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Software-Tool To Determine Functional Flexibility Based On Employee Specific Risks

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Abstract

During training of manual assembly operations, all employees experience continuous improvement caused by learning. This improvement is known as learning behaviour and describes individual improvement of competence and skill. In an assembly system, employees are required to learn various tasks to ensure overall productivity. Job rotation supports the constant change of tasks to enable an environment where employees maintain their skills by changing tasks in defined time-frames. Functional flexibility describes how many employee-workstation-combinations are possible and needs to be determined based on internal and external factors. Especially employee specific risks are predominant in terms of affecting the outcome and can be encountered by considering these risks when determining the level of functional flexibility. This paper provides an approach to assess employee specific risks with the goal to deduct an expected impact. An overall approach describes the process in order to implement a software-tool to determine the level of functional flexibility. The result is considered as a tool to support the decision-making process of leaders and executives in production systems regarding determining a necessary competence matrix.

Keywords

Software-Tool, Functional Flexibility, Risk Assessment, Learning Behaviour

1. Introduction

Human labour is an essential element in production systems with a high density of manual tasks. For example, assembly systems of high variant products are often characterized by low automation. Especially in socio-technological production systems the workforce has a significant role besides technological and organisational factors [1]. Due to physiological and psychological factors, human work is not constant over time [2]. This leads to challenges in workforce planning, because decision-makers need to consider various factors to determine a specific strategy to encounter the risks. Mostly, decisions regarding the workforce lead to a trade-off between different target values. Due to an ongoing demographic change, the shortage of skilled workers underlines the importance of workforce decisions [3]. A constantly increasing number of short-term absences caused by sickness over the past 30 years intensifies the need to support effective decisions in the context of workforce planning [4]. The absences directly lead to high losses, especially in the production industry [5].
Therefore, it is important in industrial companies to plan a production system, where each employee has to work on a determined number of workstations to ensure an organisation's outcome [6]. Thus, each employee needs to learn the competences and skills to operate the required tasks. Due to individual physiological and

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psychological limits, the process and pace of learning differs. This leads to differing learning behaviour and must be considered during the decision-making process to encounter a possible negative impact on the system [7].

Functional flexibility determines the average amount of tasks each employee needs to be trained on [8]. The amount of necessary flexibility is determined by the boundary conditions, which need to take the trade-off between training losses and losses caused by untrained workforce into consideration [9]. Furthermore, risks can have an impact on how to configure the necessary amount of functional flexibility and the associated competence matrix. Short-term absences and fluctuation were identified as the main drivers for risk-based workforce decisions [8]. This paper continues the proposed approach of AST and NYHUIS (2022) and designs a software-tool which helps decision makers with the decision-making process regarding functional flexibility and risk assessment [8]. Thus, the following paper provides a short insight into the theoretical basis of the development (Sec. 2). Afterwards a process is presented which provides a structured approach for the risk assessment (Sec. 3). The risk assessment is a complement to the mentioned approach, since it provides an example on how to utilize the tension between short-term absences and fluctuation in order to deduct the optimal amount of flexibility to encounter the consequences of the risks. This includes a description of the software-tool which incorporates the theory and provides a demonstrator as basis for further development. A model of procedure is presented afterwards, which describes the process of how to use the software-tool in order to gain reasonable results (Sec. 4). This includes an explanation of the interpretation of the results. A short exemplary application shows a fictious use-case which provides a reference for usage and enables an investigation of plausibility (Sec. 5). A brief presentation of limitations is necessary to discuss the potential for further research (Sec. 6). Lastly, a short summary and conclusion will be presented (Sec. 7).

2. Theory

2.1 Learning Behaviour and Functional Flexibility

In assembly systems all involved employees need to learn the tasks necessary to complete them. This includes all motor and cognitive processes relevant to task completion and are referred to as competence in the context of this paper. Thus, the overall learning consists of a combination of cognitive and motor learning [10]. It is possible to describe the learning process with mathematical functions, as long as the tasks are repetitive and separate times of each repetition can be measured. In an industrial context, this was firstly discovered by WRIGHT (1936) who investigated constantly decreasing costs of an airplane production [11]. The resulting power function is the basis for further research regarding the learning behaviour of manual tasks. Thus several approaches were developed to describe the process of learning within different situations [12]. Generally, learning curves follow constant improvement and converge asymptotic towards a limit value [13]. This limit is defined by the product or task and is the idealistic time of completion. The learning theory states, that in the beginning of the learning process the deviation is at the highest point and it takes a certain number of repetitions to reach for the accepted amount of productivity [12]. The number of executions depend on the individual learning behaviour and the higher the individual learning ability, the quicker this amount is reached [8]. During decision-making processes regarding the deployment as well as training of employees these inefficiencies need to be taken into consideration. Within a preliminary study, it was shown that different levels of functional flexibility lead to different amounts of trainings losses [14]. Two extremes can be elaborated, whereas the minimum flexibility states that each employee can be deployed at one task and at the highest amount of flexibility states that all employees can be deployed at all tasks.

