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# An Approach Towards Securing Future Viability Of SMEs In A VUCA World Using Artificial Intelligence To Increase Resilience

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**Abstract**

Global crises pose major challenges for production companies: Rising material and energy costs, supply bottlenecks and the lack of planning certainty due to the dynamics of a pandemic or war weaken the planning stability. In this volatile, uncertain, complex and ambivalent environment (VUCA world), companies need responsible employees who recognise the individual need for action and initiate concrete measures early to increase a company's resilience. These measures affect multiple divisions. For example, disruptions in the supply chain are mitigated by various configuration elements such as expanding the supplier network or increasing stock in the company's own production. Therefore, measures encompass every element of the value network, whether in production or logistics. The example also shows that measures to increase resilience can influence other target characteristics of a company: Inventory increases can buy resilience at the expense of resource efficiency. Thus, measures must be defined for each design element depending on individual requirements in terms of resilience and must consider the scope for action of the respective company. This poses a great challenge, especially for small and medium-sized enterprises (SMEs). Here, decision-making is done by generalists who often do not have the detailed knowledge for this specific problem or the capacity for this additional task. The danger is that SMEs will take insufficient measures that do not secure their future viability in a VUCA world. In this paper, a solution approach for a methodology is presented, that allows to derive influences on production companies from the developments in a VUCA world and measures to increase resilience can be identified depending on individual company characteristics. Furthermore, a possible conceptualisation of the methodology in an AI-based software product is presented, which supports SMEs in the outlined complex problem by enabling them to apply the methodology. Both will be realised in a research project.

**Keywords**

VUCA, Resilience, Resilience Measurements, Future Viability, SME

## 1. Introduction and need for research

The times when companies could still plan under stable and thus calculable environmental conditions have been over since the 1980s at the latest. Technical progress, especially in logistics, and the introduction of the internet enabled the globalisation of goods and information flows and led to the interconnection of production in networks [1]. This was not only accompanied by opportunities for companies. The global economy, the environment, politics, society and technology have always had an influence on companies that must be taken into account in order to continue to do business in a future viable manner [1]. Due to advancing globalisation, the influencing factors listed above are also subject to permanent change. Due to this increasingly rapid, short-cycle and erratic change in environmental conditions, the predictability of influences on companies became more and more challenging - a trend that continues today [2,3]. The

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business environment is therefore now described as volatile, uncertain, complex and ambivalent and referred to as a VUCA world [4]. Examples from the last two years, such as the crises caused by COVID-19 or the war in Ukraine, as well as singular events such as the blockade of the Suez Canal, illustrate this [5–8]. In addition to crises or singular events, a VUCA world is shaped by the consequences of climate change, which companies increasingly have to deal with as they already have an impact on production systems [9,10]. For example, an increasing frequency of extreme climate events leads to the destruction of production facilities and transport routes or a shortage of raw materials and intermediate products required for production. In addition, there is a demand from politics and society that companies produce in an ecologically sustainable manner in order to contain the consequences of climate change and make the global economy climate-friendly [5,6,11]. With these changing influences on companies, their strategies for dealing with them have also changed. While flexibility, reconfigurability or adaptability were still considered success factors for future competitiveness a short time ago [1,12], they are no longer sufficient today [10]. In order to be prepared for the diverse and disruptive influences described above, resilience is the solution approach to design companies in a future viable manner **(prerequisite 1)** [13]. Resilience is the ability of a system to maintain the functionality necessary for its existence when disruptive events occur and to recover its operation as quickly as possible by implementing appropriate measures [14].

