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TRANSPARENCY AND TRAINING IN MANUFACTURING AND LOGISTICS PROCESSES IN TIMES OF INDUSTRY 4.0 FOR SMES

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ABSTRACT

Based on our experience from multiple projects in the areas of production planning, scheduling, and delivery reliability in collaboration with small and medium enterprises (SMEs), we know that employees continue to change the planned manufacturing sequence at their workstations. Thus the expected optimum of the production planning cannot be reached. We will discuss the influence of different employee behavior patterns on the overall production output. We have developed a planning tool for optimization of production planning in manufacturing SMEs by means of simulation. This planning tool can not only support planners and machine operators, but can also be used as a training tool for employees in addition to improving the production sequence. It uses behavioral patterns to increase learning effects and generate higher system understanding on the side of the employees. In this study we use a simulation model to prove the negative effects of specific behavioral patterns.

1 INTRODUCTION

Production planning and control in small and medium-sized manufacturing companies is carried out by experienced employees, sometimes supported by complex software systems. The planners have to keep an eye on a variety of factors in order to factor in all target criteria, such as:

- Which customers are more important (customer classification)?
- Which products have higher profit margins?
- Is sufficient supply available? Which supplies are delayed?
- Current machine utilization (targets)?
- Which production sequence makes the most sense?

In doing so, a considerable amount of important information is incorporated into the creation of the entire production plan. Unfortunately, there hardly exists a production plan that is executed exactly the way it was planned. This is not only due to changing conditions, but also to employees who change the production sequence at their work centers. Each employee has preferences regarding the sequence of individual products, for example. Sequences are also changed because it makes sense from a local point of view to produce one product earlier than the other.

However, the planner in the manufacturing company can only be successful when they assess all influences affecting their partial decisions and their respective effects. Therefore, there is a need for application-oriented methods and procedures for designing production planning and control that consider all relevant aspects and criteria.

Production lists and schedules in small and medium size enterprises (SMEs) are often still in printed form. These printouts are sent to the individual workstations and employees. Some of these lists are already obsolete when they are printed and in addition, they are not very flexible when changes in the production process occur. Furthermore, these lists only give feedback at the end of a shift, when compared to the actual production output, about what has been produced and what has not.

Information systems can support employees in carrying out their tasks and operational processes. A great variety of commercial software products from various vendors for information or production planning and control systems exists at the market. Other approaches to the topic include flexible simulation support integrated into the Enterprise Resource Planning (ERP) system (Yang et al. 2016), multi-objective decision support models (Stricker et al. 2015) or integrated planning solutions to harmonize sales, purchasing, production and the supply chain (Auer et al. 2012), to name but a few. However, these information systems are often oversized, too complex, and too costly for manufacturing SMEs. In addition, they lack the integration of the most important asset of SME manufacturers, their longtime employees and their tremendous wealth of expertise.

Therefore, we have developed a digital production scheduling list available at each workstation to solve the aforementioned problems of printed lists, while leaving the responsibility in the hands of experienced planners. A display for that list is all that is needed to inform employees what to produce next. Employees can simply start and stop individual jobs or mark them as completed using Start and Stop buttons on their device. This low-cost solution results in no (unknown) sequence changes in production. The production planner is immediately informed about all process times and can detect deviations in real time.

However, this only solves part of the problem. Another challenge is to make machine operators aware of the effects of their actions, such as deviations from the plan and local optimizations. In order to counteract these problems, we focus on the training and further development of machine operators and planners. Based on typical deviations from plan we identified three behavioral patterns of machine operators which we describe based on the HEXACO model of personality structure of Ashton and Lee (2007). The contribution of this paper is to examine the impact of these three behavioral patterns on the overall performance of a manufacturing company through a simulation model. In this way, we can demonstrate the effects and make machine operators and planners aware of them in later trainings.

2 BACKGROUND

2.1 Tool for Planning and Control

In this paper, we will present our solution to the current shortcomings in production planning and control in SME in the manufacturing industry. We have developed a tool to assist employees in planning and control of manufacturing operations. This tool aids planners by giving them good starting solutions for their planning tasks, see Figure 1.

