Hydrogen Technology Business Process Management Modeling: Standardization and digitization of processes within the hydrogen infrastructure

Uta Kühne[1], Miriam O'Shea[2], Benjamin Wagner vom Berg[3] and Lars Wöltjen[4]

Abstract: Standardization and digitization are important factors to accelerate the development of hydrogen infrastructure for transport and mobility purposes. The digitization of administrative processes in particular can help to make information-intensive and often complex processes within authorities more efficient and transparent. A uniform standardization of technologies and process descriptions can simplify and accelerate the market launch and approval processes. The project 'Hydrogen Technology Business Process Management Modeling' concentrate on the two focus areas standardization and digitization to ease the application process of hydrogen filling stations.

Keywords: Hydrogen infrastructure processes, Standardization and digitization, Business Process Management Modeling

Addresses Sustainable Development Goal 9: Industry, innovation and infrastructure

1. Introduction

Digital technologies are an important driver for sustainable development and therefore have a special place in the implementation of the United Nations Agenda 2030. Within the 17 Sustainable Development Goals (SDG), information and communication technologies are directly named in several goals, for example in SDG 4 "Quality education" and in SDG 9 "Industry, innovation and infrastructure". Using digitization as a tool can increase resource efficiency, manage the energy transition and improve climate protection [Bm21].

The digitization of administrative processes in particular can help to make information-intensive and often complex processes within authorities more efficient and transparent. This enables the user to obtain quick and targeted information, improves the relationship between citizens and the state and opens up new opportunities for innovation for the economy through accelerated processes. Digitization is therefore an innovation driver that can become an innovation accelerator, especially when expanding a green hydrogen

[1] Hochschule Bremerhaven, Smart Mobility Institute, An der Karlstadt 8, 27568 Bremerhaven, Germany, uta.kuehne@hs-bremerhaven.de
[2] Hochschule Bremerhaven, Smart Mobility Institute, An der Karlstadt 8, 27568 Bremerhaven, Germany, moshea@hs-bremerhaven.de
[3] Hochschule Bremerhaven, Smart Mobility Institute, An der Karlstadt 8, 27568 Bremerhaven, Germany, benjamin.wagnervomberg@hs-bremerhaven.de
[4] Hochschule Bremerhaven, Smart Mobility Institute, An der Karlstadt 8, 27568 Bremerhaven, Germany, lwoeltjen@studenten.hs-bremerhaven.de

infrastructure. An important companion of digitization is standardization. In hydrogen and fuel cell technology in particular, the topic of standardization is a complex, internationally oriented and continuous process. Due to the novelty of the technology carriers and their application, especially in mobility, there are different technical requirements for identical technologies as well as ambiguities in the classification of e.g. hydrogen filling stations in various application scenarios [No22, JD18]. A uniform standardization of technologies and process descriptions can simplify and accelerate the market launch and approval processes [Bm22].

In 2021, we first reported on our project H2BPMM, which stands for 'Hydrogen Technology Business Process Management Modeling'. In this article, we would like to publish the latest findings and open them to discussion. The results are twofold and directly match the two focus areas of the project: (1) standardization and (2) digitization to ease the application process of hydrogen filling stations. In the area of standardization, the analysis of documents and the interviews with two focus groups have supported the development of a general taxonomy of the configurations of filling stations, which we present in a morphological box. Further analysis led to the identification of today's typical filling station. Moreover, through the classification of the parameters of the taxonomy, it became apparent that there are two types of configurational factors, one of them leading directly to the relevant legal procedure for the application. This finding is very important in the pursue to ease the application process. In the second focus area of the project, digitization, those parameters driving the relevant legal procedure have been used to build a tool that implements the relationships between the configurational setup of the filling station and the legal procedure being relevant for it into an automated decision table. Thereby, the first and critical task in the application process is supported and the user is guided to find the right legal procedure which in turns leads to a known set of documents and parameters to be supplied within the application. With the digitization of processes in connection with the development and expansion of hydrogen technology, a contribution should be made to making those processes clearer and more efficient and thus to accelerate infrastructure expansion and climate protection. The H2BPMM project contributes to this by simplifying the complex matter of the approval process for both focus groups, thus saving time and money.