Cross-training approaches can be used to determine the required deployment schedules to reach for highly efficient training [15]. Furthermore, job rotation approaches based on different skill levels can be used to utilize workforce flexibility [16]. Besides developing skills of employees, job rotation approaches can also be used to encounter boredom and monotony [17]. Employee specific risks have an impact on productivity and can cause turbulence within operations. The development of a software-tool which supports decision making processes regarding the recommended amount of functional flexibility can lead to transparency and increase risk resilience.

Existing research regarding functional flexibility focuses on assignment models to determine deployment schedules based on individual productivity [18]. Further investigation shows, that a moderate level of flexibility is advised to encounter the influences of process change [9]. Whereas the approach enables an assessment of flexibility, it does not provide a detailed insight into prospective losses caused by individual learning behaviour and does not enable an individual risk assessment. Another approach provides a model which enables the user to assign workers to tasks and deduct training schedules considering effects of flexibility and productivity losses, but does not provide an approach to evaluate risks as well [6]. The approach of AST and NYHUIS (2022) is considered as preliminary work, which provides an evaluation to estimate trainings losses as a function of functional flexibility [8]. Therefore, the paper proceeds to develop the approach of estimating trainings losses for different levels of functional flexibility caused by individual learning behaviour to encounter the risks short-term absences and employee fluctuation.

2.2 Decision-Making

Decision-making in production systems requires an evaluation of many different influencing factors which have an impact on the outcome of any decision. Especially because of the relation between human, organizational and technical factors a sensitive consideration of possible influencing factors is necessary. Thus, decision-making tools help responsible decision-makers to evaluate possibilities to identify the best possible conclusion for a specific problem. Tools for decision-making have various applications e.g. problem-solving [19], risk management [20–22] or employee scheduling [23]. Decisions can be separated into decisions in case of certainty and decisions in case of uncertainty or risks [24]. As described before, the proposed tool supports the decision-making process in case of risks, which is why the following descriptions do not include the process in case of certainty. According to the theory of decision-making, decisions require the following three elements: (1) a distinct amount of alternative courses of actions (at least more than two), (2) knowledge about external factors and (3) assessability of decisions [25]. In the case of the presented approach, all of these three elements are given. The targeted decision aims for determining the optimal amount of functional flexibility under consideration of employee specific risks. This implies, that the object of decision is influenced by the number of possible employee-task-combinations and fulfils the first element. The second element is given by the knowledge of the employee specific risks. These need to be evaluated to determine the optimal course of action regarding the amount of flexibility. The third and last element is the assessability, which is based on the approach to determine training losses based on individual learning behaviour [8]. This leads to the assumption that the proposed software-tool can be considered a supportive tool for decision-making. A necessary requirement of tools for decision-making is the objectification of the situation [24]. By describing a situation with mathematical functions, it is possible to evaluate different outcomes based on the same approach. This supports the comparability of different outcomes and helps to determine an optimum. In terms of functional flexibility, the training losses caused by deployment of employees can be estimated by algorithmic approaches [8,26]. Therefore, the costs of functional flexibility can be calculated and the results can be compared with the benefits regarding the consequences of employee specific risks. This leads to the requirement to develop an approach which helps decision-makers to individually assess employee specific risks. The results are the basis for the following determination of the optimal flexibility to encounter the consequences.

2.3 Hypothesis

The determination of functional flexibility in assembly systems is a mandatory process for leaders and requires an analysis of several factors. This complex set of influencing factors leads mostly to an approach which is based on experience and instinct [27]. Furthermore, the decision-making process can be described with the decision-making theory which can help to develop a standard approach which supports decision-makers to determine functional flexibility. This leads to the hypothesis which is used as a guideline for the following development of the software-based tool:

> *"The decision-making theory can be used to develop a software-tool, which utilizes the tension between short-term absences and fluctuation in order to determine the optimal amount of functional flexibility inside an assembly system."*

The resulting software-tool aims for providing a basis for further research, a possibility for companies to incorporate it and teaching in learning factories to raise awareness regarding the importance of functional flexibility and employee specific risks. Thus, the approach shown in this paper describe a possible utilization of the approach of AST and NYHUIS (2022) to evaluate the connection of training losses and functional flexibility with further detailing as wells as an assessment of employee specific risks [8].