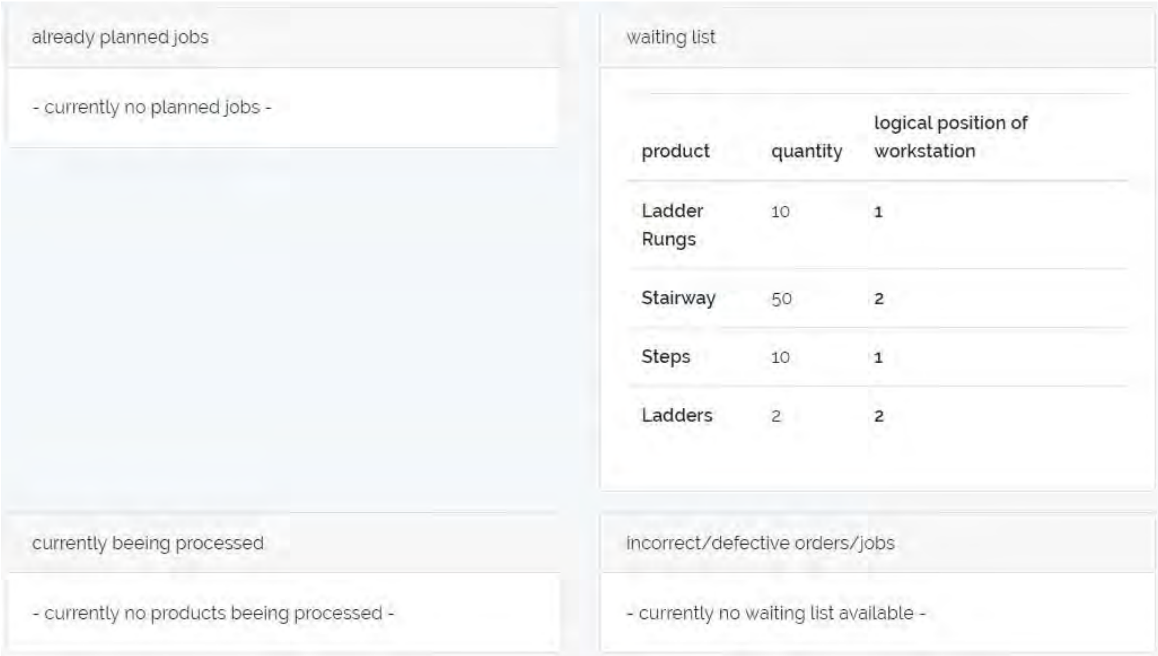

Figure 1: Example of a production plan in our planning tool.

After planning has been finished, the tool displays the pre-planned tasks to the machine operators who can mark these tasks as completed when they are finished, while the system still gives them the freedom to make their own decisions. The machine operators therefore receive the recommended work sequence, but can still react flexibly to current conditions and adapt the plan as they see fit. Every confirmation of or deviation from the plan can be monitored by the planners directly and in real time in the system, enabling them to intervene promptly. Besides addressing these points we have attached importance to the fact that an implementation in the company can be carried out by the planners themselves; requiring no major process changes or investments.

The experience we have gained with this tool and in previous projects has once again made it clear that individual machine operators repeatedly deviate from the planning. The reasons for this deviation vary and have led us to look more closely at the causes and consequences. The consequences will be discussed in detail in this paper based on a simulation model and for the causes it is planned to specifically address and improve them in a training program.

2.2 Production Planning and Control

Before we begin with the discussion of behavioral patterns and our simulation approach to show their effects on overall productivity, we begin with a short introduction to the area of production planning and scheduling (PPS) to delimit and classify the topic and the application area of our tool. Production planning and control as a sub-area of the operative production management has to ensure the economic design and the smooth flow of the production processes. Today, production planning and control covers the entire technical order processing from quotation processing to shipping. It plans and controls the operational tasks of design, sales, purchasing, parts production, assembly and shipping. The goals of production planning and control are high adherence to schedules, high and uniform capacity utilization, short throughput times, low warehouse and workshop stocks and high flexibility at the lowest possible cost (Bonney 2000).

In general, production planning and control can be divided into primary and secondary requirements planning. We focus on secondary requirements planning and there we are concerned only with a sub-area of secondary requirements planning, mainly in the area of scheduling.

2.3 Personality Profiles

For the derivation of our personality profiles we use the HEXACO model of personality structure by Ashton and Lee (2007) as a starting point. This extends the probably best-known trait taxonomy model, the Big Five, also known as five factor model (Wiggins 1996; Costa and McCrae 2012), by another factor: Honesty-Humility. Besides this additional factor both models have a few further differences, e.g. the factor Emotionality in the HEXACO model is not as negative as Emotional Instability in the Big Five, Openness is not so much associated with intelligence as with curiosity, and Honesty-Humility is not a part of Compatibility, but a factor of its own.

As with the Big Five, the properties of the HEXACO model are regarded as factors or dimensions. HEXACO conceptualizes human personality in terms of six dimensions: Honesty-Humility, Emotionality, Extraversion, Agreeableness (versus Anger), Conscientiousness, and Openness to Experience. Each factor is composed of traits with characteristics indicating high and low levels of the factor. These factors can describe human behavior in almost all areas of life. In research there are differing opinions as to which of the two models is better or more complete and whether lexical studies confirm the relevance of six dimensions (Ashton et al. 2014). In any case, the HEXACO model is a meaningful alternative to the Big Five and is useful to further describe the personality traits we have identified. We want to make clear that we use it only for the extended description of the three personality traits, not for psychological studies.

