Scenario-Based Foresight in the Age of Digital Technologies and AI

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Abstract. Scenario-based foresight is used less and less in the corporate world despite continued high satisfaction with the obtained results. In the age of digitalization, many companies feel increasingly forced to short-termism instead of strategic planning. However, emerging digital technologies, such as artificial intelligence (AI), represent a promising approach to cope with the traditional challenges of scenario-based foresight as well as new challenges added by digitalization. Therefore, this work-in-progress paper identifies and analyzes use cases for scenario-based foresight with digital technologies employing a systematic analysis of the relevant literature.

In the paper at hand, we show that the use of digital technologies for improving the performance of scenario-based foresight is an emerging field. We identify 14 so-called use cases, i.e., unique goal-oriented applications of digital technologies for scenario-based foresight. In general, the use cases show that currently digital technologies can enhance, not substitute the capabilities of scenario-based foresight practitioners. Digital technologies primarily support the analysis of large amounts of data, e.g., for collecting futuristic data and identifying key influence factors. However, activities that require implicit knowledge and creativity, like the interpretation of scenarios, are currently still left to humans.

Keywords: Scenario-based foresight · Scenario planning · Scenario technique · Digital technologies · Artificial intelligence · Explainability

1 Introduction

In the age of digital technologies and artificial intelligence (AI), scenario-thinking, i.e., scenario-based strategic thinking and decision making, is on the verge of radical change. However, digital technologies and AI will not change the main principles of scenario thinking (Schühly et al. 2020): 1) Networked thinking, i.e., the consideration of the interconnectedness of influence factors, and 2) multiple futures, i.e., it is not possible to predict the future and therefore different development paths must be considered (Berger et al. 2008; Gausemeier et al. 2018). So, it is not the principles of scenario thinking that are changing. Rather, digital technologies and AI can change the way scenarios are developed and perceived (Schühly et al. 2020).

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Global megatrends cause a rapid and profound change in our world (Hamidian and Kraijo 2013). As a result, volatility, uncertainty, complexity, and ambiguity are increasing significantly in our environment. In this so-called VUCA (volatility, uncertainty, complexity, ambiguity) world, it gets more and more challenging to make valid long-term recommendations and statements with conventional scenario-based foresight (Schühly et al. 2020). With increasing availability of data and emerging powerful digital technologies, digitalization offers promising opportunities to deal with the ever-faster changes in the environment. However, digitalization also creates entirely new challenges for scenario-based foresight practitioners. These new challenges can be structured with help of the 5 Vs of Big Data: volume, velocity, variety, veracity, and value (Sagiroglu and Sinanc 2013; Demchenko et al. 2013):

- **Volume:** The amount of data is increasing exponentially. 2.5 quintillion bytes of data are created every day. This number will increase even further and faster than before in the coming years (Marr 2018). In addition to the amount of data, the number of relevant data sources is also increasing. Consequently, more data must be processed and analyzed in the same amount of time. If done right, this enables scenario-based foresight practitioners to make more informed data-driven decisions.
- **Velocity:** Velocity measures how quickly data are coming in. Whereas some data come in batches, other data come in in real-time. Therefore, the different velocities present a challenge for analysis. On top, with increasing volume and velocity, the half-life of information decreases. For scenario-based foresight, that means that scenarios must be monitored and revised more frequently.
- **Variety:** Data can be structured, semi-structured or unstructured. For the use in scenario-based foresight, a pre-processing of the data is required.
- **Veracity:** Veracity means that data need to be consistent and trustworthy. Consequently, scenario-based foresight practitioners also need to carefully assess the quality of futuristic data.
- **Value:** The value of data is measured by the value contribution that collected data can bring for a specific goal. For scenario-based foresight practitioners, it will become a crucial task to distinguish relevant data sources from less relevant ones, e.g., in the identification of key influence factors.

These challenges induced by the information age only add to the already existing, traditional challenges of scenario-based foresight. Traditional challenges include, in particular, the high complexity of the methodology itself and the large amount of time required for its application. Consequently, the use of scenario-based foresight is declining in practice, although satisfaction with the obtained results remains at a high level (Rigby and Bilodeau 2018; Bain and Company 2018). In the VUCA world, companies rather tend to focus on short-termism than on long-term planning (Barton et al. 2018). Studies have shown, however, that companies who systematically make use of (scenario-based) strategic foresight are significantly more successful and less volatile in the long term than their short-term oriented competitors (Barton et al. 2018; Rohrbeck and Kum 2018; Rohrbeck et al. 2018). In order to enable companies again to use scenario-based foresight more, it is necessary to find a way to improve its overall performance and adapt it to the surrounding circumstances in the age of digitalization.