3. Risk Assessment

A risk assessment of employee-oriented risks is part of the proposed software-tool. The result of the assessment is input information for the determination of the recommended amount of functional flexibility to encounter the risks. The following section describes their conflict (Sec. 3.1) and provides an approach for assessing these risks (Sec. 3.2).

3.1 Conflict of Short-Term Absences and Fluctuation

Two risks regarding the deployment of employees in production systems were previously identified. Therefore, short-term absences and fluctuation have a major impact on deployment and competence development decisions [8]. Short-term absence refers to the unexpected outage of employees, which can be caused by e. g. sickness. This can lead to a situation, where untrained employees need to compensate missing employees, which leads to unexpected training losses and turbulence in operations. To encounter this risk, functional flexibility needs to be maximized. However, fluctuation states that employees will not return to their job due to e. g. resignation or retirement and therefore cause opportunity costs, because the organization invested into training which cannot be utilized. Therefore, functional flexibility needs to be minimized. [8]
Regarding the role of functional flexibility, these risks are in conflict, because of their consequences. To develop a software-tool to determine the amount of functional flexibility it is necessary to describe the interaction between involved parameters. The risks evaluation can be supported with data provided by a company. For example, short-term absences can be calculated with the ratio of absent and available employees, whereas fluctuation can be calculated by evaluating the number of employees leaving without returning. The software-tool requires an assessment of both of the risks. This leads to the main restriction of the tool, because most of the data account as sensitive regarding data security [28]. Especially required health information to estimate potential short-term absences are often not accessible or restricted. Therefore, both risks can be evaluated qualitatively in order to avoid accessing sensitive data based on perception of the decision-maker. Furthermore, training losses need to be predicted to enable a basis for evaluating the costs of risks. Functional flexibility is the target value and can be deducted by evaluating training losses of the workforce and assess the tension between short-term absences and fluctuation. The following Figure 1 shows the connection between the aforementioned factors.

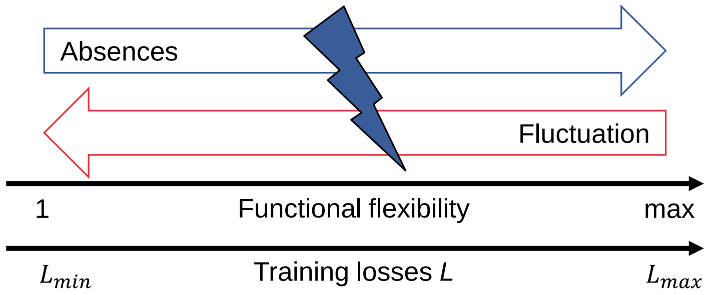

Figure 1 - Conceptional presentation of the conflict between short-term absences and fluctuation based on [8]

The proposed approach complements existing research which also states that neither the minimum nor the maximum amount of functional flexibility is optimal [9]. The resulting framework evaluates the factors with an acceptable number of degrees of freedom.

3.2 Assessment of Employee-specific Risks

This section deals with the main content of this paper and provides an approach to assess employee-oriented risks with the goal to build a basis for determining the functional flexibility. Thus, a qualitative evaluation with a quantitative outcome is necessary to transfer the risk assessment into a reasonable amount of flexibility to encounter the risks. As stated before, the risks are in conflict and the ideal amount of flexibility of the one risk is the worst amount for the other one. Therefore, this connection can be utilized to deduce the optimum to encounter both of the risks. This can be achieved with questions regarding the importance of the risks or the willingness to provoke specific consequences of each risk. The goal is to develop an approach which enables decision-makers to a more objective evaluation. With a total of ten questions, which address the risks, decision-makers can assess their role within the determination of functional flexibility. These questions can be answered with a 5-step LIKERT scale, which offers the opportunity to quantify personal attitudes [29]. For each question the one extreme favours the importance of short-term absences and the other extreme favours fluctuation. This requires a specific phrasing of the questions, but enables an evaluation which can be directly converted into the risk assessment. The result of each question is added to an overall sum, which then is used to display the resulting amount of flexibility to encounter the evaluation. This means, the 5-step scale leads to a result of -2, -1, 0, 1, 2 for each question depending on the input of the user and therefore points towards a specification of the result. The following example shows the function of the questionnaire:

Question
"Short-term absences mean high turbulence in staff scheduling."

