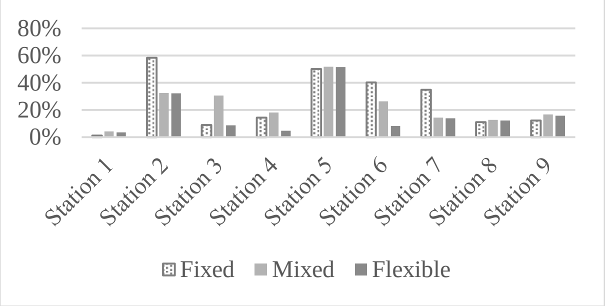

Fig. 3. Work crew assignment.

5.2 Discussion

Virtual verification tools provide insight into the effects of a process with measurable data that can serve as a means of comparison between different alternatives (i.e. operator flexibility). Results from the visual model helped develop an understanding of how and when would operator crews interact in a multi-product assembly line. The results of the visual model are not be taken lightly as they provide a graphical understanding on whether the situations proposed in the DES model are achievable. Visual results, although not at the same level as physical tests, do provide insight into the concept before implementation.

There exists a high degree of complexity in an multi-product assembly system of which a mix of very different products with varying levels of work content between stations is but one of the factors. Yet answering whether or not the realization of a conceptual system is possible to handle with different level of operator flexibility is a relevant question as it details the requirements, in the case of this study cost of assembly, associated to such a project.

The results of the study served to establish a cost of assembly as function of operator flexibility. The results indicate a potential for the reduction of idle and blocked time in assembly. Further development of the model may illustrate operational benefits in the presence of varying levels of demand and seasonality. Additionally, future studies might include a greater number of parameters associated to operator flexibility cost such as variability in work performance, ergonomics, learning curve of operators, and an operator’s limitations to perform efficiently enough assembly work for a variety of products. The inclusion of the above state parameters may affect the numerical outcome of the cost of assembly, yet this in itself makes a case for the use of virtual verification as a tool for decision making in a multi-product assembly system.

REFERENCES

Americon, A. and A. Antonio (2011). Factory Templates for Digital Factories Framework. *Robotics and Computer Integrated Manufacturing*: 755-771.

Babuska, I. and J. T. Oden (2004). Verification and validation in computational engineering and science: basic concepts. *Computer Methods in Applied Mechanics and Engineering* **193**(36): 4057-4066.

Beach, R., A. Muhlemann, D. Price, A. Paterson and J. A. Sharp (2000). A review of manufacturing flexibility. *European Journal of Operational Research* **122**(1): 41-57.

Boyer, K. K. and G. K. Leong (1996). Manufacturing flexibility at the plant level. *Omega* **24**(5): 495-510.

Boysen, N., M. Fliedner and A. Scholl (2007). A classification of assembly line balancing problems. *European Journal of Operational Research* **183**(2): 674-693.

Boysen, N., M. Fliedner and A. Scholl (2008). Assembly line balancing: which model to use when? *International Journal of Production Economics* **111**(2): 509-528.

Bukchin, J., E. M. Dar-El and J. Rubinovitz (2002). Mixed model assembly line design in a make-to-order environment. *Computers & Industrial Engineering* **41**(4): 405-421.

Camisón, C. and A. V. López (2010). An examination of the relationship between manufacturing flexibility and firm performance: the mediating role of innovation. *International Journal of Operations & Production Management* **30**(8): 853-878.

Chambers, S. (1995). Flexibility in the Context of Manufacturing Strategy - Process and Content. London, Champman & Hall.

Comstock, M., K. Johansen and M. Winroth (2004). From mass production to mass customization: enabling perspectives from the Swedish mobile telephone industry. *Production Planning & Control* **15**(4): 362-372.

Daaboul, J., C. Da Cunha, A. Bernard and F. Laroche (2011). Design for mass customization: Product variety vs. process variety. *CIRP Annals-Manufacturing Technology* **60**(1): 169-174.

Dangayach, G. and S. Deshmukh (2001). Manufacturing strategy: literature review and some issues. *International Journal of Operations & Production Management* **21**(7): 884-932.