The three types of machine operators we examine here can be simplified and described with the terms local optimizer, lazy, and stressed. A machine operator described as local optimizer tries to avoid tool changes as best as possible to keep set-up times as little as possible. Lazy describes a machine operator who always picks the last arriving product in the buffer area in order to avoid additional moving and to keep distances travelled as short as possible (of the goods and of himself). The third type of machine operator is described as stressed. The picking strategy of the worker seems arbitrary, due to the fact that they are nervous, confused or simply stressed.

Described in the terms and dimensions of the HEXACO model, the local optimizer probably has high scores in the dimension of Extraversion, and can be described as confident and feeling positively about themselves. In addition they might score high in the Conscientiousness dimension, meaning they are organized, disciplined, and goal oriented (Lee and Ashton 2019).

A lazy machine operator could score low in the Honesty-Humility area, and thus be inclined to break rules for personal profit and to be motivated by material gain. In addition, they would typically score low in Conscientiousness, meaning they are unconcerned with orderly schedules and the habit of avoiding arduous tasks. This type is the most difficult to describe as the underlying reasons for laziness are not known (Lee and Ashton 2019).

The stressed machine operator relates to high scores in Emotionality, pointing to their reacting to stress with fear. Low scores in Conscientiousness may lead them to be satisfied with their work, although it contains some mistakes, and to make decisions out of impulse or with little reflection (Lee and Ashton 2019).

Due to our professional background (teaching at higher education institutions and consulting on logistics improvement at various companies) we are aware of the importance of considering individual characteristics of employees. Their receptiveness to learning new things or for the analysis of business processes also requires different approaches to training and further education for each employee. The dimension of Openness to Experience is here particularly relevant to trainings and instruction. Workers with a high score in this dimension are open to new ideas and curious about different fields of knowledge. They use their imagination and are open to unusual ideas. People with very low values in this dimension, on the other hand, feel little intellectual curiosity, avoid creative aspirations and feel little attracted to ideas that may seem radical or unconventional. Another relevant dimension for trainings is Agreeableness. Training in companies may become difficult when workers score low in that area as that may indicate a low willingness to compromise, a critical attitude with regard to others‘ mistakes, and a stubbornness in defending their own point of view (Lee and Ashton 2019).

The relationship between personality and job performance has been the topic of various scientific research studies. These studies show that individual differences in personality traits can be decisive in predicting and explaining employee motivation and behavior and that differences in work situation characteristics can influence employee motivation and behavior (Barrick et al. 2001; Lee et al. 2005). Likewise, the influence of personal characteristics on job and personnel selection has been widely explored (van der Linden et al. 2017). However, all these studies have in common that they mainly refer to the relationship between personality and job performance from a behavioral science perspective. In contrast to those studies, the main aim of this paper is to examine the influence of the different personality profiles on the actual production output of SME in the manufacturing industry.

3 SIMULATION CASE STUDY

For the problem at hand, we chose a discrete-event model. This "classic" modelling and simulation approach is the most-often used model in logistics. Discrete event simulation is suitable for logistics, since most logistics processes are discrete in nature (Scholz-Reiter et al. 2007). It demands a comparably heightened effort in modelling and requires comparably high computing times during simulation, but it delivers results with high exactness (Banks et al. 2009; Schriber and Brunner 2011). For the implementation of the simulation model we orient ourselves on the VDI guideline 3633 (2000).

3.1 System Boundaries and Simplifications

For this paper, a manufacturer of metal profile gratings, ladder rungs, and steps was considered. Deliveries from external suppliers and shipping and distribution to the customer were excluded from the simulation. We mainly focus on the topic of machine utilization. The process times on which the simulation is based were assumed to be average times for the employees due to the requirements of the workers' council, so that it is not possible to draw any conclusions about individual employees.
In order to illustrate and implement our task, we again limit our investigation to only a sub-area of scheduling and furthermore make a number of simplifications compared to reality. Our system includes the following elements and inputs: orders (order amount + due date), process times, set-up times, five different products (products A, B, C, D, E), and five manufacturing steps (pressing, lasering, trimming, profiling, and welding). Furthermore, we have defined our system boundaries and simplified our system as described in Table 1.

Table 1: System Boundaries and Simplifications.