Answer
Does not apply at all (-2), Does not apply (-1), Neutral (0), Does apply (1), Fully applies (2)

If no short-term absences occur or the occurrence does not have a negative impact on the workforce planning, the minimum flexibility would be in favour. The following Figure 2 shows the proposed questionnaire. At the end of the questionnaire, the overall result is shown as absolute values as well as the recommended flexibility.

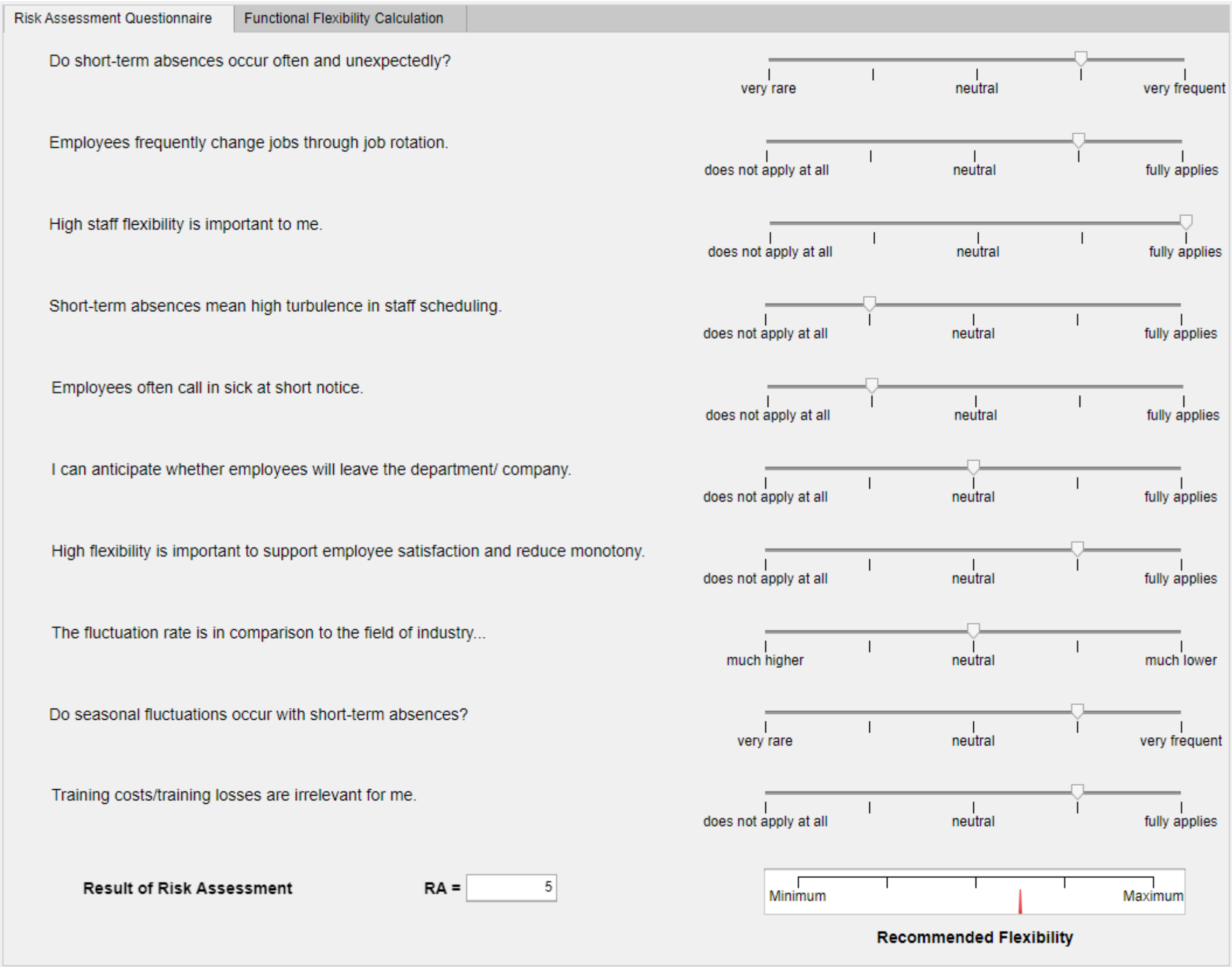

Figure 2 – User interface of risk assessment questionnaire with exemplary input

3.3 Risk based Determination of Functional Flexibility

The aforementioned risk assessment questionnaire provides a basis for deducting functional flexibility. The range for the result of the risk assessment RA reaches from $RA_{min} = -20$ to $RA_{max} = 20$, whereas 0 is the previously set default value $RA_{default}$. With each answer in the questionnaire, the resulting value is added to the overall result. If all results are in favour of fluctuation the overall result is $RA = R_{min} = -20$ and if short-term absences are in favour, the overall result is $RA = RA_{max} = 20$. The scale is then standardized, in which the default value (50 %) is characterized by an equally importance of the risks and then transferred to the accumulated losses, because this is the value which is used in order to evaluate the functional flexibility. With the same number of losses, a wide range of flexibility can be achieved depending on the determined competence matrix. In case of an equally