To increase the resilience of manufacturing companies, it is the task of factory planners to adapt factory operations to current requirements of a VUCA world. Factory operations tasks include operating, steering, controlling and maintaining as well as other services [1,15]. This is becoming increasingly challenging for companies [16]. Measures to ensure future viability through resilience cannot be limited to one area of consideration within the company. For example, disruptions in the supply chain can be countered by various design objects such as expanding the supplier network or increasing inventory in the company's own production. Measures can therefore encompass every element of the entire value network, whether in production or logistics **(prerequisite 2)**. The example also shows that measures often contradict themselves: With the help of inventory increases, resilience can be bought at the expense of resource efficiency and vice versa. Factory planners therefore need a precise understanding of their company's system in order to define measures according to their individual requirements. In conclusion, the selected measures must be aligned with the company's characteristics, which depend, for example, on the strategic company goals or the possibilities for action **(prerequisite 3)**. In order for companies to be able to apply the measures to their system as easily as possible, measures must be described in concrete and practical terms **(prerequisite 4)**. This task has become a demanding ongoing task for factory planners due to the increasing and challenging influences on manufacturing companies in a VUCA world, which force a permanent adaptation of the factory and factory operations [15].

In large companies, measures defined in factory planning projects are developed by an interdisciplinary project team with a wealth of experience and knowledge [1]. These are often accompanied by comprehensive changes, which are usually decided by the management. In large companies, the management is thus comprehensively supported by specialist planners in the definition of measures. This is not possible in SMEs, for example, due to fewer personnel resources and a lack of expertise. Another complicating factor is that the management of SMEs is usually busy with day-to-day business and not only lacks the detailed knowledge for these additional tasks, but also does not have the capacity to deal with them sufficiently [17]. As a result, there is a danger that SMEs will not recognise the influences from a VUCA world. Therefore, they will not correctly assess the consequences and resulting demands on their own company, or will not be able to adapt to the requirements in a targeted manner with the help of suitable measures. Consequently, this means that SMEs are not able to position themselves future viable in a VUCA world. However, for Germany as a production location dependent on SMEs, this is of great relevance [18]. It follows that SMEs need decision support for this task that can be applied at a low-threshold level, e.g. by implementation through a software product **(prerequisite 5)**. In summary, the following requirements apply to decision support for SMEs to ensure their future viability in a VUCA world:

1. Increasing entrepreneurial resilience
2. Taking into account the design fields of production and logistics
3. Consideration of individual company characteristics
4. Definition of concrete and practice-oriented measures for action
5. Low-threshold applicability

A literature review identified approaches that enable companies to become more resilient [6,19–25] in the face of influences from a VUCA world. Above all, the approaches to increasing resilience primarily describe organisational recommendations that are aimed at a strategic orientation of the companies and are consequently not very concrete. The table below compares approaches that include methods for increasing resilience not only at the organisational level and examines them with regard to the prerequisites listed above.

Table 1: Overview of existing research approaches

| Research Approach | Prerequisite | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Triple R-Supply-Chain-Modell [6] | x | x | | (x) | |
| World Class Manufacturing performance measurement [26] | (x) | | x | (x) | |
| BEVUCA [27] | (x) | | | (x) | |
| Resilience and Relocalisation [28] | x | (x) | | (x) | |
| Measurement-Resilience Roadmap [29] | x | (x) | (x) | | |
| ERUC [30] | (x) | (x) | x | x | x |

x fulfils
(x) with restrictions

The Triple R supply chain model [6] is a method for increasing the resilience of primarily the supply chain. Furthermore, although the model provides options for action, these are not concrete and are not geared to individual company characteristics, so that this must be done by the user. The World Class Manufacturing performance measurement [26] provides an approach for companies to strategically select best management practices depending on their specific needs in a VUCA world. However, it does not explicitly address resilience and the management practices are not concrete. BEVUCA [27] provides an approach to business excellence in a VUCA world by identifying success factors that can serve as orientation for companies. Though, concrete measures for action are not given and the requirements of resilience is not explicitly addressed. The approaches presented are management approaches with only little reference to practice. Moreover, none of the approaches offers a low-threshold application, e. g. through software or other support. In the study "Resilience and Relocalisation" [28], resilience in SMEs is analysed and recommendations for action are based on this. However, these are not described in a concrete and practice-oriented enough manner and do not take into account company-specific characteristics. In addition, although the area of logistics is examined immediately but production and the measures that can be taken here are not. The Measurement-Resilience Roadmap [29] is a five-step procedure that supports companies in increasing the resilience of the supply chain according to their individual requirements; aspects of production are not taken into account. Concrete measures are not described, but are still to be developed by the SMEs themselves. ERUC [30] is a software-based decision support tool for selecting measures with which companies can increase their resilience according to their individual requirements. However, the tool can only be used to support ramp-up management, which means that no measures are given in production and logistics over the entire factory life cycle. Measures for the preventive design of the production system against future-critical influences of a VUCA world are therefore not possible through ERUC and measures for improving entrepreneurial resilience are limited to the specific use case of a production ramp-up.

