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DIGITALISATION IN AUTOMBILE INDUSTRY

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Abstract

Digitalisation offers ways as well as means for manufacturers to adapt their production systems to handle diversifying and rapidly changing market demands. Yet, small and medium sized enterprises are often overwhelmed by the speed of development of ICT solutions as well as ICT business schemes. This paper discusses how tools of the Digital Factory enable decision-makers to assess digitalisation measures during the planning process to take full advantage of newly available technologies. Potentials and prerequisites for the application of available tools are argued and illustrated considering an in-depth example on the simulation of an automotive supplier's tool management process

Introduction

As consumers and marketing strategists push for shorter product life cycles and faster innovation, many manufacturing companies are struggling to keep up and resist the pressures of change. Unlike most consumer electronic equipment, the production equipment takes longer to build, and the only becomes economical after a longer period of operation. Therefore, production companies need to find ways to adapt their machines, processes and systems to deliver faster Time-to- Volume, time to market and (ideally) personalization . Digitization and use of cyber-physical (production) systems should address the above challenges. The general architecture of the is a key aspect of its application.

Their development progressed to at the rather abstract level and a more practical level . However, the conservative attitude and tight profit margins of manufacturing companies are still hampering the digitization process. The German federal government aims to solve these problems and to increase the participation of small and medium-sized enterprises (SMEs) through the "Mittel stand 4.0" program . Competence center in Chemnitz was created within the framework of this program, with among others.

A specific focus on the use of tools of the Digital Factory. These offer means to integrate a Product Lifecycle Management (PLM) perspective in all relevant decision-making processes,effectively improving trust in devised digitalisation strategies and measures implemented in the light of these. This also follows the research need concerning PLM indicated in [4].This paper reports on findings of Chemnitz' "Mittelstand 4.0" centre of competence that relate to the use of Digital Factory tools for planning digitalisation measures. Given the centre's scope, hereafter presented observations and insights were made during numerous events aimed to foster the digital transformation of SME manufacturers. The following sections provide an overview on typical digitalisation strategies and discuss the potentials of as well as the prerequisites for using Digital Factory tools when planning specific measures. An in-depth example (taken from a related Industry 4.0 project) of the digitalisation of an automobile suppliers tool management process is presented in section 4 to showcase the capabilities and benefits of using material flow simulation before the realisation phase commences. Lastly, lessons learned from the case study are discussed to reflect on previously introduced potentials and prerequisites before concluding the paper.

Overview on digitalisation strategies Ulrich et al. describe two diametrical different paths of development (or strategies) companies may take to digitalise their business. They can either transform their processes and production sites incrementally or they can undergo radical change by exchanging entire processes and systems with fully digitalised ones . While the latter promises an immediate switch to the latest technologies, it will require substantia equity and a noteworthy period of transitioning. It is assumed that SMEs typically do not have the economic strength to sustain such a revolution. Yet, they are eager to employ novel technologies in their factories to raise their competitiveness.

Following an incremental strategy, single workplaces, machines or production lines are selected as initial testing beds and digitalised one by one. Thus, hurdles experienced on the way do not affect the entire factory and requirements for a future, gradual rollout of specific measures can be derived. This way, changes to the production system, the IT infrastruc- ture and the staff qualifications may be defined rather easily whereas risks like productivity losses and deficient acceptance are reduced. Likewise, Bauernhansl emphasises the step by step integration of decentral use cases that illustrate potentials and raise acceptance on all hierarchy levels. Paulus-Rohmer et al. present a generalised implementation roadmap for manufacturing companies and their strategic positioning that comprises four steps . It can be adopted by SMEs following an incremental strategy. The first basic step concerns the identification of the present position and the actual state of the enterprise in its current environment from an internal as well as an external perspective. The following step focusses on the analysis and definition of the desired target state, including potentials and feasibility studies. The third phase refers to the realisation of the strategic position by implementing prototypes and designing business models. Finally, the overall rollout and change management processes are required for adjusting the whole organisation. The last three steps are typically performed iteratively. Alternatively, Schuh et al. formulate a general procedure that comprises six stages [8]. It focusses on the benefits of digital competencies based on the accessible information. In contrast to the incremental strategy, radical change requires major simultaneous transformations of whole production areas. Consequently, various hierarchy levels need to interact promptly according to a previously defined road- map. This demands flexibility as well as willingness of the affected employees to successfully complete such a change. Findings of project-related and other themed events hosted by Chemnitz' "Mittelstand 4.0" centre of competence suggest that SMEs are willing to undergo digitalisation when transformation processes are clearly structured, economically feasible and build on one another. Thus, risks are reduced and acceptance among workers is continuously facilitated. This makes the use of appropriate tools in the preceding planning process a necessity. SMEs particularly require support for the selection and target-oriented application of Digital Factory tools, since the range of available software and planning devices is everchanging. At the same time, these tools need to fulfil certain prerequisites to be applied efficiently.