In scenario-based foresight, we can distinguish between two major directions of thrust: scenario planning and scenario technique. Scenario planning is a deductive methodological approach. A typically predefined number of scenarios is developed with the help of a rigid scenario framework. In contrast, scenario technique is an inductive methodological approach. Future scenarios are developed by systematically combining consistent alternative development paths of key influence factors, so-called future projections (Götze 1993; Fink and Siebe 2011). Although the two major directions of thrust differ slightly in specific steps, the general steps, activities, and stages are closely related to each other. Subsequently, we will not differentiate between the two directions of thrust. Rather, we will refer to the overarching and summarizing concept of scenario-based foresight. Its evolution over time is shown in Fig. 1.

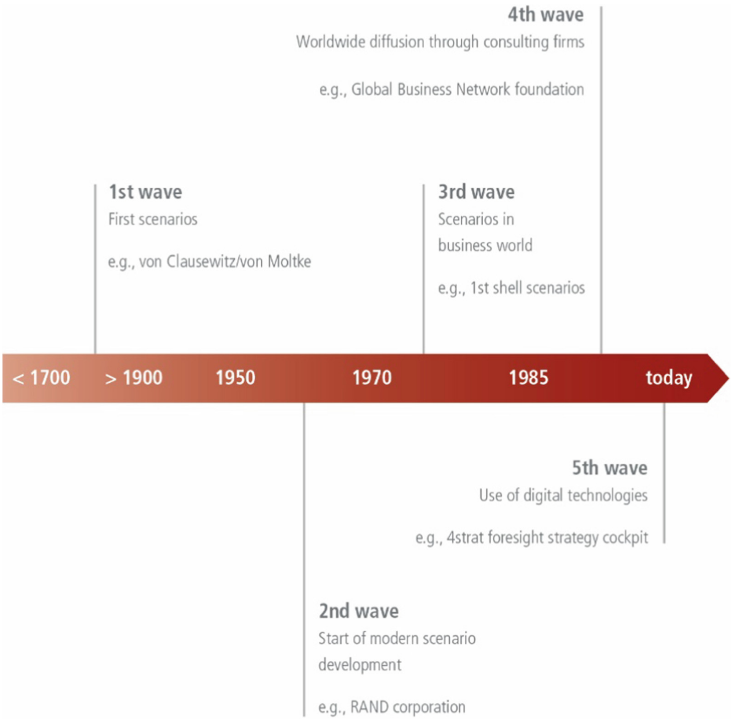

Fig. 1. Timeline of scenario-based foresight (own illustration based on Schühly et al. 2020)

In the context of strategic planning, scenarios were used for the first time by the military (first wave). The start of modern scenario development began right after World War II, when the US military worked together with the RAND corporation on future scenarios (second wave). Later, the company Royal Dutch Shell brought scenarios into the corporate world. With scenario-based foresight, the company was better prepared than most of its competitors for the oil price shocks in the 1970s (third wave). In the mid-1980s, the use of scenario-based foresight by multiple consulting firms like the Global Business Network led to its worldwide diffusion (fourth wave). Today, the fifth wave of scenario-based foresight is emerging. Emerging digital technologies, like AI, can and will change the way how scenarios are created and perceived (Schühly et al. 2020).

According to Lipsmeier et al. (2018) "digital technologies [...] comprise knowledge, skills and know-how for the creation, processing, transmission, and use of digital data as well as systems and procedures for practical implementation" (p. 32). Following the work of Berger et al. (2018), we can differentiate infrastructural digital technologies, application-oriented digital technologies, and service-oriented digital technologies. Infrastructural digital technologies, like platforms and connectivity technologies, as well as application-oriented digital technologies, like sensors and actors, can be considered prerequisites and enablers for further digital technologies. The so-called service-oriented digital technologies have the potential to enhance the performance of scenario-based foresight, e.g., by increasing the efficiency of the methodology or by increasing the quality of results. Service-oriented digital technologies cover the range of technologies for analytical insight generation (e.g., machine learning), analytical interaction (e.g., virtual assistant), and augmented interaction (e.g., gesture control) (Berger et al. 2018). Service-oriented digital technologies possess the ability to collect vast amounts of data, analyze data, extract knowledge from data, and even support decisions (Porter and Heppelmann 2014; Belger et al. 2019; Acatech 2020). Therefore, it can be concluded, that digital technologies may provide a technology-based answer to the new technology-induced challenges and the traditional challenges of scenario-based foresight (Schühly et al. 2020).

