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Activity-based shop floor management – A concept to enhance flexibility

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Abstract

Volatile markets, an increasing shortage of skilled workers and individual customer requirements as well as the growing desire for a fulfilling work-life balance among employees are influencing the production environment. Flexibility and adaptability are possible key factors to enable companies to meet these challenges. A concept for an activity-based shop floor management has been developed to make work organization more flexible in the area of production.

In this concept, first of all activity packages are defined and evaluated, for example with regard to their requirements. Furthermore, it is necessary to define competence levels into which the employees are clustered according to their abilities. Thus, a competence-oriented matching of activity packages and employees is possible. The employee can choose tasks from the pre-grouped activity packages. The result is a generally valid concept for flexible staff deployment planning, which is evaluated in the automotive industry. This concept allows a change from role-based to activity-based task assignment with gamified incentive system, whereby specialists can be deployed more efficiently according to their qualifications.

Keywords
Flexibility; shop floor management; competence orientation; work organization

1. Introduction

In today's turbulent market environment, manufacturing companies and their employees face numerous challenges. Demographic development means that the total number of skilled people will decrease in the coming years [1]. In addition, the average age of the workforce in companies is rising significantly. This leads to a shortage of skilled labour as well as the diversification of competences and performance [2]. Therefore, the efficient use of existing skilled workers and a competence-based allocation of activities to the individual worker are becoming more and more important. Due to the increasing amount of individualized products in small batch sizes (mass customization and mass personalization) as well as shorter product and technology life cycles, workers are confronted with low repetition rates and frequent changes in the activity sequences [3]. As a result, the workplace gets more and more complex and the operator has to adapt quickly to these changing requirements. Conventional learning curve effects cannot be achieved, which are predominantly based on practice through repetition (as, for example, the experience curves of [4] show). Hence, instead of long training methods shorter activity-oriented tutorials are considered that enable a new way of interacting on smart devices. As part of the digital transformation, smart technologies are being introduced into factories. This allows a flexible, personalized and automated communication with each worker [5]. In addition, playful incentive systems can be applied to increase the individual employee motivation as well as the group spirit. Digital technologies can also be used to create new opportunities for

workforce support within value creation. At the same time, employees desire a well-adjusted work-life balance due to social changes [6]. Employees would like to have flexible working hours depending on their current life situation [6]. In order to remain attractive as a company, especially in the context of the increasing shortage of skilled workers, more flexible working time models must be taken into account. Figure 1 shows the main development drivers and their impact on manufacturing companies. Flexibility and digitalization are possible key factors to meet these challenges in order to remain competitive in the volatile market.

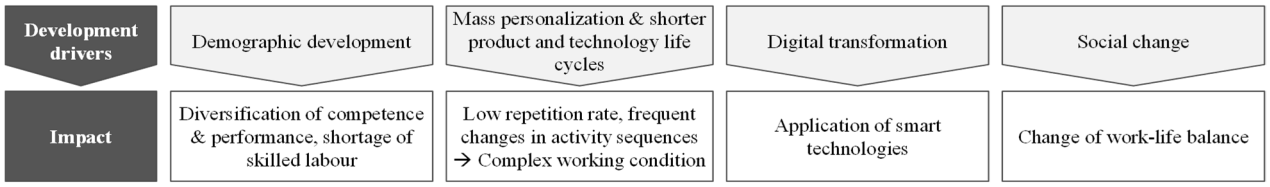

Figure 1: Development drivers and their impact on companies based on [1-6]

In this paper, a concept for an activity-based shop floor management with an integrated incentive system has been developed, to meet the listed challenges. As a result, the work organisation becomes more flexible and companies remain competitive on the market. Moreover, the concept can be combined with new working time models to give more flexibility to both the company and the workers.

The paper is structured as follows: Chapter two gives a short overview of the current state of research and the pursued research goal. Afterwards the concept of an activity-based shop floor management system is presented that can be extended by different topics as for example gamification (chapter three). One application of the approach is described in chapter four, followed by an interpretation and critical reflection (chapter five). Finally, section six summarizes the paper and outlines future research work.

2. Literature review

Within the existing literature on work scheduling, especially aspects on activity- and competence-based approaches have been analysed. The focus in the following analysis is the production area of manufacturing companies. The projects and approaches introduced hereafter are meeting the focus and given topic.