Purchasing and supply processes are not considered. We assume that raw materials and purchased items are always available on time in sufficient quantities.
Costs are only considered indirectly via delays and process times (lead times?). Costs are not evaluated specifically.
We neither consider differences in equipment or employees in terms of costs, nor any contribution margins of the products (all products are equal from a cost and profit point of view).
Customers: We do not distinguish between customers. There is no customer prioritization -> so all customer orders are equally important. The only criterion for dispatching manufacturing orders is the order due date.
Transport processes are not considered
Buffer and storage spaces are unlimited.
Unsatisfied demand is backlogged and produced as soon as possible (recorded in backlog statistic).

The five workstations pressing, lasering, trimming, profiling, and welding were implemented in the model to illustrate the process sequences of five different product types (products A, B, C, D, E). All materials first pass through the pressing process. Four of the five product types (B, C, D, E) are further processed on the laser, so that this product stream is guided over a buffer and on to the laser. The product stream is then reunited before the trimming buffer. After the trimming process the product types are separated again. Three product types (B, C, D) are forwarded to the welding station while two product types (A, E) are forwarded to the profiling work station. After processing the profiling station one product type (E) is finished with processing while the other (A) is also forwarded to the welding station. With the exception of this one already finished product type, welding is the last step in the process. The entire process is shown as a screenshot from plant simulation in Figure 2.

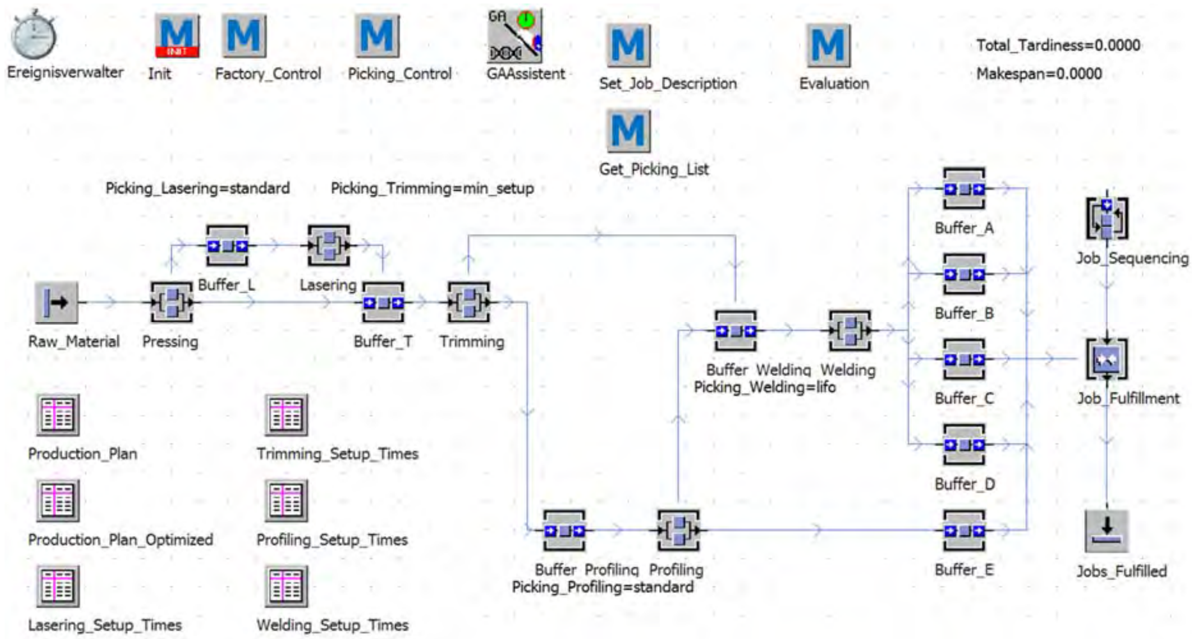

Figure 2: Process sequence illustrated with plant simulation.

3.2 Model Description

The problem described above was implemented with the software Tecnomatix Plant Simulation from Siemens in version 14.0.6. Plant Simulation is a very popular discrete-event simulator in the German-speaking area, especially because it is used in the German automotive industry as a standard tool for the analysis of production logistics processes.

To start the simulation, 100 jobs with random properties are generated. Each order consists of up to five different order items or different product types. The number of different order items is subject to a triangular distribution, whereby the lower limit equals one and the expected value equals three. A demand quantity is also randomly created for each order item. This is equally distributed in the interval one to three. In addition, each order is attributed with a random completion deadline, representing the customer delivery date. The completion deadline is also subject to equal distribution, with the lower limit being four hours and the upper limit three days.