2. Hydrogen Technology Business Process Management Modeling

As in any infrastructure-dependent technology, hydrogen mobility suffers from the typical the-chicken-or-the-egg-problem: Neither transport and mobility providers nor the infrastructure companies are willing to take the first step without financial support [Ma03, pp. 743-744]. To accelerate the development of hydrogen infrastructure for transport and mobility purposes, it is essential to simplify the approval processes involved by digitalization and standardization. Careful attention thereby is paid to digitalization being part of the solution not the problem. Here, digitalization is used to prevent multiple and unclear requests for information. In respect to the technology implemented, the end-user is not to be overburdened, using standard web browsers. Other stakeholders will enjoy

synergy effects with general applications in the area of e-government. There is an inherent complexity, which can be seen, for example, in the approval processes required by German law. Here, different legal bases apply, depending on the specific configuration of the infrastructure design. In general, two main legal bases need to be considered for the approval, dependent on various filling station parameters:

- Regulation on health and safety in the use of work equipment (Betriebssicherheitsverordnung: BetrSichV)
- Federal Immission Control Act (Bundes-Immissionsschutzgesetz: BImSchG)

In addition, there is a large number of different parameters and critical values that influence the approval of the hydrogen filling station and affect the choice of the right permit or approval procedure (see chapter 3). The aim of the H2BPMM project is to support the establishment of the infrastructure required for hydrogen drive technology.

Approval processes, e.g. of hydrogen filling stations, but other processes in mobility and logistics also, are information heavy. Here, the flow of information between different stakeholders and systems is of great importance. The design of processes of that kind must support the various users involved in respect to the provision of information adequately. For this purpose, the corresponding process must be designed with sufficient precision especially concerning the information flow. This is often not the case yet. First, the use cases of hydrogen related procedures are rather new to e-government, mobility and logistics. Second, currently used notations for the design of processes do not detail the information flow to the extent needed in information heavy use cases. Up to now, information is considered in the form of artefacts like documents or similar containers. The life-cycle is applied to these containers as well. However, a document for example contains several information objects, whose life-cycle can vary. To clearly identify what information object is needed or generated in what process step, containers need to be broken up and information objects need to be referenced individually. [cf. SZS04, KR11, SZN06, SZ06, At11] As BPMN is focused on the flow of activities and not the information flow, the notation and methodology needs to be enriched. Here, in a separate stream of analysis, the information flow is gathered and integrated into the activity flow.

The H2BPMM project started on July 1, 2020 and is planned for two and a half years. The project is being carried out by the University of Applied Sciences Bremerhaven and is supported by a large number of partners from companies, associations, societies, cities, municipalities, districts and the two states of Bremen and Lower Saxony.

3. Standardization of processes and methods to ease the standardization of the approval process

With the help of the standardization of processes, a uniform method or a predetermined result is defined for the respective application. Some key benefits of process standardization are:

- An increase in the transparency of the processes and the required documents.
- The same or similar process steps only have to be mapped once, so that duplications are avoided.
- The effort involved in submitting an application is minimized.
- As part of digitization, standardized interfaces to other users, such as authorities and municipalities are created.

An essential first step for the standardization of existing processes for which little experience is available is the recording of the current status. For the H2BPMM project and the approval process for hydrogen filling stations, this means to research different sources: first to name is the analysis of the technical configurations, the analysis of current processes, next an inspection of existing guidelines, as well as the recording of experiences from people being involved in the approval of hydrogen filling stations. Various methods have been used for this within the H2BPMM project. Existing approval processes are recorded via literature research and document analysis. The need for an analysis of the configuration arises from the fact that, depending on the technical and commercial configuration of a hydrogen filling station, a specific approval procedure applies. A so-called morphological analysis was carried out to record the typical characteristics of a hydrogen filling station. This was followed by an exchange with companies and applicants in a workshop and in the form of expert discussions. In the following, the methods to simplify the standardization and results are presented.

3.1 Morphological Analysis

The morphological analysis was developed by the astrophysicist Fritz Zwicky as a creativity technique that enables the users to fully understand complex problems and to represent all possibilities. In this way, it can make a significant contribution to solving complex problems [Zf48, pp. 122-125]. To achieve this, the method uses what is known as a Zwicky-Box, which is a vivid, multi-dimensional matrix. In our application, a subset of the Zwicky-Box called a typological field format lists the properties (influencing variables) that are independent of one another in one dimension and all of their possible characteristics in another. This creates an overview of all conceivable possible combinations of characteristics [Sm14, pp. 618-619].

In order to achieve the project goals as described above, the complexity of the approval process has to be determined first. The properties and characteristics of the hydrogen filling station have to be analyzed and documented, because they significantly influence the legal basis for the approval process. With the findings of our literature review recorded in the typological field format, the multitude of technical properties could be presented objectively and any premature evaluation was prevented (technology openness). Fig. 1 shows an exemplary section of the morphological analysis created in the project and therewith the complexity of the technical properties under study.

An evaluation of the literature review has taken place in form of expert interviews and workshops. Moreover, existing hydrogen filling stations were mapped in the typological field format and thereby most commonly used configurations of hydrogen filling stations were elicited. The latter forms the first step towards the definition of a "standard".