2.1 Existing approaches

In the KapaflexCy project [7], smartphones in combination with a cyber-physical system (CPS) are used as a central capacity provider in order to allow employees to coordinate upcoming work assignments on their own responsibility. The project aims on shortening the reaction time of companies in times of fluctuating customer demand and volatile markets on the one hand and wants to motivate employees through flexible and self-determined working hours on the other hand. Employees who work shifts receive deployment requests on their mobile devices and decide together and decentral whether they want to accept or reject requests. Requests for deployment are made according to priority rules. The required competencies are the top priority, followed by legal framework conditions. If these are met, the system takes into account the employees' time accounts and, lastly, their personal preferences [8]. In this way, employees are actively involved in personnel requirements planning. The focus of this approach is on HR-flexibility for shift workers.

Another approach for competence-based personnel scheduling was published by Denkena et al. [9]. This involves collecting production data that can be used to draw conclusions about the performance and skills of employees. Production data could be e. g. the number of good parts, the cycle time or rework. The collected data is then analysed and interpreted. This information is used by an algorithm for personnel planning in order to further develop individual employee competences. In this way, competences can be developed ideally while utilizing production capacity at the same time [9].

Dollinger et al. [10] focus on the use of so called ‘jumpers’ or ‘floaters’ in production. Among others, they want to achieve the development of competences. In order to deploy employees as jumpers in the line, the requirements at the individual workstations were first recorded. The requirements were then transferred to the required competences of the employees and stored in a workplace-competence matrix. Moreover the existing competences of all employees working in this line were recorded and also systematized in a matrix. Three deployment scenarios for jumpers have been defined: A coaching scenario, an assistance scenario and a replacement scenario. Especially by using the coaching scenario, competences of workers can steadily be improved [10].

The approach of Korder et al. [11] deals with the deployment of employees in reconfigurable manufacturing systems (RMS). When RMS are used in production, employees may have different requirements for fulfilling a work task at a given workstation. In order to enable companies to quickly and easily check the correspondence between the requirements of the machines and the competences of the employees, the publication developed an approach for formalizing employee skills comparable to the formalization of machine skills. By comparing the two, competence gaps or deficits can be identified. These can be closed by targeted further personnel development measures [11].

In the article of Arena et al. [12], ontologies for human resources optimization are used. Ontologies are suitable for knowledge-intensive applications. Therefore, they were used in the mentioned approach to create information models about the shop floor. Subsequently, employee groups and their experiences (in three levels) were defined. Afterwards, the employee groups were assigned skills to differentiate the groups. Based on the requirements of tasks, the right person for the right job could be suggested in real time [12].

2.2 Research demand

The literature review shows, that there are no concepts that deal with future challenges in work organisation by combining a competence-based personnel planning with flexible working models and a gamification approach for employee satisfaction. Especially the efficient allocation of worker skills and task requirements to deal with the growing lack of skilled worker is hardly addressed. The extension of this organisational approach with flexible working time models, employee qualification and incentive systems also has a novelty value. With the combination of the mentioned topics, the challenges of both, company and employee, can be met. On the one hand companies can cope with the lack of skilled workers, and fluctuations in customer demand can be met by a higher flexibility in personnel planning. On the other hand employees get more flexibility in working time and transparency with work tasks and achieved goals in individual qualification. Transparency, in particular, must be emphasised, as it is not yet possible for employees to compare their performance with that of their colleagues. This is especially relevant when employees have the feeling of an unfair distribution of tasks or strongly varying work performance. Therefore, the aim of this paper is to develop a universal approach where all described challenges can be met.

3. Activity-based shop floor management – approach of a new work organisation

This chapter presents a holistic concept for activity-based shop floor management. The concept was developed for the production area. In the first step, the ideal match between skilled workers and given tasks should be enabled for more flexibility in distribution of tasks. This is the foundation for adding the matching with a flexible working time model. By embedding the results in a gamification approach, an incentive system for employees was created, which can also be completed with employee qualification in the last step.

3.1 Competence-based matching between tasks and workers

This section presents an instrument for matching activities with operational employees of production. For matching, activities and employees must be specified with selected attributes. For employees, the goal of

matching is to independently select activities according to their competencies and time availability from a dynamic and individual task pool. A generally valid procedure is required for attribute specification. A characteristics value is rated using a four-level scale ranging from not available (value 0) to low (value 1), medium (value 2), and high (value 3).