importance of both risks, the amount of losses to train the designated employees equals the same amount to train the rest of the employees to achieve maximum flexibility. As shown in Figure 3, a result of the risk assessment is that both risks are equally important to avoid, which means the training losses are set to the average. The overall goal is to identify the specific competence matrix, which leads to the highest flexibility at the average amount.

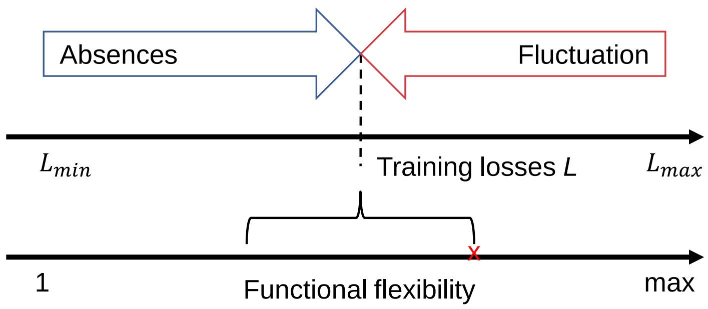

Figure 3 - Interpretation of risk questionnaire based on [8]

If the risks assessment leads to a result which favours one risk over another, it automatically leads to a different amount of accepted losses and therefore to a different optimum for the functional flexibility. Figure 4 shows, that the direct transfer of the result of the risk assessment to the losses leads to a varying optimum of flexibility, which is oriented within the line of the best-case scenario.

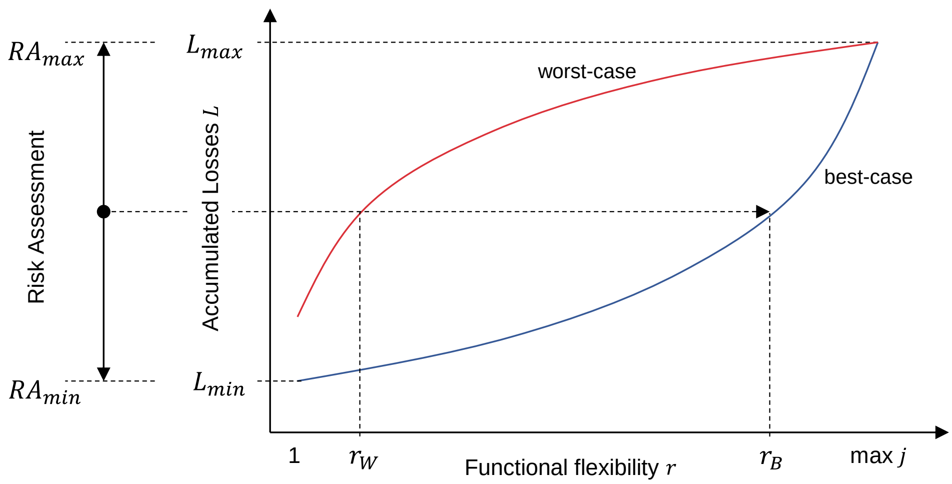

Figure 4 – Concept for deducting the amount of flexibility based on the risk assessment applied from [8]

The best-case scenario for the losses represents the optimum which can be achieved with each amount of accumulated losses. The result of the assessment therefore leads to the optimum competence matrix which supports decision-makers with determining the preferred competence matrix. Furthermore, the resulting competence matrix can be used as an input for combinatorial algorithms to deduct optimal deployment schedules [26].