Potentials and prerequisites for Digital Factory tools Digital Factory tools provide general means to support production system planning. The following section gives an overview on the general concept. Thereafter, potentials for its application in planning digitalisation strategies are discussed. At last, prerequisites for the efficient application of such tools are argued based on experience from "Mittel stand 4.0".

Overview on the Digital Factory concept The VDI 4499 Part 1 elaborates the target, the scope and characteristics as well as application areas of the Digital Factory [9]. Its general definition includes that a variety of tools and methods for visualisation and simulation are integrated by consistent data management. Moreover, it is characterised by a holistic approach that typically focusses on but is not limited to the early production planning phase. Application areas include design, project management, production system planning, production ramp-up, serial production, order management, etc. Likewise, Kühn names the application areas of these tools as product development, factory and production planning, production ramp-up and production operation as well as order management .

The Digital Factory considers various physical and imma-terial planning objects that can be categorised as follows:

 Plant, machinery, and logistics: efficient planning of facilities and equipment in close relation to material and information flows

 Floorspace and layout: appropriate arrangement of buildings, rooms, spaces, and objects

 Auxiliary operations: integration of auxiliary functions related to the main processes into the factory

 Organization: planning of structures, sequences and required qualifications

 Building, design and infrastructure: definition of an appropriate design of the working environments as well as the efficient supply of required media

Thus, the application of Digital Factory tools in these areas support technical planning tasks and may enhance the fulfilment of previously defined economic and organizational goals. Selected potentials from their applications in a digitalisation process are presented in the following section.

Potential in Different Application Scenarios

With reference to the planning objects mentioned above, the possible benefits of using digital factory tools can be identified at different stages of designing a digitization strategy . This is detailed below taking into account the roadmap described by Paulus-Rohmer et al. (See item 2). 4244 Raw state assessment of production systems can be supported 4244 by digital factory tools, for example to identify 4244 bottlenecks and other causes of loss of operational 4244 efficiency and plant logistics.

Critical areas and security can assess aspects of the current structure and highlight aspects. The different tools available provide the means to 4044 the potential in different application scenarios With reference to the planning objects mentioned above, it is possible to identify 4044 the possible benefits of using the Digital Factory tools at various stages of designing a digitization strategy.

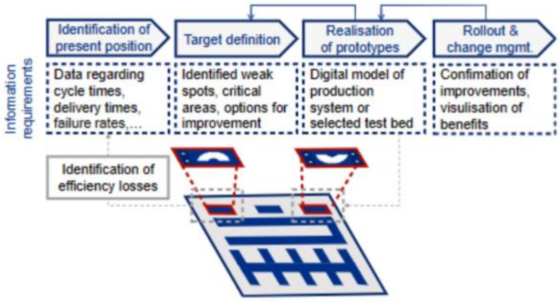
This is detailed below taking into account the roadmap described by Paulus-Rohmer et al. (See item 2). Raw condition assessment of production systems can be supported by digital factory tools, e.g. Critical areas and security can assess aspects of the current structure and highlight aspects.

Prerequisites for planning digitalisation using Digital Factory tools

Since Digital Factory tools vary in their scope of application, it is necessary to always select the appropriate tools for the issues at hand. Each phase of the digitalisation process requires specific information that can be generated using a domain specific Digital Factory tool. For instance, material flow simulation may support digitalising logistics process while human work simulation can be beneficial to design a human robot cooperation work system. Data integration between domain specific tools and factory ICT systems is of great importance for an iterative digitalisation strategy.

Data acquisition, preparation and conversion typically demand many resources in planning projects. An automotive study showed that standardisation, stringent data management, system integration and workflow management are rated as the most important challenges for Digital Factory tools. The digitalisation of production systems provides the means to improve the availability of data in general.

Thus, models can be built and updated more quickly and more efficiently, if ICT systems and tools provide suitable interfaces. A survey among German SME’s showed that re-planning and re-scheduling has become significantly more important in the recent ten years [13]. Digitalisation in the production environment is due to but also furthers this development. Digital Factory tools can support handling more frequent change in companies. To show their full advantage, a comfortable user experience is a necessity. Only if the tools integrate seamlessly into all relevant planning processes, they will show their full potential. Consequently, planners and plant managers can be assisted but will not be replaced by tools.