Activity specification:
First, the activities, which are derived from the production orders, and thus the work tasks must be classified. Therefore, each activity is characterized by six relevant characteristics: requirement degree, frequency, availability, planned activity duration, basic condition as well as priority (see Figure 2). The requirement degree represents the level of physical and psychological demand of an activity on the employee. The frequency is defined by the number of repetitions of the activity within a defined time period, whereas the availability describes how many employees in the respective company can perform the activity. The planned activity duration requires a time analysis for the corresponding activity and defines the planned processing time. The attribute basic conditions comprises topics from occupational health and safety such as safety instructions or basic training, which the employee must present for the maintenance of the system. It must be fulfilled for the execution of the activity. The priority is primarily determined by the time criticality, e. g. urgent parts have a high priority (value 3). In addition, the prioritization also takes into account whether an activity is connected to a bottleneck system or a particularly important customer order.

Employee specification:
Analogous to the activities, the employees are characterized with the characteristics degree of competence, availability, basic prerequisite as well as the selected working time model and the competence development goals. The degree of competence shows to which extent an employee fulfils the physical and psychological prerequisites for the execution of a required task. This makes it possible to compare each activity with a competence level, see Figure 2. The evaluation of the characteristics is carried out exclusively on the basis of available competences, to ensure that tasks are assigned with the help of the competences actually available and not theoretically certified. Availability and basic prerequisites are defined analogously to the activity attributes of the same name. The availability of the employees refers to the activities. The characteristics of employee availability are therefore defined for each task.

Matching:
The specification of employees and activities forms the basis for matching. For this purpose, activities are proposed to the employees whose degree of requirement is less than or equal to the employee's level of competence. In addition, the basic prerequisite of an activity is taken into account, which the employee must fulfil in order to be able to carry out the task. Due to the prioritisation of time-sensitive tasks, activities with high priority (3) must be processed with priority. As far as prioritisation permits, the planned duration of the activities is taken into account. In order to minimise the division of labour across shifts, the remaining working time of the worker is taken into account in the distribution of tasks. In addition, a points system is introduced for matching. Activities are provided with additional points (AP), whose requirement degree (RD) exceeds the competence degree (AD) of the worker. This serves to qualify employees in a targeted manner. Points can also be awarded for activities that require an extraordinarily high level of physical or mental effort (E) or have a special significance (SO) for the organizational unit or the company. These three criteria are evaluated analogously to the activity and employee attributes on a four-point scale, from no value (value 0) to high (value 3). The additional points are calculated as follows (1):

$$AP = (RD - AD) + E + SO \quad (1)$$

Using this logic, employees can earn a maximum of 9 additional points for an activity, which they can redeem profitably for themselves or their team (see Section 3.4). The point system therefore offers an additional incentive to carry out activities. The following figure (Figure 2) illustrates the matching between

activities and employees. All activities are specified and collected in the activity-pool. Only the tasks, which are relevant to the employee, are displayed. The additional points are calculated according to the employee's qualifications. The employee then selects an activity from his or her individual and dynamic activity pool, which he or she then processes.

