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Classification Approach for Use Cases Within a Demonstration Factory Environment

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Abstract

Industry 4.0 demonstration factories show live demonstrations of use cases in a realistic factory environment. Usually, the use cases displayed in such an environment are uncoordinated in terms of integrity and variance of addressed research topics. This paper presents a classification approach for use cases to contribute to a more structured planning and coordination of demonstration factories. When applying this developed approach to individual demonstration factories, the analytical steps lead to an accumulated heat map, which supports practitioners in identifying both strengths and weaknesses of the individual demonstration factory for further planning. An exemplary application of the approach was conducted by analyzing the demonstration factory of the nationally funded project Future Work Lab.

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Keywords: Classification model; industry 4.0; learning factory; demonstration factory; use cases.

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1. Introduction

Digital transformation and Industry 4.0 are main drivers for change in industrial manufacturing systems. With automation, information and communications technology (ICT) and cyber-physical systems, workers are facing shifts regarding tools, jobs and task profiles [1]. In order to successfully master the upcoming challenges of digital transformation in manufacturing, awareness has to be raised not only on management level, but also on worker level. One solution to foster knowledge transfer and raise awareness of technological and organizational change is the demonstration of feasible scenarios in form of use cases, often aggregated in learning factories with focus on demonstration.

Usually, learning factories focus on one or more comprehensive learning scenarios with a consistent story and different use cases. As a specific type of learning factories, demonstration factories do not necessarily build upon consistent and interconnected learning scenarios. The main intention is to give demonstrations of possibly unrelated use cases for a certain domain. Given this less story-based, more domain-driven approach, demonstration factories are carefully adjusted to meet the needs of target groups and the respective domain.

As a solution, this paper describes the development and application of a classification approach to conceptualize a planned or existing set of use cases for a demonstration factory in a structured and demand-driven way. The classification approach is based on a categorization of use cases with regard to content, followed by a classification along the value chain, leading to a cluster analysis in a heat map design. The developed approach is beneficial in terms of identifying relatively strong and weak spots in a demonstration factory. Furthermore, the method is suitable for the planning phases to decide which demonstrators to display.

The paper is structured as follows. The following chapter provides an overview of the state of the art. In chapter 3, the structure and core elements of the classification approach are presented. Based on this, chapter 4 shows the setup and implications of a practical application in a demonstration factory. The concluding remarks in chapter 5 summarize the findings and shed light on potential fields for development.

2. State of the art

Subsequently, this chapter introduces the scientific fields of relevance for this paper. The first section defines digital transformation, which is a significant driver for change in manufacturing systems. The second section specifies four different types of learning factories and names typical characteristics of each type. In the last section, the different stages of a generic value chain are introduced, which are important for the classification of use cases throughout this paper.

2.1. Digital transformation

Digital transformation describes the evolutionary development of industrial manufacturing towards connected and intelligent cyber-physical production systems. Information and communications technology are its main drivers [1, 2]. Digital transformation involves four stages: digitalization, virtualization, connectivity, automation [3]. Furthermore, digitized and virtualized systems lead to new scenarios of industrial work, namely cooperation between human and machine within a smart factory [2]. Future work trends in the workplace design focus on connectivity, context sensitivity, assistance and intuitiveness [1].

Consequently, digital transformation causes significant changes in competence profiles on all relevant job levels. For example, engineering jobs nowadays require a widespread set of competences from interdisciplinary communication over expert knowledge to complex ICT-based knowledge. Facing the increasing complexity of planning and controlling tasks within a smart factory, knowledge management is an essential tool to keep industrial production systems efficient and viable [4, 5]. As a recent approach, learning factories have been established to address the need for hands-on education and training [4].

In the context of the digital transformation of the industrial value chain, the term Industry 4.0 is often used and specific application scenarios are often referred to as use cases. Unfortunately, there does not seem to be a common understanding of the term, although a variety of implemented use cases exist. Studies propose different collections of Industry 4.0 aspects to be for example assistance systems, smart engineering, transparency, decentralization, and others [6, 7].

2.2. Learning factories

Learning factories provide a realistic representation of a factory system with core elements such as products, processes, and resources in an experience-orientated, participative, digital as well as real learning environment. In this exemplary work environment, participants can apply acquired knowledge and existing experiences in an interactive way. Thus, learning factories simulate interdisciplinary and multidimensional learning situations in a case-oriented manner [8], often referred to as use cases. The term “use case” has its origin in software engineering, where defines all possible scenarios that may occur when a user interacts with a system [9]. In the context of Digitalization and Industry 4.0, and thus, applies for this paper, the terms refers to a specific business scenario and a corresponding improvement, which was derived from a technical, technological or organizational solution space.