In practice, there are already first applications, which make use of digital technologies, e.g., AI techniques, in order to improve the performance of scenario-based foresight. One example is the foresight strategy cockpit of the company 4strat. The application supports different foresight activities, e.g., scenario building and (semi-)automatic trend monitoring (4strat 2022).

To systematically identify use cases of digital technologies for scenario-based foresight, existing approaches from the literature should be analyzed. Therefore, this work-in-progress paper aims to answer the question: *Which use cases for digital technologies exist in the literature, that can improve the performance of scenario-based foresight?* We conducted a systematic literature analysis to create a first overview of the existing use cases.

2 Research Design

Our research design for the systematic literature analysis is based on the guidelines of Webster and Watson (2002) (see Fig. 2). The review is structured in four sequential phases: 1) definition of search strategy; 2) definition of search string; 3) conduction of search; 4) analysis and evaluation of approaches. Subsequently, all phases and their results are described in more detail.

1) Definition of Search Strategy

A search strategy includes the research question for the systematic literature analysis, information on the time frame to be analyzed and the language of the publications to be analyzed, as well as the relevant databases to be searched (see Fig. 3). The research question has already been derived in Sect. 1. The time frame for the search for relevant

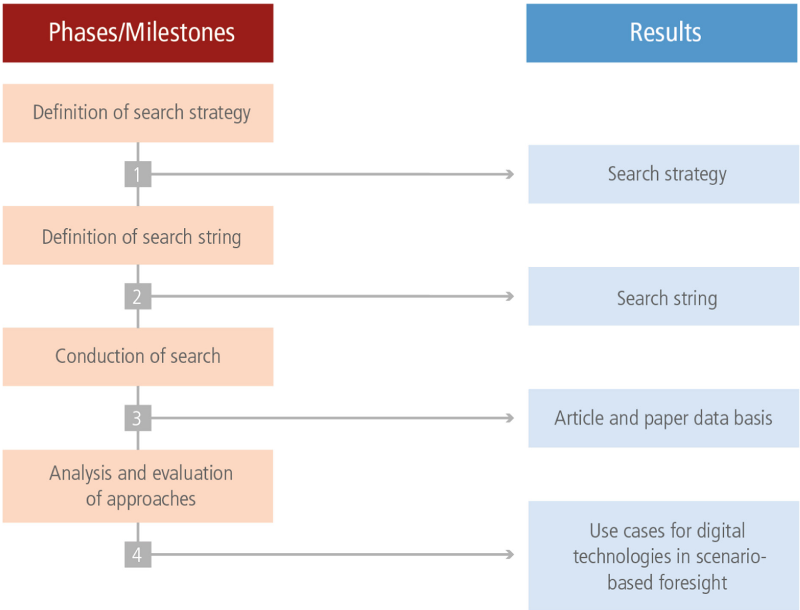

Fig. 2. Research design for literature review (own illustration based on Webster and Watson 2002)

sources is deliberately not narrowed down in order to also identify early approaches for scenario-based foresight that already make use of digital technologies. Furthermore, the databases are searched exclusively for English scientific publications because English is commonly used in the relevant literature in the field of scenario-based foresight.

For the selection of the relevant databases, five renowned databases for scientific publications were reviewed for suitability: Scopus, IEEE, Web of Science, ScienceDirect, and Wiley. For this purpose, the two directions of thrust for scenario-based foresight were used as search terms: "scenario planning" and "scenario technique". The databases ScienceDirect and Web of Science were selected because they contained the highest numbers of relevant journals and conferences in the context of scenario-based foresight. Other relevant journals and conferences from the non-selected databases and the experiential knowledge of the authors in the context of scenario-based foresight were collected in a list for an additional manual search. This list included, e.g., the International Journal of Foresight and Innovation Policy. After determining the search strategy, the search string is defined.

Language	Time frame	Databases
English	Not limited	ScienceDirect, Web of Science

Fig. 3. Search strategy components (own illustration)

2) Definition of Search String

The search string was defined iteratively (Marcos-Pablos and García-Peñalvo 2018). The initial search string was revised and finalized in three iterations, each with different researchers as sparring partners. General structuring frameworks for digital technologies and AI, such as Papers with Code (2022), and foresight-specific structuring frameworks, such as van Belkom (2020), were considered as input for the initial definition and iterative refinement of the search string. The final search string is thereby composed of two elements S1 and S2. S1 includes the two directions of thrust for scenario-based foresight and eight synonyms that are commonly used in the literature. S2 comprises 18 search terms derived from the considered structuring frameworks for digital technologies and AI. Figure 4 shows the search string.