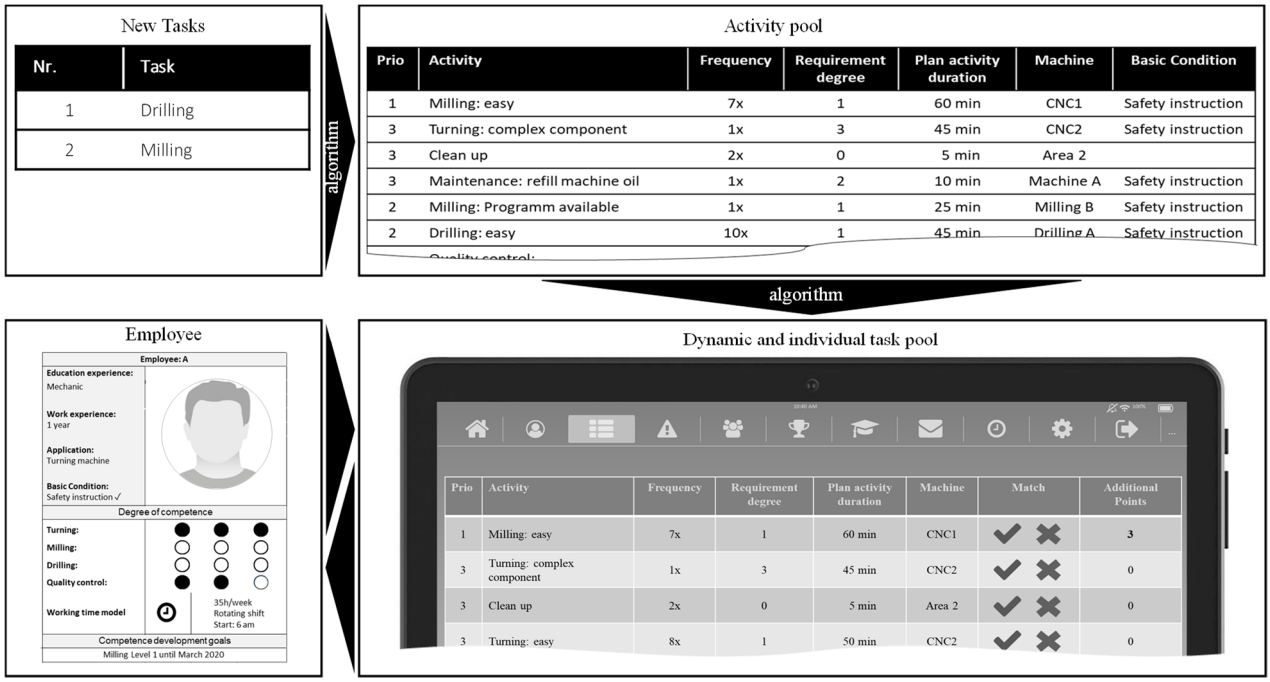

Figure 2: Overview of the competence-based matching between tasks and workers

3.2 Flexible working time models

In order to be able to react as flexibly as possible to the rapidly changing fluctuations in orders, companies are very interested in scheduling their employees as needed. Furthermore, employees wish to have the opportunity to decide flexibly and autonomously on their current working hours [6]. In this case, flexible working time models would be advantageous for both sides [13]. Of course, the entire workforce does not prefer more flexibility, which is why individual agreements should be made and different working time models offered. A working time model is to be regarded as flexible if at least one design parameter of the working time can be changed. The working time parameters include the location, duration and distribution of working time [14]. In addition, the company already benefits from knowing the current personnel requirements as precisely as possible. Overstaffing can only be identified and efficiency can be improved if the personnel requirement is known. [15, 16]

As part of the concept, numerous working time models and flexibilisation measures were analysed. There are numerous adaptable and agile measures that are suitable for classic shift work, like job sharing, group jobs, flexitime in shift work or manual/automatic/app-based resource scheduling. In the use case of our approach, described in section 4, recommendations for action were generated and discussed with the company respecting flexitime in shift work, where the worker can begin and end his daily work outside core working hours, whereby only the annual number of working hours must be covered. In addition, the model of job sharing was discussed in which, for example, two persons share a workplace in a self-organised way.

3.3 Incentive system combined with a gamification approach

Motivated employees are more productive and more satisfied at work [17]. As a result, more and more companies would like to integrate incentive systems into their daily work to motivate each individual and the group. Incentive systems comprise all material and immaterial incentives to directly or indirectly influence the willingness of employees to perform or to strengthen desired behavioral patterns [18]. Extrinsic

incentives, such as bonuses or a salary increase, only motivate in the short term. Intrinsic incentives such as assuming responsibility have a more long-term effect and increase motivation and performance [20,19]. Wanting to encourage the individual motivation of the workers as well as the group-spirit while maintaining the same levels of hierarchy and responsibility, approaches from the gaming industry are transferable. Using game-typical design elements and processes in a non-game context is referred to as gamification [21]. The aim is to change the behavior and increase the motivation of the users. Typical game elements are e. g. descriptions of goals and participants, point or price systems and comparisons [22]. Typical game processes include the accomplishment of tasks through individual or collaborative performance. [23]