In the field of industrial engineering, learning factories provide practical methods for process optimization regarding resource efficiency, lean management and quality management. Customized workshops are offered to managers, trainers, engineers, or shop floor employees. According to [4], less than one-third of the learning factories take aspects of digitalization into account. With the aforementioned digital transformation, this share is expected to grow in the future [4].

Research institutions, corporations or associations often appear as owner and operator of learning factories. Due to various specific objectives, learning factories can have different organizational forms. Below, four forms of learning factories are determined:

- **demonstration factory**: preferably live demonstration of technological and organizational use cases in a realistic factory environment
- **model factory**: simulation-based approach, giving an impression of a holistic manufacturing scenario, highlighting the implications of technological tools
- **process learning factory**: examination of processes within a factory setup, usually focusing on system efficiency by making use of lean production methods
- **experimental factory**: domain specific test bed for the experimental assessment within a factory environment, usually involving different stakeholders [10]

Throughout this paper, demonstration factories will be further examined regarding the classification and user-centered design of demonstrators arranged along the industrial value chain.

2.3. Value chain

The value chain is a concept to show that “every firm is a collection of activities that are performed to design [and] produce [...] its product” [11]. Porter defines the value chain as a sequence of five primary activities, namely Inbound Logistics, Operations, Outbound Logistics, Marketing/Sales and Service, as depicted in Fig. 1. These activities are directly related to handling the finished products. However, the description of primary activities stays generic. Additional support activities ensure that products take their way according to the planned schedule through the value chain.

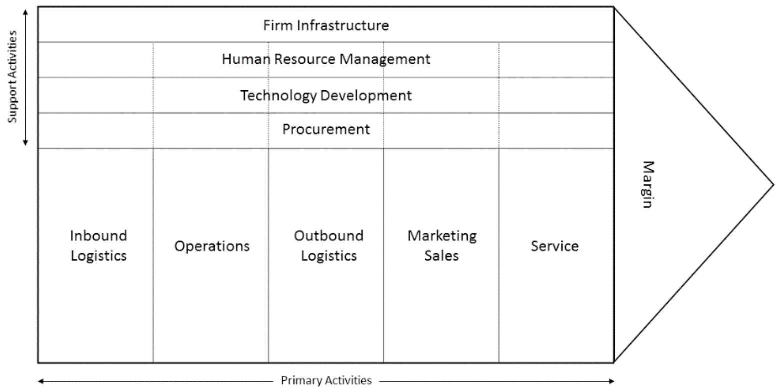

Fig. 1. Value chain model according to [11]

Beside the presented value chain model there exist additional approaches to describe the industrial process of sourcing and manufacturing a product, e.g. SCOR model. In the present case, Porter's model presents an appropriate level of detail, since the model addresses general as well as very specific steps along the product creation process [11]. Nonetheless, based on the primary activities of the presented value chain model, an adjusted value chain for the newly developed classification model will be derived.

3. Classification approach for use cases

After a scientific base was set in chapter 2, the following chapter presents the development of a new classification approach for demonstration factories that is built upon these findings. The chapter states the relevance and methodology of this newly developed classification approach, provides guidance on how to apply it and specifies the framework conditions.

3.1. Relevance for demonstration factories

Demonstration factories or laboratories intend to raise awareness for a specific issue by showing live demonstration and related examples of how real world scenarios may look like. In order to consolidate the findings and results of such factories, it is important to have an understanding of the current or planned collection of demonstration scenarios concerning their quantitative and qualitative coverage of topics, since the initial focus of the factories as well as the circumstances might have changed. The following approach shows which relevant topics are addressed by the laboratory and uncover the highly relevant ones for the future.

3.2. Description of classification approach

This paper presents an explorative approach to analyze the existing structure of demonstration cases. The results ensure a comprehensive overview of the subject areas already exhibited in a laboratory environment, their subject link to each other and, above all, topics that are not covered adequately.