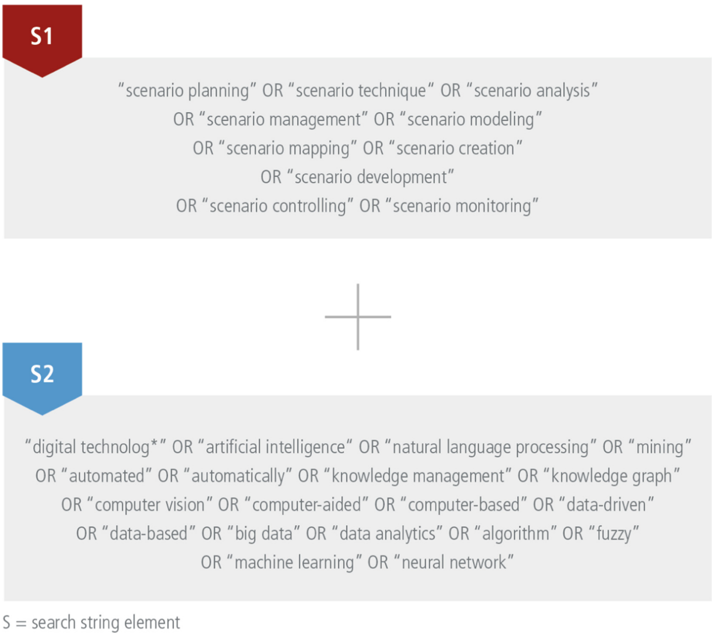

Fig. 4. Search string

3) Conduction of Search

The actual conduction of the search itself takes place in phase 3. The steps of the search are shown in detail in Fig. 5.

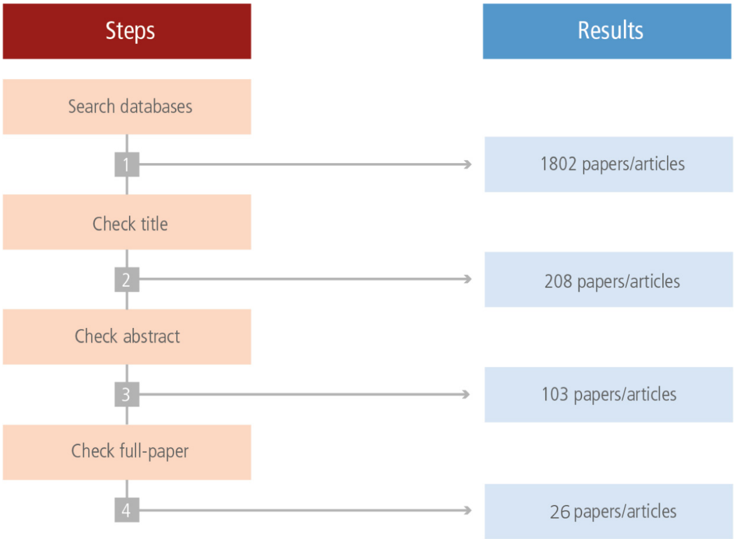

Fig. 5. Selection process of papers and articles (own illustration based on Webster and Watson 2002; Xiao and Watson 2019)

First, the databases ScienceDirect and Web of Science were searched using the developed search string. As a result, 1802 potentially relevant scientific publications, i.e., journal articles or conference papers, were identified. Second, these publications were checked for relevance based on their title. All clearly non-relevant publications were removed. In addition, duplicates were removed as well. 208 potentially relevant scientific publications remained. Third, the publications were checked for relevance based on their abstracts. This reduced the number of potentially relevant sources to 103. Fourth, the publications were checked for relevance based on the full texts. In this way, a total of 18 relevant scientific publications were identified that contain at least one approach to scenario-based foresight with digital technologies. The final database also contains eight additional publications that resulted from the manual supplementary search. The database thus comprises 26 scientific publications.

After the formation of the publication database, we analyze and evaluate the papers and articles in detail (phase 4). First, we investigate the papers regarding their publication dates to get a refined view on the development of the topic over time. Then, more general use cases for digital technologies for scenario-based foresight are extracted from the papers. Last, the resulting use cases are analyzed in more detail, e.g., regarding their degree of explainability. The results are shown in the next chapter.