4. Approach for Implementation

The approach for implementation provides a guideline to implement the process for the risk-based determination of functional flexibility, to ensure a standardised usage of the tool. The process is separated into five steps which guide the user to a reasonable result. The first step requires the user to provide information about the boundaries, e.g., number of employees, learning factor or limit values of the tasks. This information is then put together by the program to calculate the scenarios of best- and worst-case for the resulting training losses of functional flexibility. The third step includes the risk assessment to evaluate the risks (see Sec. 3.2), which helps decision-makers to evaluate the consequences of the risks with a standardized questionnaire. The transfer of the results of the assessment is part of step four, which provides information about the best possible competence matrix to encounter the result of the assessment. This step also provides the possibility to test other competence matrixes in order to compare different solutions and evaluate more information which is outside the scope of the program. This leads to an iterative process, in which decision-makers can compare different employee-workstation-combinations, to support transparency regarding the consequences of their decisions. If the user decides on a matrix, the best possible deployment schedule to develop and maintain the competences can be calculated in step five based on an algorithmic approach [26]. This is the last step, which provides a deployment schedule based on the prior selected competence matrix. The following process shown in Figure 5 displays the steps.

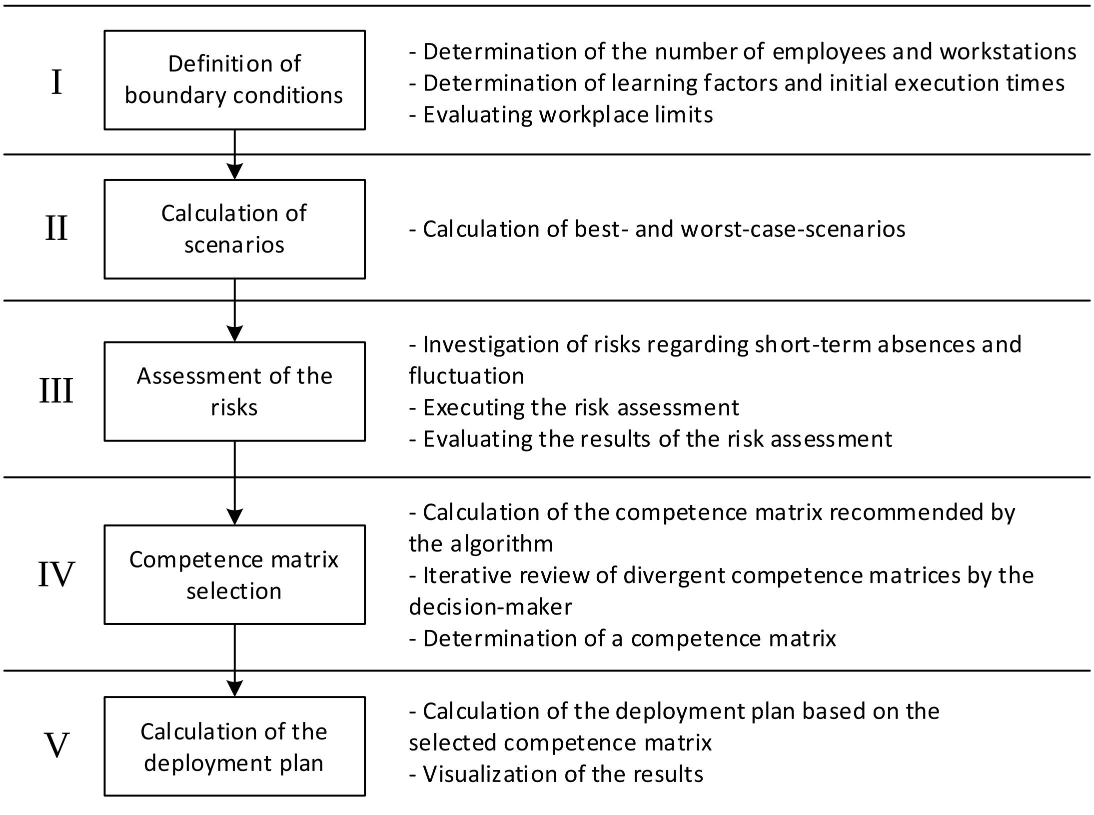

Figure 5 - Process for implementation and usage

The overall process consists of steps which require an action or input of the user and an interpretation of the provided results. The program combines the input information within the calculation of the results and enables an iterative usage. Therefore, information which aims for providing approaches to interpret the results will be displayed at each step.