Parallel to order generation at simulation time zero, the production program is adjusted in accordance with the order items and required quantities. In the initial model, a very simple production program is first generated in order to generate a starting solution for the subsequent optimization process. This simple production program prescribes the manufacturing of the complete required quantity of a product type before production is retooled for the next product type. The production sequence is simply determined by the ascending alphabetical order of the product types (A->B->C->D->E). At the end of a run, the simulation model calculates the production time (makespan) and the sum of all delays (total tardiness). In the initial model, under consideration of the above mentioned production program, a production time (makespan) of 22h 17m 40s and a sum of all delays (total tardiness) of 5d 18h 01m 47s results. The result is considered as the upper limit for the subsequent optimization procedure.

In the next step, a genetic algorithm minimizes over 100 generations, with each generation having a population size of 20, the following multi-criteria target function

$$Min\ z = 0.8 * total\_tardiness + 0.2 * makespan,$$

adapting both production sequence and lot size of every product type in every optimization step. The production lot size can have a value between one and the specific maximum requirement quantity for all orders. The best production program determined under these parameters is 16xB->17xC->17xE->15xD->13xA, which is repeated cyclically during the simulation until all orders have been processed. Although the found optimum increases the production time to 2d 01h 02m 10s, order delays are completely eliminated.

Process times at the various workstations in the manufacturing plan for each of the five products A through E are displayed in seconds in the manufacturing plan in Table 2. If no process time has been recorded, the product does not require that particular processing step.

Table 2: Manufacturing Plan.

	Product_A	Product_B	Product_C	Product_D	Product_E
Pressing	30	30	60	90	60
Lasering	-	30	60	90	120
Trimming	45	90	120	180	90
Profiling	45	-	-	-	180
Welding	560	180	260	380	-

The setup times for the changeover from one product to another have also been recorded in seconds. For the first process step, pressing, the setup time is always 600 seconds independently of the product and the sequence of products. For the following four process steps, lasering, trimming, profiling, and welding, the setup times for changeover vary with the products and the process step involved. The corresponding setup times are displayed in Tables 3 through 6.

Table 3: Setup Times Lasering.

	Product_A	Product_B	Product_C	Product_D	Product_E
Product_A	-	-	-	-	-
Product_B	-	0	300	300	300
Product_C	-	600	0	600	600
Product_D	-	600	600	0	600
Product_E	-	300	300	600	0

Table 4: Setup Times Trimming.

	Product_A	Product_B	Product_C	Product_D	Product_E
Product_A	0	900	900	300	600
Product_B	900	0	600	900	1200
Product_C	600	300	0	300	600
Product_D	300	900	300	0	600
Product_E	600	900	600	900	0

Table 5: Setup Times Profiling.

	Product_A	Product_B	Product_C	Product_D	Product_E
Product_A	0	-	-	-	300
Product_B	-	-	-	-	-
Product_C	-	-	-	-	-
Product_D	-	-	-	-	-
Product_E	600	-	-	-	0

Table 6: Setup Times Welding.

	Product_A	Product_B	Product_C	Product_D	Product_E
Product_A	0	900	900	300	-
Product_B	1200	0	300	900	-
Product_C	900	300	0	900	-
Product_D	1200	900	600	0	-
Product_E	-	-	-	-	-

3.3 Experiments

For the simulation experiments First In First Out (FIFO), for which the production sequence and lot sizes have been optimized, is applied as the standard picking behavior. The personality or character models and their properties presented in Section 2.3 are represented in the experiments as follows:

- Character Model 1 “local optimizer” (minimization of the number of setups): When the first product arrives, the machine operator will setup the machine according to the product type. Thereafter, every time a product is finished with processing, the operator prefers to pick products from the buffer, which corresponds to the current setup of the machine. Only if the operator is not able to find a product fitting to the machine setup, the operator picks the product, which is for the longest time in the buffer (applying the FIFO principle).
- Character Model 2 “lazy” (application of Last In First Out (LIFO)): The machine operator always picks the last arriving product in the buffer in order to avoid additional moving and to keep distances travelled as short as possible.
- Character Model 3 “stressed” (stochastic): The picking strategy of the machine operator seems arbitrary, due to the fact that the operator is nervous, confused, and stressed. These characteristics can often be observed at production bottlenecks In the model, every time a part is finished, a random number is determined according to a uniform distribution with lower bound equal to one and upper bound equal to the total amount of products in the buffer. The random number indicates, which product will be picked next.

Although it is possible to apply the different character models to every work station, we focused our experiments on the processes “Trimming” and “Welding” as both processes develop a comparatively high stock level over the course of the simulation. The following matrix (see Table 7) contains the different configuration scenarios and the corresponding results. Note: The first value in a cell corresponds to the makespan, while the second value corresponds to the total_tardiness.

Table 7: Results of the implementation of our character models in the simulation [makespan and time of total tardiness].