No.	Influencing Factors	Characteristics						
1.	Use	public	only on the company premises	public and on the company premises	others			
2.	Operator	private	service provider	company	federal / state / local authority	other		
3.	Responsibility process of approving	operator	owner	service provider	other			
4.	Compulsory public participation	yes	no					
5.	Fixed installation	yes	no					
6.	Target sector hydrogen filling station	passenger car	bus	lorry	shipping traffic	air traffic	rail traffic	industrial truck
7.	Type of area	industrial area	commercial area	village area	mixed area	urban area	core area	Other Special area
8.	Total hydrogen storage	< 3 tons	> 3 tons	> 5 tons	> 30 tons	> 50 tons	> 200.00 tons	
9.	Hydrogen quantity threshold in the incedent area	< 5 tons	5 tons to < 50 tons	> 50 tons				
10.	State of aggregation when it is provided at the hydrogen fueling station	gaseous	liquid	solid (chemically bound)				
11.	Pressure when releasing hydrogen	200 bar to < 350 bar	350 bar	700 bar				
12.	Hydrogen production process	electrolysis	reforming	coal gasification	bio-, photo-, thermochemical processes	hydrogen as a byproduct	Other	

Fig. 1. Excerpt of the typological field

3.2 Document Analysis

The morphological analysis delivered much information about the potential configuration of hydrogen filling stations. However, information about the scope and specific content of the approval process could not be determined within the morphological analysis. To obtain this kind of information, a comprehensive document analysis of the underlying legal texts and supporting guidelines concerning the approval process was conducted. All available literature was examined and, if it contained hints to information objects, these were

subsequently compiled, organized and structured [Sm14, pp. 545-546; 8, pp. 39-40]. Resulting, a catalogue of the information fields included in the approval processes was derived.

As mentioned in the introduction, different approval processes can be applicable depending on the individual configuration of the hydrogen filling station at hand. Consequently, a variety of different legal documents can be necessary within the approval application procedure. The previous literature review includes more than five supporting guidelines, e. g. both the volumes of the "Portal Green Power to Gas Leitfaden" [Po20] having more than 460 pages, "Genehmigungsverfahren nach dem BImSchG, Leitfaden für Antragsteller" [Ni20] and "NOW-Genehmigungsleitfaden für Wasserstoffstationen" [Na22]. The laws and ordinances were researched on the website of the Federal Ministry of Justice and the Federal Office of Justice with the current entire federal law. The initial results of the document analysis within the H2BPMM project have been discussed with various experts of the approval authorities and of applicants in companies and service providers.

3.3 Workshops and Configurations of hydrogen filling stations

During the course of the project, it became clear that the focus of the project is on two main groups - the authorities responsible for the permit and approval procedures on the one hand and the planners, applicants and operators of hydrogen filling stations on the other. Workshops and expert discussions were therefore held with both focus groups in order to learn more from their previous knowledge for the description of the current situation.

As a result of this exchange, it can be said in summary that the approval procedure to be used in each case depends on several overriding factors. On the one hand, these are parameters and limit values, such as the total storage quantity of gaseous fuels and the on-site generation of hydrogen by electrolysis. With a total stored quantity of less than three tons by one operator or three to five tons by two economically independent operators, the much simpler procedure under the Regulation on health and safety in the use of work equipment applies. If the requested total storage quantity of gaseous fuels increases to more than three tons or if the hydrogen is produced directly on site, then the planned hydrogen filling station must be approved according to the much more complex procedure under the Federal Immission Control Act. The following Fig. 2 shows the process selection based on the parameters and limit values for the Regulation on health and safety in the use of work equipment. With these insights, it is possible to make the approval process more transparent for users. Depending on the use case, an applicant can be advised to stay below the critical storage quantity in his plans. Other factors that can influence the approval process is the configuration of the hydrogen gas station and its location. A distinction is made between the following four configurations:

- The hydrogen pump will be integrated into an existing filling station. The hydrogen dispenser will be subordinate to the existing filling station and will be approved using the same procedure.
- The hydrogen dispenser is self-contained. If this system is classified as a so-called energy system, then it does not require approval according to the Regulation on health and safety in the use of work equipment.
- The hydrogen filling station will be set up on a depot. If classified as an in-house facility and not sold to third parties, this type of gas station does not require approval.
- A mobile hydrogen filling station can be designed as a container or as a truck with a box body. The approval process for this type of hydrogen filling station is still being developed.

For all four configurations as well as for the classifications according to the recorded limit values, knowledge of this makes it much easier to standardize the processes and makes the processes more transparent for applicants and authorities. These relationships form the basis for the next step in the digitization of process flows.