Case study: Simulation of a tool management process

Within the Smart Pro project [14], Robert Bosch in Homburg (Saar) has worked towards the digitalisation of various processes in their factory, following an iterative strategy. Thus, a simulation study for a n exemplary tool management(logistics) process was implemented to evaluate the effects of planned changes before their realisation. This study show- cases general issues production companies of any size face when planning for digitalisation and how the use of Digital Factory tools may support the process. The following sections discuss the investigated system, the developed simulation model, executed experiments as well as some selected results.

4.1. Production system and aims of the digitalisation efforts

The investigated system is part of a factory that produces diesel systems for various markets. Three grinding machines are in the centre of the digitalisation efforts undertaken within the Smart Pro project. Each of these grinds many rotationally symmetric metal parts in a typical 15 shifts per week working schedule. The machines allow for simultaneous processing of two parts and require two types of tools for each of the processing stations (i.e. four tools in total). One type of tool has a base body which can be reused by the supplier to manufacture new tools ("Reuse") while the other has a disposable base body that is discarded after the tool has accumulated too much wear ("Dispose"). Before the digitalisation, multiple aspects showed a lack of transparency:

 Tool wear: While the number of parts between automated dressing cycles is known, workers may start additional cycles manually. How this effected the typical life expectancy of a tool was hitherto unknown.

 OEE tracking: The overall equipment effectiveness (OEE) was previously tracked using paper forms in the shop floor. These had to be evaluated manually and the results transcribed in an ICT solution. This process was prone to inconsistencies while requiring additional manual work.

 Tool re-procurement: Due to their rather long-life expectancy and a short, reliable supply chain, only very few Reuse tools are in the process. However, the procurement process of the Dispose tools required substantial effort to validate current stock figures, future production, etc.

Identification of present position Rollout & change mgmt. Information requirements Data regarding cycle times, delivery times, failure rates,...Identified weak spots, critical areas, options for improvement Digital model of production system or selected test bed Confirmation of improvements, visualisation of benefits Identification of efficiency losses Realisation of prototypes Target definition

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The last bullet point is affected by the former ones and was therefore, selected for investigation in the simulation study.

Fig. 2 depicts an overview of the system and the relevant tool re-procurement processes. The three machines are in the centre and produce parts continuously until the wear of a tool exceeds a certain threshold. Then, the tool body is taken from the machine and is disposed or collected in the “Outbound Store Reuse” for return to the supplier. Next, a new tool is taken from the corresponding store in front of the machine and placed in the machine. This process typically requires about four times as much time for Reuse tools than for Dispose tools but is also necessary less frequent for the earlier.

Whenever the stock in “Store Reuse” drops below a threshold, a Kanban card is forwarded to the foreman responsible for tools who notifies “Disposition Reuse” (“Dispatcher notification”). From there, an order is placed with the “Supplier Reuse” and the tool is restocked within a short span of time.

Similarly, a Kanban card is used to notify the foreman of a shortage of Dispose tools, who will then notify the warehouse to ship another container of these in the next internal milk run (starts multiple times a day). The company’s ERP system monitors the warehouse stock and will notify “Disposition Dispose” (“Dispatcher notification”) when a re-procurement is required. The responsible dispatcher will then validate the company stocks and the expected tool demand extrapolating from the past demand. This typically requires multiple phone calls until, eventually, an order is placed with the supplier and the tool is restocked after a greater number of weeks with multiple containers of tools.

Considering the above-described state (i.e. the results of the first phase of the digitalisation strategy by Paulus-Rohnert al., see section 2), the simulation study was expected to quantify the potential for process improvements in the re- procurement process (phase 2). Particularly, the digitalisation of the Kanban processes and improvements for the dispatcher in “Disposition Dispose” were in the scope of research.

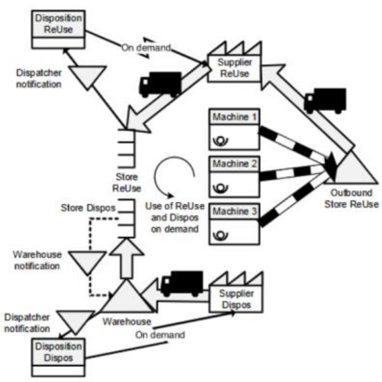

Fig. 2. Overview of the investigated production system.