It becomes clear that so far, no approach exists that fulfils all the requirements identified and listed above. Above all, most approaches do not take into account the individual company characteristics and the low-threshold application of the approaches, e. g. through software. In this context, low-threshold means that no prior knowledge is required for the application and no high time capacities are needed. SMEs in particular, as already explained, do not have the personnel capacities to derive concrete measures from the standardised approaches and to work out a future viable solution.

## 2. Idea to close the research gap

In order to close the research gap and provide SMEs with the necessary support in a VUCA world, a methodological approach is to be developed that fulfils prerequisites one to four. The procedure for this is described below in section 2.1. To ensure that prerequisite five is met, the method is to be made available to SMEs via a low-threshold AI-based software tool. The development of the software support is described in Section 2.2. Thus, an approach is presented below that closes the previously described research gap.

### 2.1 Methodological approach

Figure 1 illustrates the methodological approach that fulfils prerequisites one to four and forms the basis for the software solution. The approach is described in more detail in the following section.

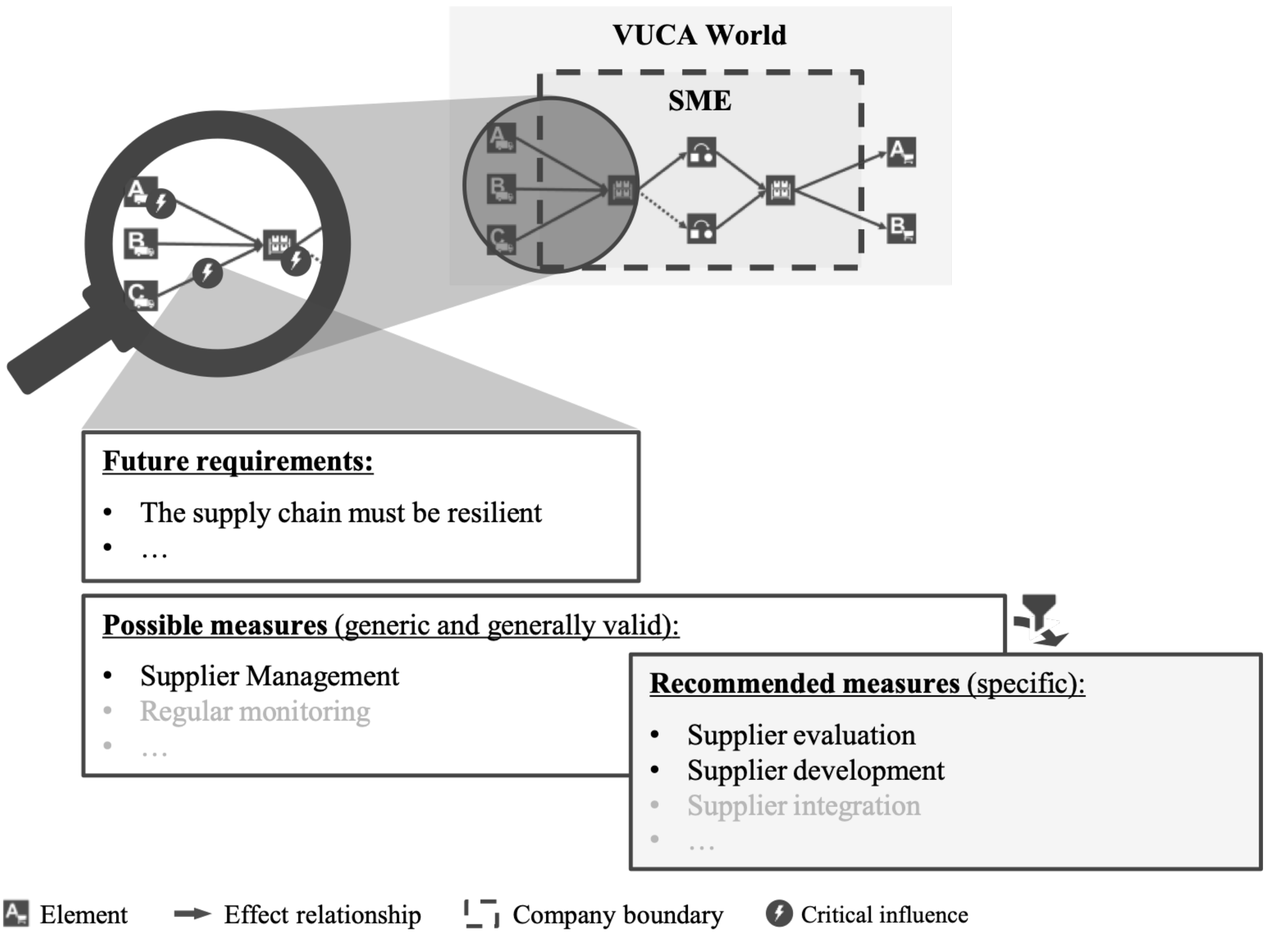


Figure 1: Methodological approach

In order to meet the needs of a large number of SMEs with the approach, they should be able to model their production systems and individual system behaviour realistically through multi-method modelling in the subsequent software application. In order for this to be taken into account in the subsequent development of the software, the first step is to identify the elementary elements and effect relationships as components of production systems. The smallest elements of a production system are located at the workplace level, such as operating resources or manual workplaces. This level of consideration is too detailed for the methodology to be applicable at a low level. A meaningful level of consideration for the project is the sub-area level with exemplary elements such as work systems. In order for the production system to be considered as part of the value network in a VUCA world, additional elements and effect relationships outside the system boundary must be added, such as suppliers or customers. To be able to model the behaviour of the production system realistically, the elements and effect relationships must also be parameterised. Relevant parameters for work systems are, for example, the scope of work or the number of operating resources. Additional information that is relevant for characterising the element or the effect relationships must also be acquired and parameterised, such as location information of the production system under consideration or its suppliers and customers. Anonymised data from industry partners are used to identify and parameterise the elements and effect relationships.