The approach consists of five steps, which the user conducts in a defined sequence. Fig. 2 shows the methodology as well as a brief indication concerning the purpose of the step. Step 1 forms the general basis for the analysis by listing all relevant use cases. Steps 2 and 3 are descriptive analysis steps whereas step 4 focuses on explorative findings. Finally, in step 5 an interpretation of the results is conducted, which represents the basis for further strategic decisions.

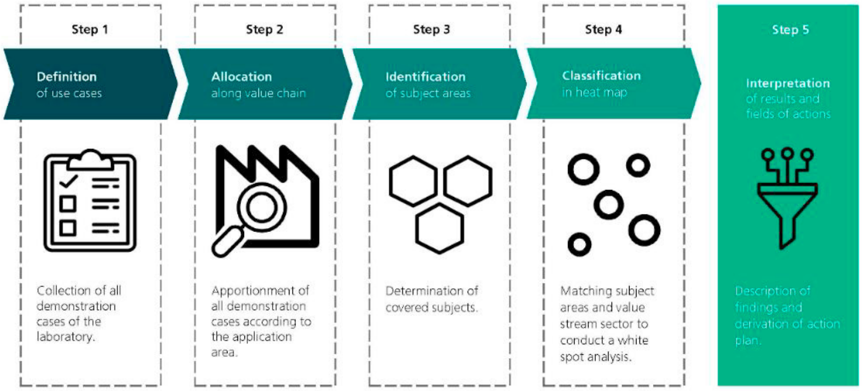

Fig. 2. Methodology for the classification of use cases within demonstration factories

A repeated application of the approach is recommended, since a continuous verification of subject coverage ensures that the customer's needs are satisfied.

Step 1: Definition of use cases

Demonstration factories mostly consist of a variety of use cases. These have to be documented as an initial preparation for later analysis steps. The objective of step 1 is to collect all demonstrators currently displayed or planned in the laboratory in a clear structure. The easiest form is a standard table or list. For reasons of clarity and transparency, the factory organization should keep a continuous list anyway.

Step 2: Allocation in value chain

Demonstration factories usually focus on specific sections of the value chain, whereas the focus on specific stages inside the focused sections might not be obvious right away. Therefore, the allocation of demonstrators to different stages or even activities in the value chain is necessary to determine the stages that are largely addressed in the current laboratory and to identify the ones that might not be addressed sufficiently.

Based on the general focus of the laboratory, the level of detail for the allocation has to be determined. If there is a broader focus, it seems appropriate to set the level of detail of the value chain allocation comparably low.

Step 3: Identification of subject areas

The subject coverage of demonstration factories is formally very different; thus it is crucial to differentiate the various use case-related aspects. Enterprises have to decide which subject areas fit their environment the most. Besides a basic literature research it is recommended to discuss or workshop the relevant subject areas in the project group, since there is no "one-fits-all" list of areas nor is it helpful to identify them solo.

Digitization and Industry 4.0 gained an increasing influence on industrial work design; as stated before, there is a rising number of learning factories that address this topic directly. A first collection of aspects that might be addressed in a demonstration laboratory specialized in Industry 4.0 were presented in chapter 2.1 and may be found in [6] and [7] respectively.

Step 4: Classification in heat map

In step 4 the two descriptive analysis steps (step 2 and 3) are combined in a so-called heat map to set the two criteria into relation. The horizontal axis represents the value chain areas from step 2; the vertical axis contains the subject areas from step 3. The resulting matrix describes the number of demonstrators in different stages of the value chain depending on their subject allocation.

Fig. 3 shows an exemplary heat map with 40 demonstrators categorized in two value chain areas as focus, which are further detailed into seven value chain stages. In this example, four subject categories are defined.

	value chain areas							
	Inbound logistics				Operations			
subject areas	incoming goods	quality control	order picking	inbound transport	pre-production	production	final assembly	SUM
human-robot collaboration	1	0	0	0	0	0	3	4
transparency/track and trace	1	0	2	4	2	3	3	15
Artifical Intelligence	0	2	0	0	0	2	0	4
Assistance systems	1	2	3	1	2	3	5	17
SUM	3	4	5	5	4	8	11	

Fig. 3. Exemplary heat map classification.

Step 5: Interpretation

The conclusion is based on both the descriptive and explorative part of the analysis. The following list shows key measures for the interpretation:

- total number of demonstrators
- total number of demonstrators per value chain stage
- total number of demonstrators per subject area
- total number of demonstrators per value chain category and subject area
- major scope for demonstrators in value chain category
- major scope for demonstrators in subject areas
- white spots: value chain category and subject area supposedly part of the innovation lab scope, but few or without any demonstrators

Depending on the laboratory's focus and the user preferences, other criteria can be added.