Model implementation and validation

A model of the system was implemented in the discrete event simulation software Siemens Plant Simulation. For this purpose, the machines were modelled as complex entities that comprise five processing stations: one station for manufacturing parts, two stations for “using” Reuse tools and another two for Dispose tools. The part station is fed continuously from an outside source and emulates the behaviour of the actual machine, where a finished part leaves the machine every few seconds. This station acts as the machines heartbeat by keeping track of the number of parts manufactured and by providing a counter to be referenced for simulating tool wear. The number of parts a tool will last is assigned when it enters an instance of the machine model. Once it is worn out, it will exit the machine and is replaced. Upon model initialisation, tool wear is assigned randomly between 0 % and 100 % to avoid that all tool changes follow an equal change rhythm.

The re-procurement processes as well as the Reuse tool body collection process were also modelled using (simple) processing stations and intermediate stores that followed the various steps described in the previous section. An overview of the simulation model is depicted in Fig. 3.

Various operation schedules have been configured for the different processes. The disposition processes and the foreman generally operate eight hours per day schedule for five days a week. Shipments from external suppliers or the warehouse follow a five days per week schedule. Production processes can be configured to work 0, 10, 15 or 17 shifts per calendar week. Recurring non-productive times (e.g., regular maintenance) have been removed from the schedules, while stochastic failures (OEE losses) were configured as such for the machines. A factory calendar can also be applied to realistically include public holidays, factory vacations, etc. in the simulation. The ERP system checks the warehouse stocks of Dispose tools every night. Additional parameters were implemented to allow for varying process lengths, stock thresholds, re-procurement quantities as well as model logic, etc. during the experimentation phase of the simulation study.

All the model's logic and parameterisation were successfully validated against historic data for production volumes and tool demand from 2016. The accuracy of the simulation production output was determined to be at about 99.68 %. The simulated tool demand was equally accurate.

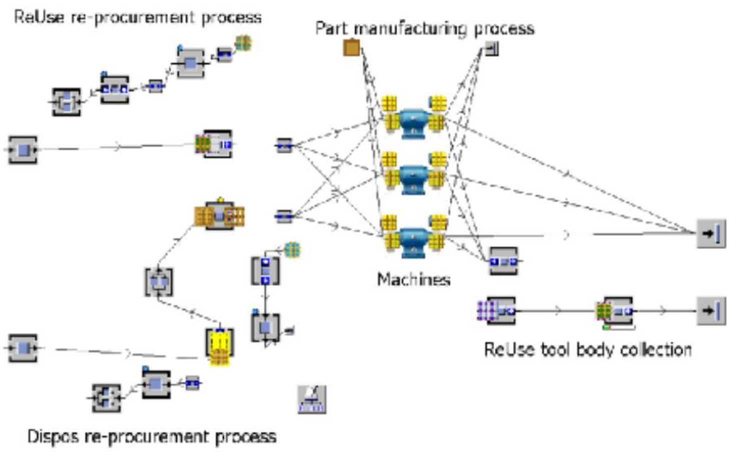

Fig. 3. Overview of the simulation model.

Results

Selected findings from the executed experiments are elaborated hereafter. For confidentiality reasons, absolute Figures had to be omitted, mostly.

The results of experiment #1 showed that it took up to approx. 3 days and an average of 11.5 hours to inform the warehouse another tray of Dispose tools had to be shipped to "Store Dispose" in the status quo. This can be explained by the discrepancy between the production schedule and the foreman's shift schedule. By means of an electronic Kanban process, this time can be eliminated. However, as the warehouse is only working 15 shifts a week, the actual response time (i.e. the time it takes to get a container on the next milk run) was measured to be at an average of 1.5 hours (approx. 1 day at the most) in the simulation. From an economic point of view, these durations become relevant, if tool shortages are experienced at the machines. This was not the case in any of the simulations executed in this experiment.

Actual saving potentials in the use of electronic Kanban can be found in the time it takes the foreman to notify the warehouse (or "Disposition Reuse). It can be calculated as the product of notifications sent and time required per instance. This valuation is trivial, can easily be done manually and, hence, does not require the use of simulation.

Afore-mentioned tool shortages can be caused by pro- longed delivery times or variations in the tool life expectancy.

Experiment #2 studied the effect of the former on the time the warehouse or “Store Dispose” was emptied. The results (relative to the maximum of either) are depicted in Fig. 4.

Fig. 4. Effect of prolonged delivery times on empty time (relative to max).

It is apparent, that an increase of 18 % will cause shortages in the warehouse of varying severity for different random number streams in the replications. A shortage at the machine is only experienced at above 125 % delivery time. After careful examination of these results with the system operator, it was decided that such situations require human intervention and cannot be solved by process digitalisation alone.