Welding / **Trimming**	Standard	Local optimizer	Lazy	Stressed
Standard	2d 01h 02m 10s 0d 00h 00m 00s	2d 14h 12m 30s 0d 00h 13m 05s	6d 10h 15m 10s 143d 22h 59m 18s	5d 14h 01m 50s 124d 20h 52m 38s
Local optimizer	1d 13h 26m 50s 0d 00h 00m 00s	3d 16h 20m 50s 77d 20h 12m 04s	10d 16h 23m 30s 444d 06h 05m 52s	5d 12h 52m 30s 101d 12h 02m 58s
Lazy	9d 04h 52m 50s 291d 09h 58m 32s	9d 05h 19m 10s 295d 22h 40m 52s	9d 04h 43m 10s 290d 20h 19m 12s	16d 00h 19m 10s 633d 23h 21m 52s
Stressed	4d 16h 57m 55s 69d 06h 09m 47s	4d 05h 42m 10s 44d 19h 39m 17s	5d 10h 05m 00s 104d 04h 34m 27s	5d 07h 01m 25s 101d 07h 39m 23s

Gray = better than standard scenario
Light orange = slightly worse than standard scenario
Red = significantly worse than standard scenario

It can be noted that all three implemented character models have significant negative effects on the output of the company when compared to the calculated standard scenario. The worst results are produced by employees who work according to the LIFO principle or random (stochastic) selection, our character models lazy and stressed. The worst result by far, an increase in process times (makespan) by 16 days (384 h) and an increase in total delay (time of total tardiness) by 633 days resulted from the combination of the character models lazy at the trimming station and stressed at the welding station, see Figures 3 and 4.

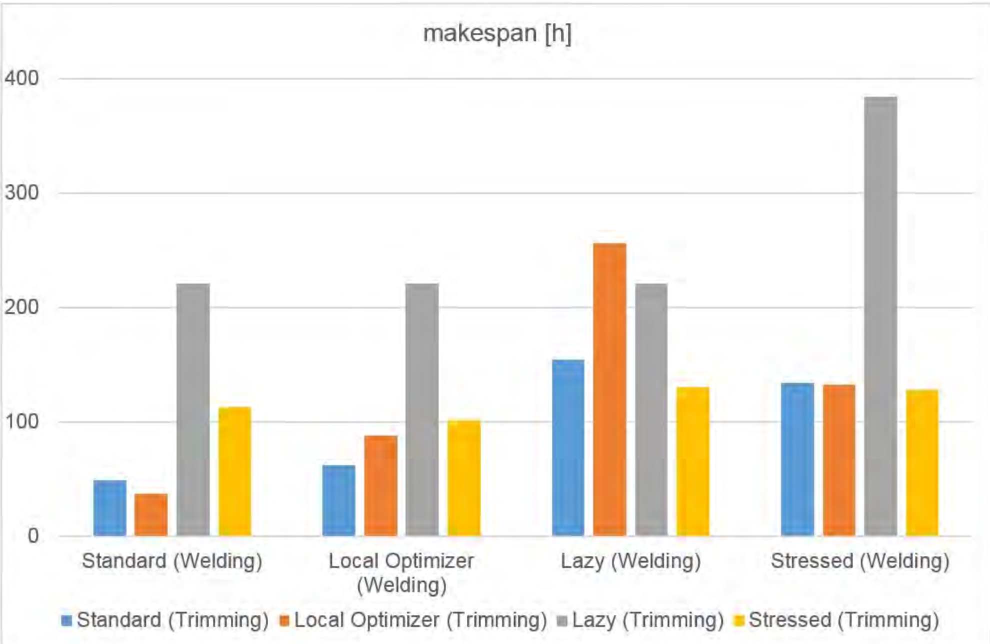

Figure 3: Makespan in hours.