5. Exemplary Application

An exemplary application shows the process of deducting a proposed competence matrix to encounter an individual risk assessment. Therefore, the following example is based on the parameters shown in [8] and thus randomized based on a real case scenario. The developed software-tool allows to put in values for the individual learning factor, the duration of the first execution and the limit values of the tasks to calculate the individual learning curve. There are different approaches which can be used to anticipate the learning factor as well as the duration of the first execution [10,30]. The limit values can be determined with systems of predefined times (e.g. MTM – Methods-Time Measurement [31]) and thus be objectively calculated. The allowed productivity deviation refers to the target productivity which needs to be achieved in order to reach the expected performance. In this scenario, the value states that 10 % of the task limit values is an allowed deviation. This is an input parameter which has an impact on the amount of resulting training losses. Furthermore, the results of the previously shown risk assessment are used as an input and the goal is to determine the amount of functional flexibility as well as the resulting competence matrix. The information is put together inside the software-tool which first allows the risk assessment (see Fig. 2) and then calculates the expected results. The following Figure 6 shows the user interface and the results based on the provided input information.

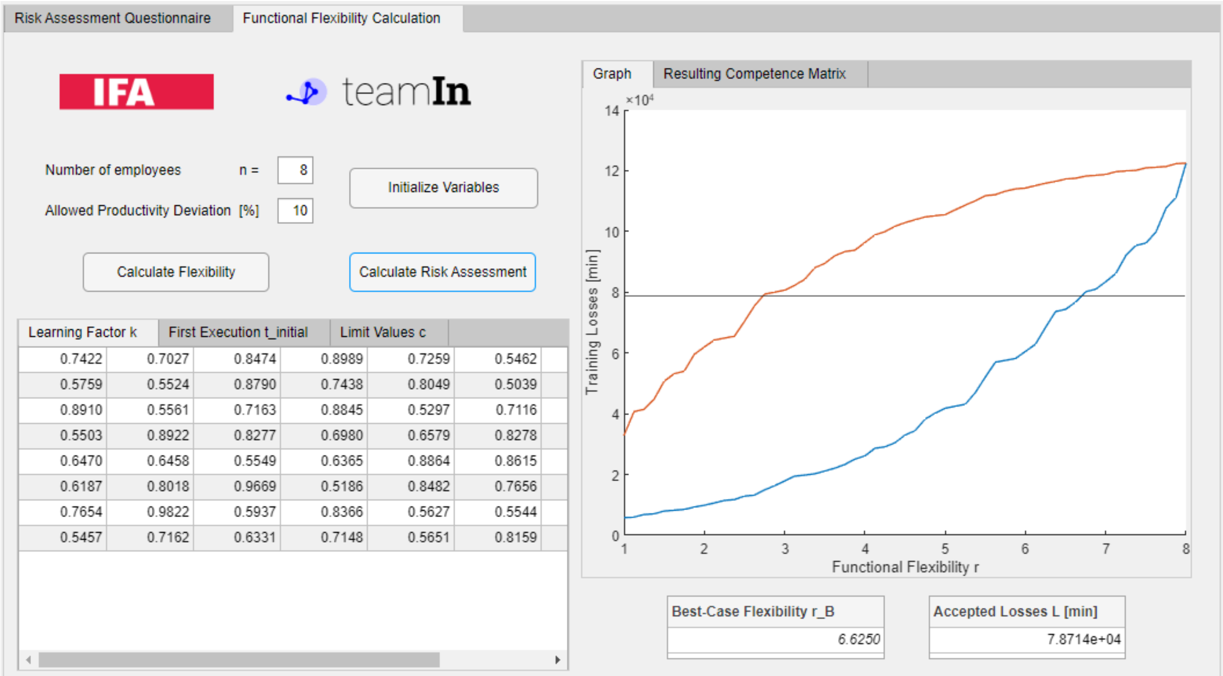

Figure 6 – User interface of exemplary application of the risk-based determination of functional flexibility

The tool allows an insight into the consequences of different results of the risk assessment and the resulting competence matrix. As shown in the example, the recommended flexibility to encounter the risks is $r_B = 6{,}625$ with an accepted amount of losses of $L = 78.714\ min$. The example shows, how the recommended amount of flexibility is oriented at the line of the best-case scenario. According to step IV (see Fig. 5), the user could now change the competence matrix and then visualize the outcome of specific employee-workstation combinations. This allows an iterative decision-making process based on the provided input information. Furthermore, the comparison with the worst-case scenario provides possibilities regarding consequences of deployment decisions. As shown in step V, the final competence matrix can then be used in order to calculate an optimal deployment plan to equally deploy all employees at the workstations. Therefore, algorithms which solve combinatorial problems can be used to determine the optimum deployment schedule [26].