Building on this, the next step is to outline the relevant development scenarios of a VUCA world with the help of scenario management in order to determine the resulting critical influences on the previously identified elements and effect relationships. For this purpose, the scenario fields to be analysed in the further project must first be defined and limited. Therefore, the value creation networks and the general political and social environment of SMEs are systematised as areas of influence that allow a structured search for influencing factors. Selected sectors in which SMEs are particularly strongly represented will be focussed on to achieve this. In the long term, however, the aim is to further develop the methodology so that it can be applied to production systems in all sectors. To subsequently determine the influencing factors, expert interviews will be conducted with industry representatives and SMEs. These are to be supplemented by a literature search. In order to reduce the number of influencing factors to be investigated to a manageable number, the critical factors for the future viability of an SME in a VUCA world are identified. For these, possible and realistic development scenarios are formed using historical data and supplementary expert interviews, which represent the critical influences on SMEs in a VUCA world.

Determining the influences is a necessary step in order to be able to define ideal conditions for each element and each effect relationship. This must be done depending on possible company-specific configurations, such as economic, social or ecological company goals. For an element or effect relationship under consideration, several ideal states can therefore result for each influence. Requirements for the future viable design of the elements and effect relationships are then derived from the ideal states, for which specific measures can then be defined. For some requirements, measures already exist that can be compiled from the experience of past industrial projects and a supplementary literature research. All measures must be described in concrete terms. This means that the measure must include a concrete guideline for action as well as the required methodological knowledge. The measure "supplier management", for example, includes the procedure and relevant criteria for supplier evaluation as well as strategies for dealing with suppliers based on the evaluation results. The measures should also be systematised in a comparable way. This makes it possible to filter the generic catalogue of measures according to certain criteria, e.g. the scenario to be considered, the sector and the company goals. These filtered measures represent the recommendations for action tailored to the SMEs.