3 Results

Overall, a slight increase in the publication rate can be observed from the year 2016 onwards compared to the years before. This supports the thesis that we are currently just at the beginning of the 5th wave of scenario-based foresight, the *scenario-based* *foresight with digital technologies* (c.f. Sect. 1). Figure 6 shows the distribution of the selected 26 publications over time.

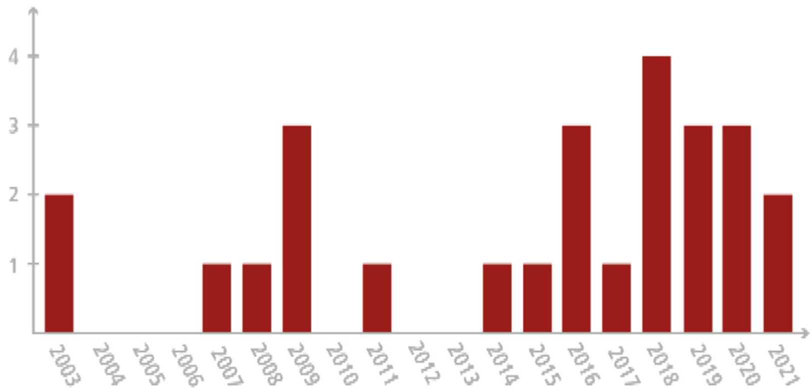

Fig. 6. Analysis of publications year-by-year (own illustration)

To analyze the 26 scientific publications of our database regarding possible use cases, we first define a use case for scenario-based foresight with digital technologies as *the goal-oriented application of one or more digital technologies, e.g., a specific AI technique, for a stage, step, or activity of scenario-based foresight*.

Following this definition, a total of 38 mentioned use cases can be identified from the sources. However, as some authors published consecutive papers dealing with the evolution of the exact same approaches, there are some identical use cases in the long list. After removing the duplicates, 27 use cases remain. However, several of the 27 use cases support the same goal with different digital technologies, i.e., they support the same stage, step, or activity of scenario-based foresight. As a results, the 27 use cases can be clustered to 14 unique use cases.

For example, Kim et al. (2016); Kayser and Shala (2020); Şahin et al. (2003) all describe the identification of (key) influence factors with the help of digital technologies. The three possible use cases therefore all pursue the same goal, i.e., they can be clustered to one unique use case (see use case no. 2). However, all authors rely on different digital technologies for the identification of influence factors. While Kim et al. (2016) as well as Kayser and Shala (2020) propose topic modeling and concept mapping, two approaches from the field of text mining which is part of natural language processing, Şahin et al. (2003) rely on the use of an artificial neural network. Therefore, different digital technologies can be considered for the implementation of each use case. Moreover, a possible solution approach can be based on a combination of several digital technologies. This can be seen for example in use case no. 8 (generate scenarios). Feblowitz et al. (2021) propose a combination of a domain-independent top k-planner and a (simpler) hierarchical clustering algorithm with a soft time limit.

Figure 7 shows the list of the 14 identified use cases. In addition to the addressed stage, step, or activity of scenario-based foresight, the list also includes the 23 digital technologies that can be used to realize the use cases, as well as the associated sources.

Use Cases			
No.	**Scenario-based foresight (stage, step, or activity)**	**Digital technologies**	**Sources**
1	Collect futuristic data as input for identification of (key) influence factors	Web mining	Kayser and Shala 2020
2	Generate suggestions for (key) influence factors	• Rule-based algorithm • Topic modeling, e.g., latent • semantic algorithm (text mining) • Concept mapping (text mining) • Artificial neural network	Kim et al. 2016; Kayser and Shala 2020; Batrouni et al. 2018; Şahin et al. 2003; Feblowitz et al. 2021; Backhaus et al. 2018
3	Conduct influence analysis	• Fuzzy association rule mining • Fuzzy linguistic MICMAC	Kim et al. 2016; Villacorta et al. 2014
4	Select key influence factors	• Modified page rank algorithm • Concept of generalized area centrality	Gräßler et al. 2019; Backhaus et al. 2018
5	Identify relevant triggers and events for scenarios	Web crawler	Sharma and Young 2015
6	Semi-automatic filling of consistency matrix	• Use of pre-defined consistency patterns • Fuzzy rule-based system	Gräßler et al. 2020; Dönitz and Möhrle 2009
7	Decompose consistency matrix	Modified design structure matrix algorithm	Backhaus et al. 2018
8	Generate scenarios	• Adaptive Neuro-Fuzzy Inference System • Top k planner and hierarchical clustering algorithm	Moayer and Bahri 2009; Feblowitz et al. 2021
9	Determine and select scenarios	• Selection algorihms Inference System • Combination of hierarchical and non-hierarchical clustering using self-organizing map neural network	Tietje 2003; Şahin et al. 2003; Pishvae et al. 2008
10	Generate fuzzy cognitive model for scenario	Fuzzy cognitive mapping expert system	Nápoles et al. 2018
11	Conduct what-if-analyses for scenarios	Sensitivity analysis	Nápoles et al. 2018
12	Classify documents to support scenario writing	Dictionary algorithm	Fergnani and Jackson 2019
13	Identify, extract subjective perspectives in input documents for scenario writing	Sentiment analysis	Fergnani and Jackson 2019
14	(Continuous) supervision of key assumptions of scenarios	Feature selection algorithm	Batrouni et al. 2018