De Toni, A. and S. Tonchia (1998). Manufacturing flexibility: a literature review. *International Journal of Production Research* **36**(6): 1587-1617.

ElMaraghy, H. A. (2005). Flexible and reconfigurable manufacturing systems paradigms. *International journal of flexible manufacturing systems* **17**(4): 261-276.

Gerwin, D. (1987). An agenda for research on the flexibility of manufacturing processes. *International Journal of Operations & Production Management* **7**(1): 38-49.

Gerwin, D. (1993). Manufacturing flexibility: a strategic perspective. *Management science* **39**(4): 395-410.

Hayes, R. H. and S. C. Wheelwright (1984). Restoring our competitive edge: competing through manufacturing.

Heilala, J. and P. Voho (2001). Modular reconfigurable flexible final assembly systems. *Assembly Automation* **21**(1): 20-30.

Hu, S. J., J. Ko, L. Weyand, H. ElMaraghy, T. Lien, Y. Koren, H. Bley, G. Chryssolouris, N. Nasr and M. Shpitalni (2011). Assembly system design and operations for product variety. *CIRP Annals-Manufacturing Technology* **60**(2): 715-733.

Jia, C., Y. Liu and X. Xia (2009). Research and application of digital assembly process planning and simulative validation. *Mechatronics and Automation, 2009. ICMA 2009. International Conference on*, IEEE.

Kara, S. and B. Kayis (2004). Manufacturing flexibility and variability: an overview. *Journal of Manufacturing Technology Management* **15**(6): 466-478.

Klingstam, P. and B.-G. Olsson (2000). Using simulation techniques for continuous process verification in industrial system development. *Simulation Conference, 2000. Proceedings. Winter*, IEEE.

Maropoulos, P. G. and D. Ceglarek (2010). Design verification and validation in product lifecycle. *CIRP Annals-Manufacturing Technology* **59**(2): 740-759.

Maropoulos, P. G., P. Vichare, O. Martin, J. Muelaner, M. Summers and A. Kayani (2011). Early design verification of complex assembly variability using a Hybrid–Model Based and Physical Testing–Methodology. *CIRP Annals-Manufacturing Technology* **60**(1): 207-210.

Mehrabi, M. G., A. G. Ulsoy, Y. Koren and P. Heytler (2002). Trends and perspectives in flexible and reconfigurable manufacturing systems. *Journal of Intelligent manufacturing* **13**(2): 135-146.

Merengo, C., F. Nava and A. Pozzetti (1999). Balancing and sequencing manual mixed-model assembly lines. *International Journal of Production Research* **37**(12): 2835-2860.

Meyr, H. (2009). Supply chain planning in the German automotive industry. Supply Chain Planning, Springer**:** 1-23.

Michalos, G., S. Makris, N. Papakostas, D. Mourtzis and G. Chryssolouris (2010). Automotive assembly technologies review: challenges and outlook for a flexible and adaptive approach. *CIRP Journal of Manufacturing Science and Technology* **2**(2): 81-91.

Molleman, E. and A. van den Beukel (2007). Worker flexibility and its perceived contribution to performance: the moderating role of task characteristics. *Human Factors and Ergonomics in Manufacturing & Service Industries* **17**(2): 117-135.

Plant, R. and R. Gamble (2003). Methodologies for the development of knowledge-based systems, 1982–2002. *The Knowledge Engineering Review* **18**(01): 47-81.

Schweitzer, P. J. and A. Seidmann (1991). Optimizing processing rates for flexible manufacturing systems. *Management science* **37**(4): 454-466.

Slack, N. (1987). The flexibility of manufacturing systems. *International Journal of Operations & Production Management* **7**(4): 35-45.

Souza, M. C. F., M. Sacco and A. J. V. Porto (2006). Virtual manufacturing as a way for the factory of the future. *Journal of Intelligent manufacturing* **17**(6): 725-735.

Upton, D. (1994). The management of manufacturing flexibility. *California management review* **36**(2): 72-89.

Weyand, L. and H. Bley (2010). Considering Worst-Case Scenarios within Final Assembly Planning, na.

Zülch, G. and S. Stowasser (2005). The Digital Factory: An instrument of the present and the future. *Computers in Industry* **56**(4): 323-324.