### 2.2 Development of AI-based software tool

In order to make this methodological approach available to SMEs in a low-threshold manner, it is to be transferred into an intuitively operated and on narrow AI-based software tool after conceptualisation. The software tool is composed of various self-learning algorithms, which each assume partial functionalities. Three basic requirements must be met for this: One, data describing the partial problems must be defined, provided and prepared. These are then also used to train and validate the AI. Two, the algorithms for the individual software functionalities must be programmed and three, these must be transferred into a software architecture.

**Data** is fundamental to the project and must be appropriately defined, provided and prepared for further use. The different requirements, e.g. in terms of scope or level of detail, for the data sets are to be *defined* depending on the individual partial problems of the research project. A data set consists of several data instances that are described by attributes. The individual attributes make it possible to describe the circumstances to be investigated with the software tool. For example, the development of the electricity price is to be forecast as a possible factor influencing companies in the VUCA world. For this purpose, all identified development-determining characteristics, such as gas price, concession fees or grid charges, must be combined as attributes into data instances. The decision on the number and relevance of the attributes is already relevant for the quality of the results of the later software tool. On the one hand, it is important to limit the attributes so that the algorithm does not become unnecessarily complex. On the other hand, no relevant attributes should be excluded in order to avoid exclusion bias. For the respective partial problems, different data are *provided* in each case. With the help of past geopolitical and economic data, the developments of the influencing factors can be described. In combination with anonymised industrial data, the influencing factors can be identified as future-critical and assigned to the relevant elements and effect relationships of the production systems. The historical geopolitical and economic data are available in sufficient quantity through public news agencies or authorities and the industrial data can be obtained from cooperating SMEs. Depending on the data quality, the facts to be described and the outcome, the data must be *prepared* differently. In any case, this includes data cleansing and evaluation, and in the case of self-learning algorithms, standardisation and labelling depending on the type of training.

The **algorithms** to be programmed should apply the methodology described in section 2.1 applicable for SMEs through functionalities in a software. In particular, the three functionalities of scenario building in a VUCA world, trouble shooting of the production systems and filtering of the action catalogues are to be realised. *Scenario building* from developments in a VUCA world serves to predict the relevant future-critical influences on the respective SMEs. The influencing factors identified during the creation of the methodology serve as the basis for scenario building. A forecasting algorithm, modelled on scenario management and based on current geopolitical and -economic information, describes the realistic future developments of the influencing factors. Since the algorithm works numerically, the influences must be parameterised. The developments of the influencing factors are grouped into influences affecting SMEs with the help of a grouping algorithm. A classifying algorithm is used to identify the influences that are critical for the future. During the software application, influences can become relevant with which the algorithm has not been trained. To ensure that these are nevertheless recognised and that scenario building remains applicable as a software functionality, this functionality is to be realised by a self-learning algorithm. *Trouble shooting* is used to allow the future-critical influences identified through scenario building to affect elements and effect relationships of the production systems and to identify resulting vulnerabilities. With the help of a classifying algorithm, the future-critical influences are assigned to the respective elements and effect relationships, which are defined as classes. This algorithm must also be self-learning so that it can still assign the influences to the correct elements and effect relationships during the software application that were not yet taken into account in the training phase. The model of the production system created by the user can be supplemented with the influence parameters on this basis. The prerequisite for this is that the model modules allow this addition through appropriate design and that the influencing parameters are systematised in a compatible manner. The vulnerabilities are then identified by simulation. They are valid for individual companies because the company-specific characteristics are taken into account through modelling and parameterisation of the production systems. The filtering of the measure catalogues serves to filter specific measures for the company-specific vulnerabilities of the elements and effect relationships from the previously defined generally valid and already defined measure catalogues. The filtering is to be realised with the help of a classifying self-learning algorithm that assigns the identified weak points to the specific measures, i.e. the classes, taking into account the filter criteria. Criteria to be considered in the filtering process include not only the design requirements for the elements and effect relationships, but also, for example, the economic, social or ecological corporate goals. The algorithm must be self-learning so that specific measures in the software application can be identified even for vulnerabilities not taken into account during the training phase. The algorithms can be based on different techniques, e.g. k-Nearest-Neighbour or Support Vector Machine in order of classification. Depending on the data, the techniques that describe the respective circumstances realistically and generate the smallest possible bias must be determined. A decision on the technique to be used is therefore not meaningful in advance, but must be precisely selected during the implementation.