3.3. Practical application

The application of the classification approach is oriented towards demonstration factories. Furthermore, it is also suitable for model factories and can help to deduct strategic implications, although in some cases step 2 of the approach might not be necessary.

According to the description of the approach, the different steps have to be conducted successively. Since step 2 and 3 are not dependent on each other, they can be applied by themselves. In this case, step 4 cannot be conducted, since both step 2 and 3 are crucial predecessors for this analysis step.

For most steps it is recommended to have an interdisciplinary team to conduct the classification approach or review the outcome, since it is beneficial to have insight from people with different backgrounds.

4. Application of the classification approach in the Future Work Lab Stuttgart

4.1. Future Work Lab

Future Work Lab (FWL) is a project led by the Fraunhofer Institute for Industrial Engineering IAO and the Institute for Manufacturing Engineering and Automation IPA as well as the Institutes of Human Factors and Technology Management IAT and Industrial Manufacturing and Management IFF of the University of Stuttgart, Germany. The practice-oriented innovation lab around the key factors work, people and technology were established to inform, inspire and advise companies, politics, and other enablers alike [12]. To achieve this, the project is divided into three areas, closely connected to each other to ensure an overall knowledge and technology transfer for interested parties:

- **demonstration world** - a laboratory showcasing different scenarios and technologies
- **learning world** - a center for competence development and consulting, offering a portfolio of events, workshops and seminars
- **idea world** - a factory-oriented think tank around Industry 4.0, offering an exclusive space for innovation, dialogue and research [12]

This paper focuses on the so called demonstration world, since the presented classification approach assesses the use cases displayed in the laboratory. Following the proposed differentiation in chapter 2.2, the demonstration world belongs to the group demonstration factory, as different live use cases represent future work scenarios. One of the main objectives of Future Work Labs' demonstration world (FWL demo world) is to show scenarios which companies are able to relate to. It is intended to give an initial impulse to set first steps, since there are no plug-and-play solution sets for Industry 4.0 nor a standardized approach on developing suitable solutions.

A use case is typically based on a work scenario that includes a flaw from a work design perspective. For example, the information supply is paper-based or the working tools are not integrated. This challenge is then addressed and/or optimized by the application of technology or technical enhancements. In the beginning of 2019, 40 use cases are in operation inside the FWL demo world, mainly focused on manufacturing work as the research project predefined.

Because of its importance for the Future Work Lab, it is crucial to gain a profound understanding of the current status of the demo world, especially regarding the topics and scenarios already addressed. By analyzing the demonstrators based on the classification approach presented in chapter 3, the project team plans to disclose research gaps and deduce recommendations and fields for further action. This analysis will be the basis for further research activities, since there are still topics the project aims to cover.

4.2. Classification of Future Work Lab use cases

The approach for the classification of use cases described in chapter 3 was exemplary applied in the Future Work Lab's demo world in order to verify its relevance and objectives.

4.2.1. Definition of use cases

As described in chapter 3.2, the first step is to define and write down the different use cases planned or already in operation inside the respective demonstration lab. For the FWL demo world, this includes 40 use cases. They were clearly documented in the form of a standard list.

4.2.2. Allocation of use cases along the value chain

When allocating the use cases of the FWL demo world along the value chain, it becomes apparent that over 75 per cent of the use cases are categorized in the operations section. This is mainly due to the fact that the FWL demo world follows the logic of an in-company value chain and its main focus is the manufacturing environment within the company. To give a more comprehensive overview of the FWL demo world, the generic value chain from chapter 2.3 has to be adjusted. The operations section is divided into three parts, namely manufacturing, assembly and quality management. For the given approach, maintenance is added as another important secondary activity. Due to the focus on the earlier mentioned in-company value chain, marketing/sales and service are not considered for this analysis. The adjusted value chain model for the FWL demo world is shown in Fig. 4. With this approach, use cases of a production focused demonstration factory such as the FWL demo world can be classified adequately.