Fig. 7. List of 14 identified use cases (own illustration)

Use cases nos. 1 to 5 refer to the phase of identifying key influence factors.[1] Text mining approaches are particularly suitable for analyzing large amounts of data in order to generate suggestions for influence factors. This is in line with the findings and experiences of Bauer et al. (2022), Steinmüller (2022), and van Belkom (2020). Afterwards, humans need to discuss and add to the proposed key factors before selecting the key factors (Kayser and Shala 2020).

Further use cases show a similar pattern. Use cases nos. 6 and 7, e.g., primarily aim at reducing the evaluation effort in the context of determining scenarios. But the actual evaluation or the definition of necessary rules for rule-based approaches is still performed by humans (Dönitz and Möhrle 2009; Backhaus et al. 2018; Gräßler et al. 2020). With regard to divergence, a characteristic of socio-digital sovereignty (Hartmann 2020; Hartmann 2022), humans have extensive intervention capabilities throughout those use cases, and thus have autonomy and discretion regarding different courses of action.

Use cases nos. 12 and 13 refer to the elaboration of the scenarios. Digital technologies provide the input for this activity, e.g., by means of a classification of useful documents by a dictionary algorithm (Fergnani and Jackson 2019). The creative elaboration itself is ultimately carried out by humans.

Tasks such as defining the object of investigation, projection development or scenario interpretation, which require creativity, tacit knowledge, or qualitative data, are left to humans. In this context, digital technologies can specifically complement human capabilities, e.g., by taking over the analysis of large data sets (Bauer et al. 2022; Steinmüller 2022; van Belkom 2020).

Consequently, the scope of support provided by digital technologies is currently (still) limited. For clarity, we structure the use cases with the help of a stage model for the use of digital technologies. The stage model represents a synthesis of the knowledge ladder according to North (2016) and the four capabilities of smart, connected products (Porter and Heppelmann 2014). This results in four stages for the use of digital technologies: 1) collect data, 2) analyze data, 3) generate knowledge from data, 4) support decisions.

We must note that the stages do not allow any direct statements concerning the intelligence or explainability of the digital technologies described in the use cases. Furthermore, a single use case can be simultaneously assigned to different steps of the step model if the functional scopes of the proposed digital technologies for its realization differ significantly in their scope of support. Figure 8 shows the use cases assigned to the four stages of the stage model for the use of digital technologies.

[1] For the general stages of scenario-based foresight, cf. (Huss and Honton 1987; Götze 1990; Fink and Siebe 2011; Ködding and Dumitrescu 2022).

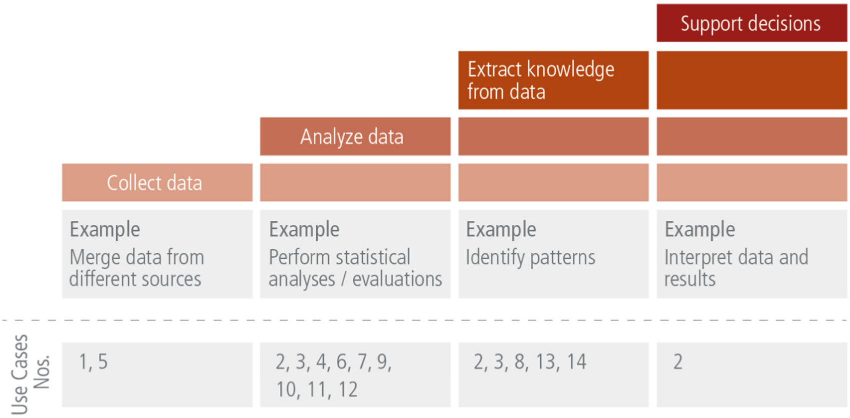

Fig. 8. Use cases classified according to the step model for the use of digital technologies (own illustration based on North 2016; Porter and Heppelmann 2014)

A glance at the chart confirms that digital technologies are currently most frequently used to analyze large volumes of data. While there are a few cases, where knowledge is generated from data, only one use case supports the user in decision-making. This is the identification, or rather recommended proposition of influence factors with the help of an artificial neural network (see use case no. 2).