The purpose of the **software architecture** is to develop the back- and frontend of the software. Development task of the *backend* is to integrate the previously described algorithms as software functionalities. During software application, it must be ensured that the algorithms are constantly fed with the latest data on developments in a VUCA world. Therefore, interfaces to data mining-based monitoring services such as Google Alerts, Awario or Mention have to be considered in the software architecture. Development of the *frontend* must succeed in making the software low-threshold to use. For this purpose, the user interfaces are to be designed intuitively according to the mock-up visualized in Figure 2 as a reference. For example, the elements and interdependencies required to describe the system behaviour must be transferred to a System Dynamics model in which the users can map their individual company structure via drag & drop.

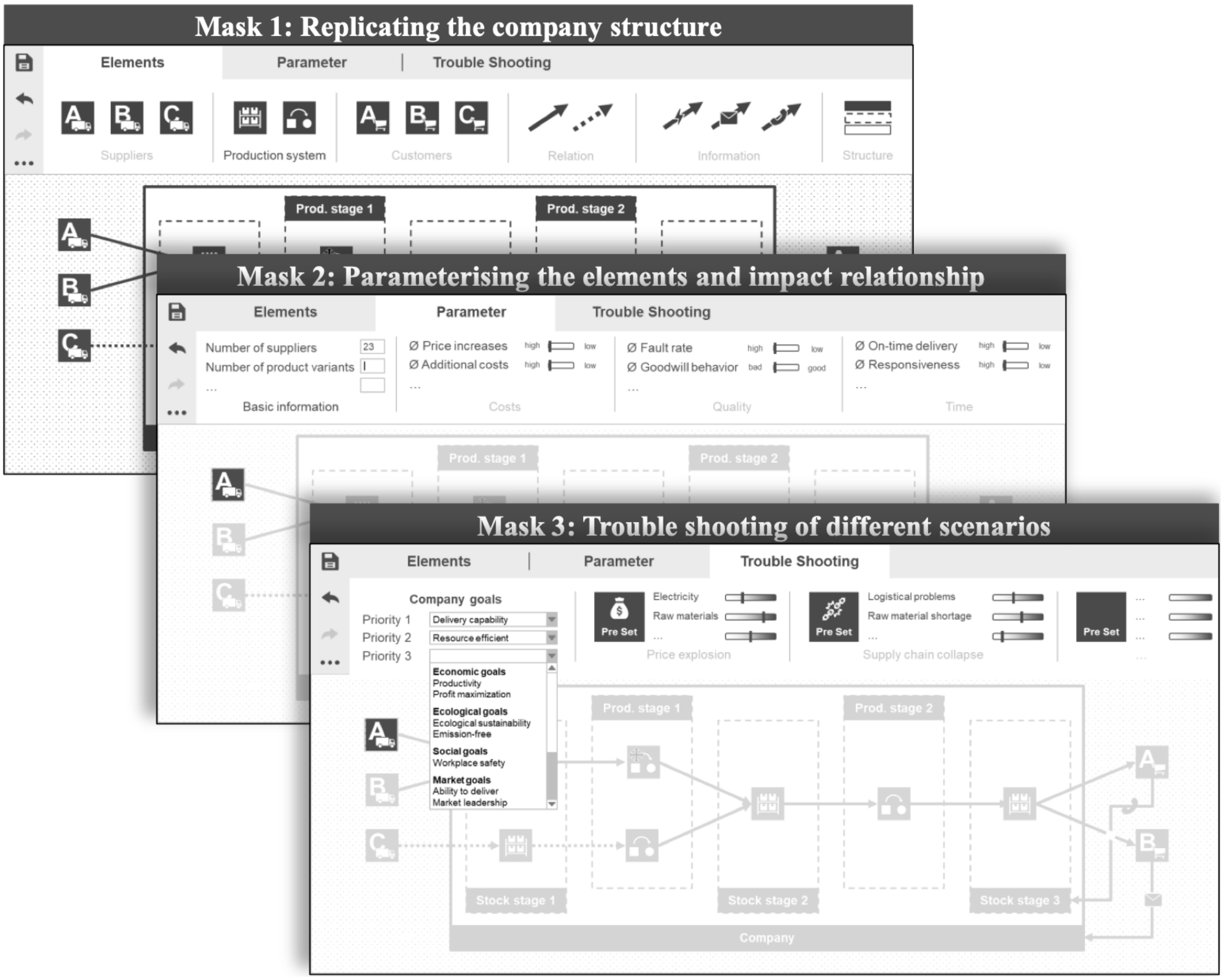


Figure 2: Mock-up of the possible front end of the software solution

## 3. Challenges and action strategies

For the project to be successful, the methodology described in section 2.1 must be valid and the development of the AI-based software support described in section 2.2 must be successful. The difficulty in developing the methodology is to summarise all elements and effect relationships of different production systems in a generally valid way without neglecting relevant features. This is also relevant for the algorithms to be subsequently programmed in order to avoid over- or underfitting of the AI. By successively testing the defined elements and effect relationships for applicability, this potential source of error can be prevented as early as possible. The acquisition and preparation of reliable data is the greatest challenge for the realisation of AI-based software support. Section 2.2 describes in detail which data must be used and prepared in order to train the respective algorithms. The procurement of historical data is unproblematic due to their easy availability. The systematic processing and labelling of the data for the various algorithms, on the other hand, is time-consuming. Particularly the labelling of the data requires great care, as this determines the solution spaces of the classifying algorithms and has a corresponding influence on the recommended measures for SMEs. The labels must therefore be validated before training. Obtaining the industry data, on the other hand, is more challenging. Data sets of several SMEs per area of the production system are needed, which