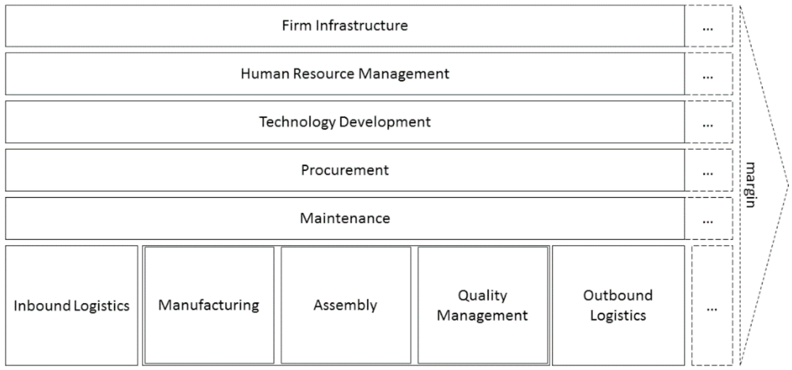

Fig. 4. Adjusted value chain model based on [11]

4.2.3. Identification of subject areas

In order to later conduct the white spot analysis, it is crucial to get an overview of the topics covered by the existing use cases. The demonstrators are mostly stand-alone solutions. Therefore, existing Industry 4.0 categories such as the ones presented in chapter 2.1 are not suitable for the topics of the FWL demo world. Since a suitable categorization approach was required, an expert workshop was conducted by the FWL demo world work package leaders and the project team due to their familiarity with the demonstrator contents. The objective of the workshop was to define the subject areas that the laboratory addresses with their use cases.

As a result of this workshop, the demonstrators were articulated in the following substantive categories:

- ergonomics and safety
- qualification and learning on the job
- connected manufacturing systems
- digital assistance
- human-robot-collaboration
- intelligent machinery and systems
- virtual engineering and planning

4.2.4. Classification in heat map

In order to finalize the analysis part for the FWL demo world, the heat map to detect white spots in the demonstrator's subject list was conducted (see Fig. 5).

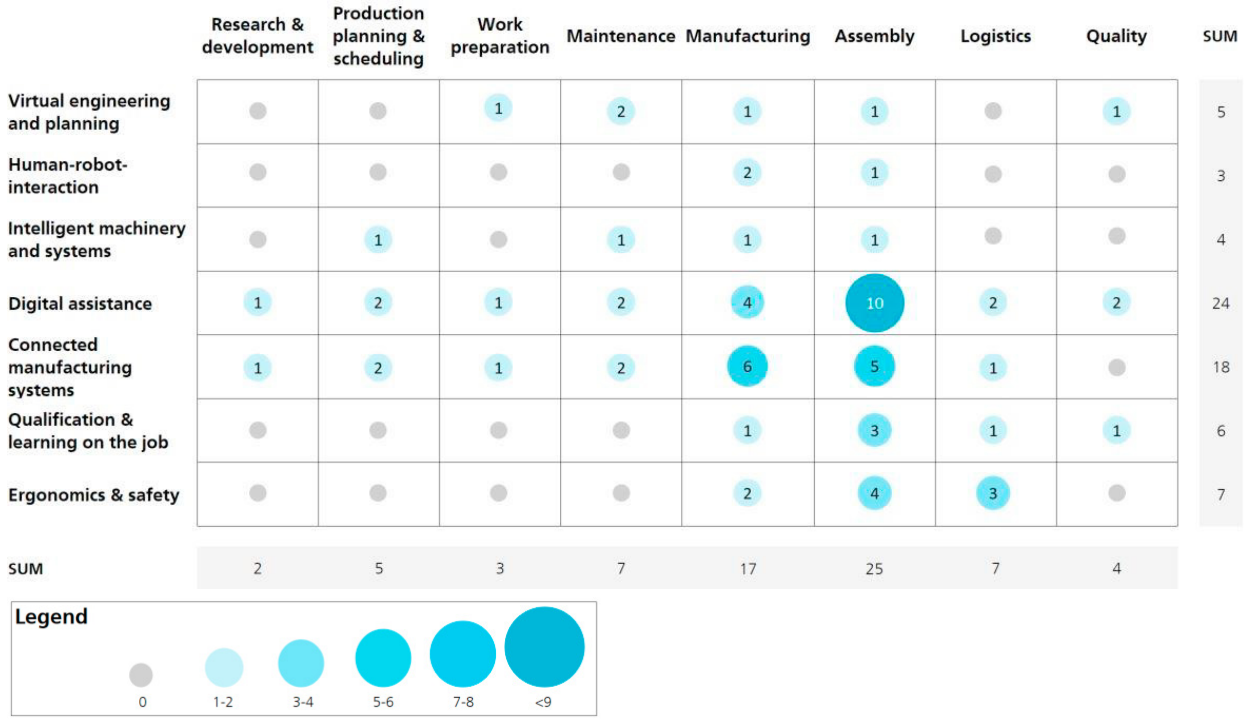

Fig. 5. Heat map classification for Future Work Lab use cases (n=48, multiple answers were permitted)