However, the scope of support of the use cases does not allow any conclusions to be drawn about the explainability of the digital technologies used. For the concept of digital sovereignty, explainability of digital technologies is a crucial component (Hartmann 2020; Hartmann 2022). For this purpose, we have derived four categories for the analysis of the degree of explainability of digital technologies (see Fig. 9). The categories are based on the work of (Ilkou and Koutraki 2020; Lawson et al. 2021). It comprises four stages: 1) (procedural) algorithm, 2) symbolic AI, 3) sub-symbolic AI: classical machine learning, 4) sub-symbolic AI: deep learning.[2] The degree of explainability decreases from level 1 to 4.

(Procedural) Algorithms, such as web crawlers, are easily explainable to the user (stage 1). Symbolic AI is also referred to as good old-fashioned AI in literature (stage 2). Symbolic AI is a part of AI that uses clearly defined, logical knowledge. The explicit knowledge representation is done via symbols. In sub-symbolic AI, however, machine learning approaches use algorithms that learn a task through learning from data. This implicit knowledge is represented by models. Moreover, deep learning approaches with neural networks with many layers, so-called deep neural networks (stage 4), can be distinguished from classical machine learning approaches (stage 3). Deep learning approaches are much more difficult to explain to the user than classical machine learning approaches (Ilkou and Koutraki 2020; Lawson et al. 2021; Akkus et al. 2021). Figure 9 shows the assignment of the 23 possible digital technologies for the realization of the 14 use cases.

[2] So-called in-between methods (cf. Ilkou and Koutraki 2020), i.e., methods between symbolic AI and sub-symbolic are not considered in this step model.