have been identified as elementary elements and effect relationships to describe the system behaviour. It is to be expected that the data quality as well as the quantitative availability of the required data sets is not sufficient in all SMEs for the project. For each of the data sets, data requirements lists are therefore to be defined, with which the quantitative and qualitative availability of the data in the SMEs is to be checked in advance. If individual data sets cannot be procured in sufficient quantity or quality, these areas of the production system are excluded from the horizon of consideration for the time being. As soon as data availability can also be ensured for these data sets, the methodology for the respective areas of the production system is to be further developed. The consideration of all design fields of production and logistics is an advantage of the project compared to other approaches and is therefore a unique characteristic that should not be neglected. One challenge in the application is that SMEs are comparatively sceptical about AI-based solutions. In order to counteract this, cooperating SMEs are involved in the project as early as possible, both through data procurement and through the validation of the interim results. On the one hand, this ensures the applicability of the methodology as well as the software tool in SMEs and, on the other hand, increases the willingness of SMEs to use it.

## 4. Summary and outlook

So far, there is no approach that offers companies adequate support to adapt to the influences of a VUCA world in a future-oriented way. This is a major challenge for SMEs in particular, which they find difficult to overcome due to a lack of resources and expertise. The method outlined above not only enables companies to recognise the requirements arising from a VUCA world, but also provides specific recommendations for action, for the future viable design of the respective production system. Future research activities of the Institute of Production Systems and Logistics (IFA) and GREAN GmbH will develop the valid methodology and transfer it into a low-threshold and AI-based software tool so that it can be ensured that the methodology is applicable for SMEs.

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## Biography

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**Peter Nyhuis** (*1957) studied mechanical engineering at Leibniz University Hanover and subsequently worked as a research associate at Institute of Production Systems and Logistics (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.