In this figure, the bubbles represent the number of use case citations in the respective x and y combinations. A grey small bubble means no use cases in this matrix cell, and the more use cases classified in one matrix cell, the darker and bigger the regarding bubble appears.

For the FWL demo world digital assistance in assembly represents the most addressed topic, since there are ten use cases registered in total, followed by connected manufacturing systems in manufacturing (six use cases) and assembly (five use cases). In general, manufacturing and assembly are the two value chain areas that address all subject areas. Digital assistance is the only area that addresses all value chain stages, because there are no use cases for connected manufacturing systems in the segment quality. Human-robot-interaction and intelligent machinery and systems are the areas with the smallest number of use cases. Human-robot-interaction as well as ergonomics and safety are the two areas with the lowest number of connected value chain segments.

4.2.5. Interpretation

The heat map supports the initial focus of the Future Work Lab, since the majority of the use cases are located in manufacturing and assembly, followed by maintenance and logistics. The least addressed value chain step is research and development. Digital assistance appears to be the most covered topic in the Future Work Lab. This conclusion is in line with the findings from [7], which implies that the majority of Industry 4.0 use cases are assistance systems [7]. However, it has to be stated that the term assistance systems may be interpreted differently across industry.

Generally, the Future Work Lab is in accordance with the initial thematic focus. From a more detailed perspective as outlined in the heat map, the project team deducted four major action fields for future use case developments:

1. Digital assistance in the manufacturing process related areas such as quality, logistics and maintenance is not yet addressed in detail.
2. Ergonomics and safety in assembly holds significance, although a use case related to work preparation will be added.
3. Qualification and Learning on the job are becoming a highly relevant topic for the industry and hence, new approaches will be considered in future scenarios. Synergies with the related subject of digital assistance will be leveraged in addition.
4. Upcoming topics like artificial intelligence, blockchain and cyber security will be added to the research focus in the subject area intelligent machinery and systems.

Following the defined action fields, the project team and cooperation partners will perform workshops for the design and implementation of new use cases.

4.3. Implications and limitation of the approach

The developed approach contributes to research with a structured classification process for use cases in learning factories. The application gives a positive evaluation of the approach in terms of sufficient applicability in a representative demonstration factory environment. Furthermore, the results led to useful information regarding the structure of use cases and possible actions for the application field.

Limitations of the approach exist regarding the scope of the classification process which is focused on the learning factory type of demonstration factories and their subject structure. Further assessment of the use case structure of demonstration factories could provide additional insights for practitioners.

5. Conclusion

Main objective of developing the classification approach was to support applied research and allow an improved and structured organization of such environments. In this approach, an analysis of the individual use cases based on the value chain and Industry 4.0 category affiliation can be conducted and a heat map matrix generated as a final result. Then, the most relevant characteristics of this matrix can be identified and scrutinized in order to deduce recommendations and fields for further actions. To verify the relevance of this description approach, it was fully applied to the FWL Demo world and its 48 use cases in operation. The project team was able to identify research gaps and thus, motivate further development of use cases not yet displayed.

The application of the classification approach is recommended for similar research laboratories and demonstration factories, which focus on use cases and scenarios. Especially laboratories with a broad research focus will benefit, since the presented method offers orientation and deeper insights into the currently addressed topics.

For the FWL Demo world, a significant progress for gaining a better understanding of the status was achieved by applying the method. This may be the basis for further research activities, since there are still uncovered topics.

In order to capture more details about the use cases inside a demonstration factory, we suggest to include a technological maturity analysis of the individual demonstrators through Technology Readiness Levels in the future. Among others, Technology Readiness Levels are already known through concepts developed by NASA or Horizon 2020 [13, 14]. Further expansion of the use case evaluation matrix in chapter 4.2.4 may be achieved by including this third dimension into the existing approach.

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