Experiment #3 aimed to determine, if varying tool life expectancy would cause tool shortages like the above. The simulations showed this was not the case.

Lastly, experiment #4 was executed to evaluate a new dynamically forecasting disposition algorithm. To assess its performance, a safety stock for the warehouse was defined and the time it was violated (i.e. the time the warehouse stock was below the safety threshold) measured. Fig. 5 depicts the results, comparing the original (fixed value) disposition rulesto the dynamic ones. Again, the minimum, average and maxi- mum results from all replications are shown. The values have been standardised to the maximum value measured for the original disposition rules in the status quo (0/0). The variation of the tool life expectancy follows experiment #3 (i.e. x % of the tools have a life expectancy that is reduced by y %).

The results indicate that the new algorithm serves to improve the process’ robustness by drastically reducing and levelling the time of safety stock violations. However, this correlates with a slightly increased average stock (approx.6 %). Whether this is economically relevant depends on the Dispose tools value and the potential costs of tool shortages.

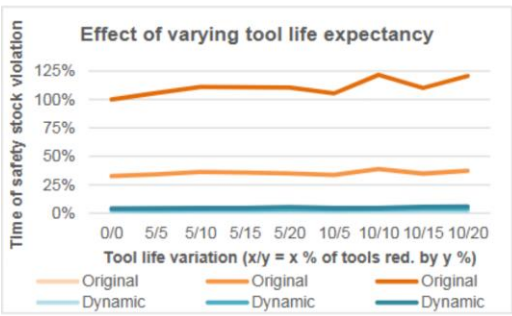

Fig. 5. Effect of varying tool life expectancy (relative to Original max at 0/0).

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0% 50% 100% Empty time (rel. to max) Delivery time Effect of prolonged delivery times Warehouse empty Store Dispose empty 0% 25% 50% 75% 100%125%

0/0 5/5 5/10 5/15 5/20 10/5 10/10 10/15 10/20

Time of safety stock violation Tool life variation (x/y = x % of tools red. by y %) Effect of varying tool life expectancy Original Dynamic

Discussion of lessons learned

The case study presented in the previous section provides an example for the application of Digital Factory tools in a digitalisation project. Considering the potentials and prerequisites discussed in section 3, it shows that a material flow simulation can be used to evaluate digitalisation measures for a logistics process prospectively. However, experiment #1 also illustrates that the tool choice is important, as trivial questions are more efficiently answered without applying complex models and tools. Still, the application of simulation was valuable in this study considering the other experiments.

These gave a better understanding of the system's dynamics and how a new disposition algorithm would change them.

Data acquisition and processing proved expectably difficult but also very valuable in the process of developing digitalisation measures. Hitherto distributed knowledge was collected and discussed with various stakeholders before it got used in the simulation study. This has sparked valuable discussions and illustrated the need for the digitalisation of the processes because some input data and pieces of information could not be collected accurately in the original system state so that more complex data analysis was required to gather valid inputs for the simulation. Moreover, the experiences support the hypothesis that Digital Factory tools require interfaces to integrate seamlessly with factory ICT systems, to allow for efficient planning in an iterative digitalisation process.

Using Digital Factory tools, it also becomes possible to economically assess digitalisation measures during the planning phase (e.g. using the framework presented in [15]).

The case study showed, however, that this must be done very carefully and mindful of the actual benefits digitalisation brings in the long run. Its greatest advantage lies in creating transparency in processes that hitherto required tedious manual data acquisition and evaluation or lacked sufficient data acquisition altogether. Hence, Digital Factory tools provide the means to support the implementation of specific measures and can also benefit from digitalisation. Yet, they should not be used as the sole basis for the strategic decision on whether a factory should undergo digitalisation or not.

Summary and outlook

This paper discusses how Digital Factory tools can be used in planning a SME manufacturer's digitalisation strategy.

Relevant potentials during the initial system analysis, the target state definition and the implementation of measures were elaborated. Since the application of the Digital Factory concept in the planning phase for specific digitalisation measures demands for an efficient use of resources, prerequisites for the application of available tools were summarised. These findings from Chemnitz' "Mittel stand 4.0" centre of competence were showcased and discussed based on a simulation study of an automobile supplier's tool management process. The latter showed that especially the choice of tools is an important one in the planning process.

Furthermore, it highlighted the fact that digitalisation measures do not always translate into immediate cost savings. Future work in the centre of competence will aim to familiarise more SME companies with the digital transformation and Digital Factory tools. More research intel tool-assisted digitalised work process is also planned.

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