In order to find a suitable incentive system, bonus points are combined with selected gamification elements (see Figure 3). The result is a scoring system, where company-points can be awarded for task-specific work or trainings on the one hand, as for example a video about the handling of a machine (learning nugget). On the other hand, bonus-points can be gained for task-unspecific qualifications, e. g. back workout. In the chosen approach, the bonus-points are only remunerated in non-cash benefits. The approach supports the team spirit, because the workers are in no competition with each other and can also collect team-points. Within the framework of the activity-based shop floor management, the individual tasks are scored on the basis of their requirements for the employee. Three categories of the scoring can be distinguished: 1-5 (low requirement level), 6-10 (medium requirement level), 11-15 (high requirement level). In order to stimulate the daily performance of the employees, a certain number of points can be declared as standard performance, which each worker should fulfil during the working day. Of course, the qualified employees should not only complete the tasks with the most points, but should also work through activities from each category in order to retain their connection to the machine through cleaning work, for example, but also to prevent the creation of a class-divided workforce. Playful learning in an informal setting shows better results in terms of learning success, as learning through reward (bonus-pints) is linked to positive experiences [24]. Figure 3 shows one view of the implemented mockup with gamification elements: in the upper part the worker has his own profile where he has a permanent overview of his current skill and performance status. In the lower part, performance, points and detailed skills as well as qualification goals are listed.

Figure 3: Individual user display with performance and skill display

3.4 Operational employee development

Qualification concepts previously used in production no longer meet today's qualification requirements. Through shorter product and production life cycles as well as rapidly changing technologies, employees must constantly acquire new knowledge [25]. Previous measures for the qualification of employees in manufacturing companies were mostly carried out off-the-job, e. g. in learning facilities away from the workplace [26]. There, employees are taught defined lessons on a specific topic within a few days. However,

it cannot be predicted with certainty that employees will need the knowledge they acquire for fulfilling the work task. One possibility to meet the changed requirements is the micro-learning approach of [27]. In this approach, employees are taught knowledge directly at the workplace by means of information-communication-technology (ICT) using short learning units. The on-the-job qualification can be carried out by the employee at the moment when the knowledge is needed. The learning strategy of companies thus changes from strategic to operative. In order to develop these short learning units, so-called learning nuggets, the company must be willing to keep the capacity of an interdisciplinary team of employees, team leaders and human resources partially free. The technical infrastructure for the presentation of video or text-based units for example, must be created. Last but not least, the corporate culture must be given to accept forms of learning close to the workplace and the employees must have the willingness to learn in a self-organised way [27]. The approach described in this publication can be combined with micro-learning to build the skills employees need. Thus, the range of tasks can be extended step by step. For example, individual short video sequences could be recorded in which longstanding, experienced employees explain facts or technologies. These contents are necessary for further development to the next higher competence level.

3.5 Roadmap for the implementation

With five consecutive stages, companies can apply the developed concept. Figure 4 shows the roadmap of the concept schematically: according to the classification of the work tasks and the employees (step 1), a competence-based matching of activities with their requirements to employees with their competences takes place within the scope of the activity-based shop floor management (step 2). On the basis of this agile organization of tasks, it is possible to combine it to flexible working time models (step 3). Furthermore the integration of individual, gamified incentive systems follows, which integrate a point system into the workflow (step 4). At the last step, a new learning approach is implemented, which enables operational further training through small learning units (learning nuggets).

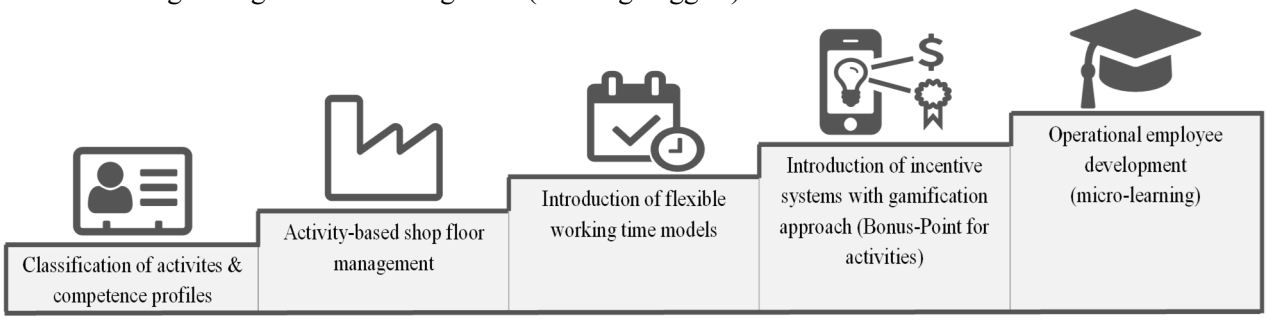

Figure 4: Roadmap – activity-based shop floor management with a gamified incentive system