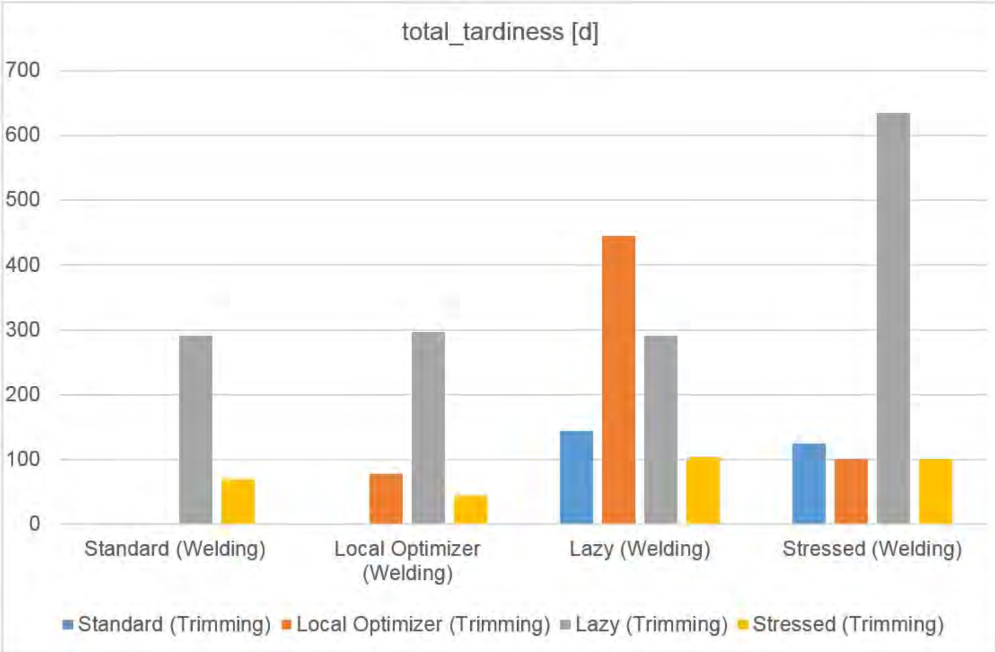

Figure 4: Total_tardiness in days.

The results of the simulation study are validated with the help of an industrial partner on the real application case. However, it can already be concluded that there is a need for employees to be familiarized with holistic acting and thinking within companies. The simulation study confirmed the hypothesis that small changes in the production process at individual workstations, triggered through individual employees for various reasons, have a large negative impact on the overall output volume of the company. The planned goals worked out by production planning can be made null and void by the actions of individual employees. In the present example, only 2 workstations deviated from the production plan; in practice, we have previously also registered deviations at more than 2 workstations.

We therefore advocate training concepts such as simulation or business games in order to be able to present a holistic picture and the effects of the actions of the individual persons at the work stations. This knowledge should be acquired by all employees involved, so that training of individuals is not considered useful. Production planning can also benefit from the findings of the simulation study and from joint training. The preferences of the employees and the behavior of the employees at the workstations can also be factored into the production plans. While this may not allow the theoretically best production result to be achieved, it may be better than demotivating employees or risking even more deviations from the production plan.

4 CONCLUSIONS & OUTLOOK

4.1 Training Concept

The vast majority of current teaching and training courses is paper-based and relies on traditional front-of-class teaching as a teaching and learning method. Our digital training concept for production planning and control has decisive advantages over the classic form of teaching and learning. It offers added value to both students and workers in manufacturing companies.

A large number of parameters and information flow into production planning. Once created, however, the production plan does not remain constant, but is subject to constantly changing conditions and the individual influence of the executing employees as exemplified in the model. Our training concept not only explains the background and the creation of the initial production plan, but also clarifies the effects of individual adjustments.

A software shows the production both from the point of view of production planning and from the point of view of the individual machine operators. They can now individually plan their optimum operating sequence and experience the effects directly. As part of a game-based learning approach, it is also possible for different teams to compete together or against each other. The trainees thus go through an interactive learning experience.

The training program aims to increase machine operators' and production planners' understanding of the overall system and opens them up for the reasoning behind decisions of the other parties. The training offers the added value of trying out different things and making effects visible directly without additional costs compared to classical teaching methods or trial and error approaches. The design of the training program for both target groups, students and workers in manufacturing companies, offers the opportunity to combine theory and practice in an application-oriented training.

Our training offer depicts SME-specific structures and is easy to understand and configure, for example through drag and drop functionalities (your own production can be depicted virtually as close to reality as possible and necessary). It offers an interactive teaching experience and follows the game-related (gamification) approach. Through our advanced training courses, participants can playfully deal with the specific questions and challenges of production planning and control and they can try them without risk. We expect above-average learning success through the practical and targeted application of newly acquired knowledge and interrelationships in a practical learning environment. Participants can experience how different functions and departments in the company work together and how they meet challenges with creative solutions. It becomes clear which consequences individual decisions can have and different approaches and ideas can be trialed without risk. The ability to think analytically, to deal with conflicts and to work in a team will be promoted and the handling of complexity and uncertainty will be trained.

Our approach follows the saying "I Hear and I Forget, I See and I Remember, I Do and I Understand", which is attributed to Confucius. Training concepts in which the participants carry out their own activities and have responsibility for their actions promise a higher learning success than those that rely exclusively on information seen and/or heard.