The exemplary application shows a fictious case to visualize the result and function of the software-tool. Based on the aforementioned hypothesis (see Sec. 2.3) the tool serves as a supporting element in the decision-making process regarding deployment decision under consideration of employee specific risks.

6. Limitations

When software-tools aim for supporting decision-making, which include human behaviour, the tool is most likely confronted with inaccuracies. Especially in a tool which is based on the prediction of developing performance, the variables and parameters need to be communicated as very sensitive regarding their ability to represent real life behaviour. As already presented in [8], the main limitation of the tool is the prediction of individual learning behaviour. There are different approaches which enable a prediction. [10] focus on the prediction of tasks with long cycle times, but present an approach which can be transferred to other tasks as well. This requires a detailed investigation of the correlations of the tasks to develop a function which can directly convert the learning factor into the initial execution time and vice versa. Furthermore, [30] present a possibility to predict individual learning behaviour based on equations which help to calculate the learning factor and the initial execution time as necessary elements to calculate individual learning curves. Another approach by [32] requires the selection of different learning types or learning profiles based on experience, which then provide information about the individual learning behaviour. All of these approaches imply a distinct amount of inaccuracies and if less information can be based on measured data, the higher the inaccuracies.

The presented approach to assess employee specific risks can be seen as a possible approach to utilize the model of [8]. The assessment itself aims for a standardized evaluation of the risks short-term absences and fluctuation, but still has a subjective component. The subjectivity can be encountered by further methods which allow an objective or quantitative evaluation of risks. Furthermore, the approach can be extended with additional questions to enable a more company specific assessment.

However, the structure of calculating training losses remain the same for other determining factors. Therefore, companies can use the basic calculation by [8] to consider other external factors e.g. market conditions or internal factors e.g. motivational aspects to deduct the necessary functional flexibility to encounter consequences.

7. Conclusion and Outlook

The goal of this paper is to introduce an approach to utilize the previously developed connection of training losses and functional flexibility [8]. Therefore, a risk assessment questionnaire was presented, which enables decision-makers in production systems to determine the optimal amount of functional flexibility based on employee specific risks. The method to quantitatively describe different levels of flexibility by predicting training losses supports transparency and reveals consequences of workforce related decisions. The risk assessment consists of ten questions that can be answered with a 5-step LIKERT scale, which enables a quantification of subjective impressions [29]. By adding the results of each question, an assessment can be made regarding the role of short-term absences and employee fluctuation. Both risks can have an impact on potential losses, whereas the overall goal of a company is to avoid losses. Furthermore, a process of implementation and usage is presented, which is a guideline to use the presented approach. This is a five-step process to ensure a standardized usage of the tool. Each step aims for guiding the user towards reasonable results and is simultaneously providing information about the generation of the results as well as providing information about the interpretation of the results. Lastly, limitations regarding the usage and the accuracy of the tool are discussed. The major limitation is the accuracy of the parameter prediction to anticipate the training losses. The parameter prediction is essential for the tool, but holds the biggest threshold against the meaning and accuracy of the overall result. However, the limitations provide an insight into the biggest potential of the tool. More research is necessary in order to investigate the possibilities to predict parameters to ensure more precise calculations of training losses. Furthermore, the tool can be transferred into existing human-resource management software, to enable more detailed possibilities for decision-makers in production systems to support transparency and standardized decision-making processes.

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Biography

Jonas Ast, M.Sc. (*1991), studied mechanical engineering at the DHBW Mosbach and then part-time Business Management at the University of Leeds. In mid-2019, after working in an industrial company, he started working as a research assistant at the Institute of Production Systems and Logistics (IFA) at Leibniz Universität Hannover. His work focuses on production and work design.

Prof. Dr.-Ing. habil. Peter Nyhuis (*1957) studied mechanical engineering at Leibniz University Hannover and subsequently worked as a research assistant at IFA. After completing his doctorate in engineering, he received his habilitation before working as a manager in the field of supply chain management in the electronics and mechanical engineering industry. He is heading the IFA since 2003.