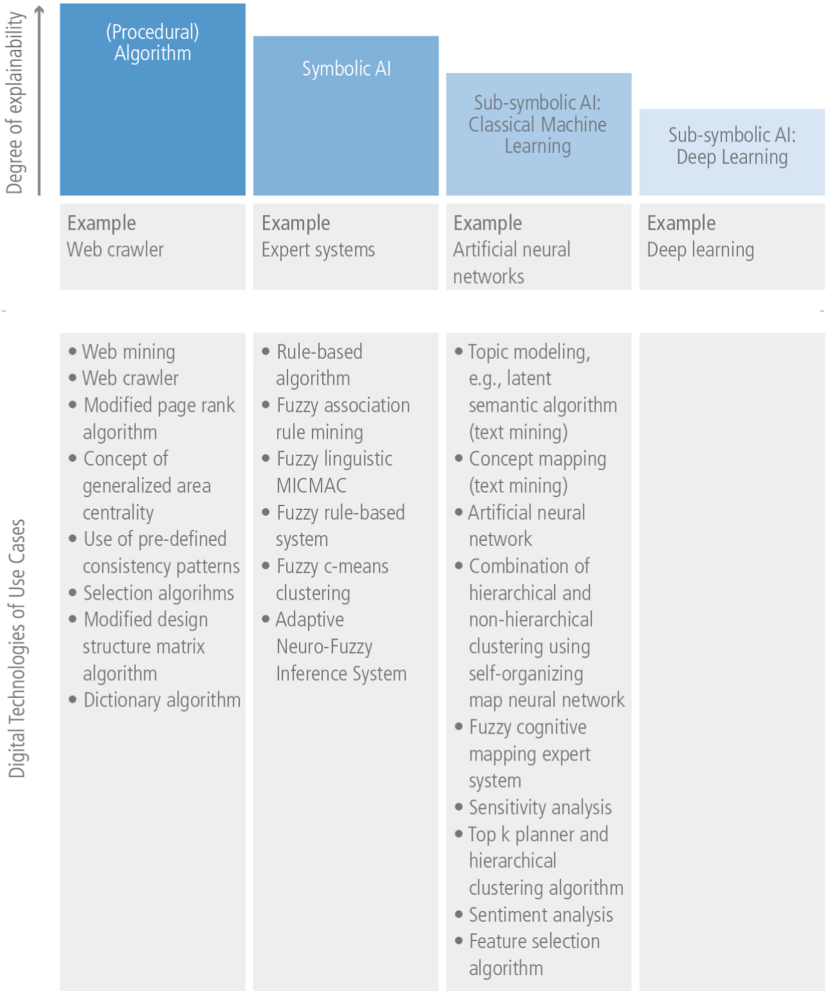

Fig. 9. Digital technologies of use cases assigned to different categories of explainability (own illustration based on Ilkou and Koutraki 2020; Lawson et al. 2021)

Explainability is an essential element of the transparency of digital technologies, a characteristic of socio-digital sovereignty (Hartmann 2020; Hartmann 2022). Regarding the use cases examined, we find that a large proportion of the technologies used can be explained rather easily to the user. These are primarily the eight digital technologies classified as (procedural) algorithms, such as the modified Design Structure Matrix algorithm (Backhaus et al. 2018), and approaches from the field of symbolic AI, such as the fuzzy rule-based system for semi-automatic filling of a consistency matrix (Dönitz and Möhrle 2009). Text mining approaches or simple artificial neural networks for the identification of influence factors or sentiment analysis belong to the field of sub-symbolic AI. These approaches can still be (almost) fully explained to the user, but only with significantly more effort.

4 Discussion

Research Outcome: Our research question was "*which use cases for digital technologies exist in the literature, that could improve the performance of scenario-based foresight?*". Our findings suggest that there are (at least) 14 use cases for scenario-based foresight with digital technologies in the literature as of today. These use cases can be realized using 23 different digital technologies. Currently, digital technologies (still) play a minor role in scenario-based foresight. Digital technologies primarily provide support for tasks in which large volumes of data are processed and analyzed, e.g., in the context of identifying influence factors. Approaches from the field of procedural algorithms and symbolic AI are frequently used. However, approaches from sub-symbolic AI, such as the use of simple artificial neural networks, are also making their entry into scenario-based foresight. Deep learning approaches, however, have not been used to date. Humans continue to be the focal point in the development and interpretation of future scenarios. However, the number of publications on improving the performance of scenario-based foresight with digital technologies has increased in recent years, and so has their significance (Schühly et al. 2020).

For foresight practitioners, the work-in-progress paper provides an initial structuring framework for use cases with digital technologies in scenario-based foresight. It represents a starting point for exploratively identifying new use cases and for classifying them accordingly.

Limitations: The limitations of the work-in-progress paper are closely linked to the chosen research design. First, the selected databases and the manually added conferences and journals may have excluded further conferences and journals with useful papers and articles. Second, the search string itself represents a limitation as the obtained results depend strongly on it. An inclusion of specific steps or activities of scenario-based foresight or the use of more synonyms could yield further interesting use cases. Third, the forward and backward search of the analyzed 26 papers and articles is still carried out right now. Thus, the results could not be included in this paper. The analysis of the results will form the basis for the derivation of new use cases and the adaption of existing use cases for scenario-based foresight with digital technologies.

Implications for Future Research: Limitations of the work-in-progress paper indicate an immediate need for research. In the short term, it is essential to analyze the findings of the forward and backward search for the paper database. Subsequently, those papers should be analyzed as well for relevant use cases. Additionally, it is possible to expand the focus of the literature. E.g., the search term "foresight" can be included in addition to the two directions of thrust for scenario-based foresight as well. Then, it is necessary to analyze which use cases for digital technologies can be transferred from general foresight to scenario-based foresight.

In the medium term, it is useful to derive possible future use cases for scenario-based foresight with digital technologies exploratively. This way, not only existing approaches to improve the performance of scenario-based foresight would be considered, but it would also be able to consider the sheer endless possibilities of emerging digital technologies. On top, an explorative study on use cases that go beyond the current activities, steps, and stages of scenario-based foresight seems promising (Steinmüller 2022; Bauer et al.

2022). Those new use cases could enable completely new methodological activities in scenario-based foresight.

In the long term, the general methodology of scenario-based foresight should be methodically developed further based on the prioritized and selected use cases, in close coordination with the technical realization of those use cases. In this context, it will be important to define which task will be performed by humans and which by digital technologies in the future. This also includes the design of the digital sovereign collaboration of human and technology in scenario-based foresight (Steinmüller 2022; Bauer et al. 2022).

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