4.2 Influence of Personality Traits on Overall Productivity

The results of the simulation confirm our thesis that the different personality characteristics have influence on the overall productivity of a manufacturing company. Depending on the personality traits of the individual employees, they can influence both the output of their own workstation and the overall output. The combination and interaction between different personality characteristics at different workstations can increase this effect. The missing holistic acting and thinking of the employees at the individual workstations leads to a deviation from the previously planned production plan. In our discussed simulation model, only two of five workstations deviated from the production plan due to the individual influence of machine operators. However, the negative influence of deviating from the production plan can already be clearly seen here. This knowledge is of crucial importance for the company management, for the production planners, for the development, implementation, and application of training concepts, and of course for the employees at the individual workstations.

REFERENCES

Auer, S., W. Mayrhofer, and W. Sihn. 2012. "Implementation of a Comprehensive Production Planning Approach in Special Purpose Vehicle Production". *Procedia CIRP* 3:43–48.

Ashton, M. C. and K. Lee. 2007. "Empirical, Theoretical, and Practical Advantages of the HEXACO Model of Personality Structure". *Personality and Social Psychology Review* 11(2):150–166.

Ashton, M. C., K. Lee, and R. E. de Vries. 2014. "The HEXACO Honesty-Humility, Agreeableness, and Emotionality Factors: A Review of Research and Theory". *Personality and Social Psychology Review* 18(2):139–152.

Banks, J., J. S. Carson II, B. L. Nelson, and D. M. Nicol. 2009. *Discrete-Event System Simulation*. 5th ed. Upper Saddle River, New Jersey: Prentice-Hall, Inc.

Barrick, M. R., M. K. Mount, and T. A. Judge. 2001. "Personality and Performance at the Beginning of the New Millennium: What Do We Know and Where Do We Go Next?". *International Journal of Selection and Assessment* 9(1-2):9–30.

Bonney, M. 2000. "Reflections on Production Planning and Control (PPC)". *Gestão & Produção* 7(3):181–207.

Costa, P. and R. R. McCrae. 2012. "The Five-Factor Model, Five-Factor Theory, and Interpersonal Psychology". In *Handbook of Interpersonal Psychology: Theory, Research, Assessment, and Therapeutic Interventions*, edited by L. M. Horowitz and S. Strack, 91–104. Hoboken, New Jersey: John Wiley and Sons.

Lee, K. and M. C. Ashton. 2019. The HEXACO Personality Inventory - Revised, A Measure of the Six Major Dimensions of Personality, Scale Descriptions. http://hexaco.org/scaledescriptions, accessed 10th April.

Lee, K., M. C. Ashton, and R. E. de Vries. 2005. "Predicting Workplace Delinquency and Integrity with the HEXACO and Five-Factor Models of Personality Structure". *Human Performance* 18(2):179–197.

Scholz-Reiter, B., F. Wirth, M. Freitag, S. Dashkovskiy, J. Jagalski, C. de Beer, and B. Rüffer. 2007. "Mathematical Models of Autonomous Logistic Processes". In *Understanding Autonomous Cooperation and Control in Logistics - The Impact of Autonomy on Management, Information, Communication and Material Flow,* edited by M. Hülsmann and K. Windt, 121–138. Berlin: Springer.

Schriber, T. J. and D. T. Brunner. 2011. "Inside Discrete-Event Simulation Software: How it Works and Why it Matters". In *Proceedings of the 2011 Winter Simulation Conference,* edited by S. Jain, R. R. Creasey, J. Himmelspach, K. P. White and M. Fu, 80–94. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Stricker, N., A. Pfeiffer, E. Moser, B. Kadar, and G. Lanza. 2015. "Supporting Multi-Level and Robust Production Planning and Execution". *CIRP Annals - Manufacturing Technology* 64(1):415–418.

van der Linden, D., D. H. Pelt, C. S. Dunkel, and M. P. Born. 2017. "Personality, Personnel Selection, and Job Performance". In *Encyclopedia of Personality and Individual Differences,* edited by V. Zeigler-Hill and T. Shackelford. Cham: Springer.

Norm VDI3633. 2000. Simulation von Logistik-, Materialfluss- und Produktionssystemen - Blatt 1: Grundlagen. Berlin: Beuth Verlag.

Wiggins, J. S. 1996. *The Five-Factor Model of Personality: Theoretical Perspectives*. New York: Guilford Press.

Yang, S., T. Arndt, and G. Lanza. 2016. "A Flexible Simulation Support for Production Planning and Control in Small and Medium Enterprises". In *Procedia CIRP, Volume 56, Part of Special Issue: The 9th International Conference on Digital Enterprise Technology – Intelligent Manufacturing in the Knowledge Economy Era*, edited by Y. Li, J. Gao, and P. Maropoulos, 389–394. Amsterdam: Elsevier B.V.

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