4. Application of the approach

The described approach was applied in a manufacturing company in the automotive industry. A pilot production area with about 15 employees was selected for implementation. In a first step, all work tasks were categorised and evaluated according to their requirements and rated by the four levels described in chapter 3. Comparable with qualification matrices already used in many companies, the existing competencies of each employee in the pilot area were recorded and also grouped according to the four levels. Subsequently, the work organization logic underlying the approach was implemented in a software tool. On a smartwatch, the employees were able to control the assignment of tasks in real time. A smartphone as well as PC- or tablet-based information terminals in production are also possible. In particular in context of usability for older employees a tablet at the workstation would be recommended. The implementation of the approach in the pilot area showed several advantages. Time savings has to be mentioned first, as the employees get real-time information about task status and unscheduled tasks with high priority. Also the status of machines could be considered with the software tool, so that the employees don’t have to check the status of machines

regularly. By avoiding long ways on the shop floor the employees can use their time more productively. Furthermore, the decision support by ranking the single work tasks or describing them by given requirements was stated as an advantage. This also relieved the workload of the team leader so that he could increasingly take over the coaching and individual development of the employees. All in all, positive feedback from employees was recorded.

5. Interpretation and critical reflection

The presentation of the concept and the application of the approach is followed by a critical reflection of the success factors and the effort involved in the implementation. The success of an activity-based shop floor management system with an integrated incentive system depends essentially on the acceptance of the employees and their integration in the development and implementation phase. During the conception phase, numerous discussions were held with the employees on the shop floor as well as from related areas (e. g. work preparation, human resources, and works council) in order to allow early integration of the employees. The employees emphasized positively that the activities on the company side and the needs and wishes of the workers had been equally incorporated into the concept. Of course, the high initial effort for the implementation of such a system must not be disregarded: For the formation of activity groups all tasks must be considered in detail, whereby an analysis of the job descriptions is not sufficient. In addition, a classification of the products according to their degree of difficulty as well as the allocation of production times for an optimal production planning are required. This additional effort is incurred in the area of work preparation where the processing time of the activities is already estimated. The actual additional expenditure would thus be reduced to the evaluation of the difficulty. However, it should be noted that the difficulty of the task usually correlates with the processing time, therefore only a separate consideration of the work requirements is added. Finally, the employee's commitment to the machine changed drastically and must also be taken into account. Prior to the approach, one employee was responsible for one or two machines, supervised them completely and was responsible for their operation. Now, one employee is currently performing activities on all machines in the field of activity and has to adapt to the new system of general group responsibility for all machines.

6. Summary and outlook

The research demand and the literature review demonstrate that a flexible concept for an activity-based shop floor management, which realizes a competence-based assignment of activities to workers, needs to be developed. In this paper a concept was presented which supports the successful handling of future challenges in the production environment. In view of the increasing shortage of skilled workers, the focus lies in particular on the more efficient use of skilled workers. In addition, work organization is adapted to the changed environmental conditions and significantly more transparency is created for the company as well as the employees. The implementation takes place on the basis of a five-stage roadmap to an activity-based shop floor management with a gamified incentive system.

Since the implementation has only just begun, the concept needs to be tested for a longer period of time. In the context of a longer experimenting period, the satisfaction of the workers and the long-term increase in productivity has to be evaluated. In addition, long-term data evaluation can identify bottlenecks in the execution of activities, from which qualification demands can be derived. The presented concept was designed for the shop floor, but can transferred to other areas. The conceptual approach is even applicable in indirect areas. This work setting also necessitates an assignment of activities with different requirements and employees with different competencies. The applicability of the concept in this new use case should be evaluated in another test phase. Since the approach described contains the scoring of individual activities as well as the variable processing of these in flexible working time models, a performance-related remuneration system can be integrated in a further step.

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Biography

Barbara Tropschuh (*1994) is currently a PhD candidate at the Institute for Machine Tools and Industrial Management (*iwb*) at the Technical University of Munich (TUM). She received her master's degree in Mechanical Engineering from TUM. Her research activities focus mainly on competence- and strain-oriented workforce scheduling.

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