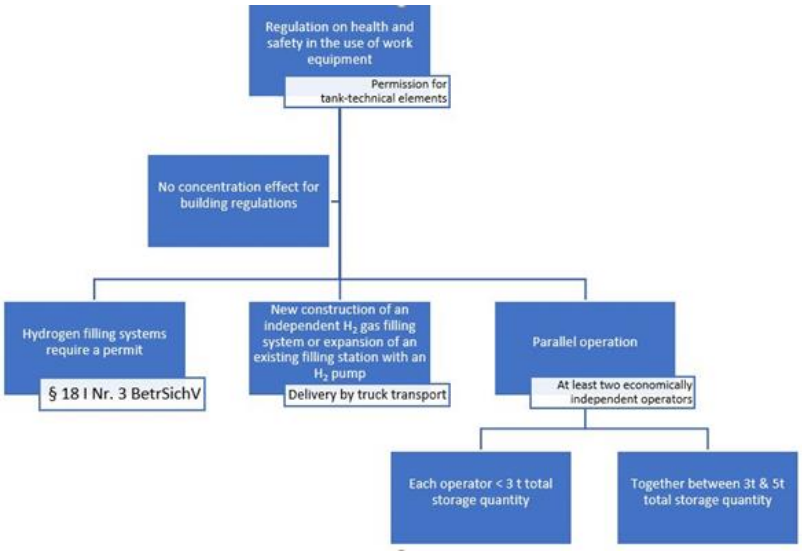

Fig 2. Parameters and limit values of the Regulation on health and safety in the use of work equipment

4. Demonstrator – Decision support for accelerating the expansion of the hydrogen infrastructure

The approval procedures used in Germany, such as the Regulation on health and safety in the use of work equipment or the Federal Immission Control Act, are not only very different in terms of content, but also entail planning and approval phases of different lengths and different costs. In order to make it easier for applicants and authorities to take the first step in selecting the right procedure, a demonstrator was developed in the H2BPMM project, which proposes the approval path to be selected based on the configuration of the respective hydrogen filling station, which is determined by various parameters. Besides the already mentioned prerequisite concerning the knowledge around the approval process in terms of activities, configurations and legal aspects, it is indispensable to identify which information is required at which points within the process. This takes place as a basis for digitization within the standardization work package.

To support the applicant, a tool is needed that provides him or her with information on the procedure based on the planned configuration of the hydrogen filling station and the intended location. This tool was implemented in a "demonstrator" within the H2BPMM project and opened on the project website to public for trial use. Modeling wise, the standard BPMN symbol palette as well as the Decision Model and Notation (DMN) standard were used. An automation of the exemplary process was possible with the help of the CAMUNDA Workflow Engine, i.e. the model could be deployed and executed from the university server. This example prototype proved that (at least partial) automation and therefore support for the applicant is possible with a low investment.

In the following, the notations and systems used to record the current status and to create the demonstrator, as well as the demonstrator itself, are presented. Within the BPMN standard, the workflow (Fig. 3) for decision-making and the issuance of the relevant approval procedure was set up.

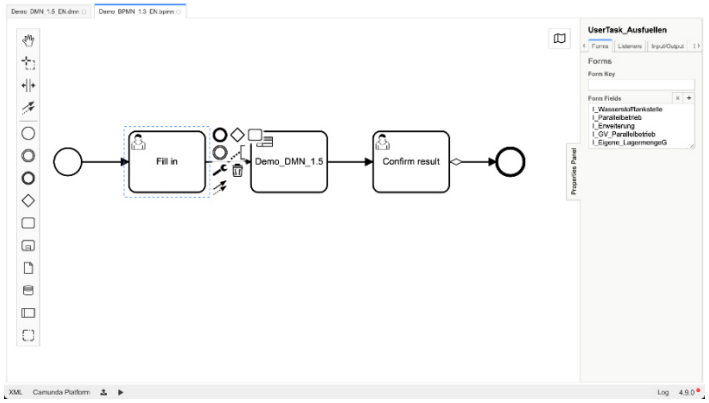

Fig 3. BPMM flow chart demonstrator

The "Fill in" process step is marked here to demonstrate how the definition of parameter queries to be filled out by the user is accomplished. In this process step, the input parameters are determined, which must be described within the decision tables and answered by the applicant. These relate, among other things, on the storage quantity of hydrogen, a possible parallel operation with other operators and the question of the production of hydrogen associated with the filling station. The input parameters are essential for the output process step in which the approval procedure to be used is defined. Within the DMN tool, the parameters are described, the rules for decision-making are defined and the decision modeling is implemented. At the end of the process, the approval procedure defined at the decision level is confirmed as the output parameter and result of the query. The DMN structure of the decision support demonstrator is shown in Fig. 4 below.

The DMN structure includes five decision tables, with the following procedures:

1. Procedure based on the type of integration of the planned hydrogen fuel dispenser together with other fuel station operators.
2. Procedure based on the storage quantities with the limit values for the transition from one procedure to the next procedure.
3. Procedure based on production of hydrogen
4. Procedure due to network connection e. g. with high voltage network
5. Result procedure

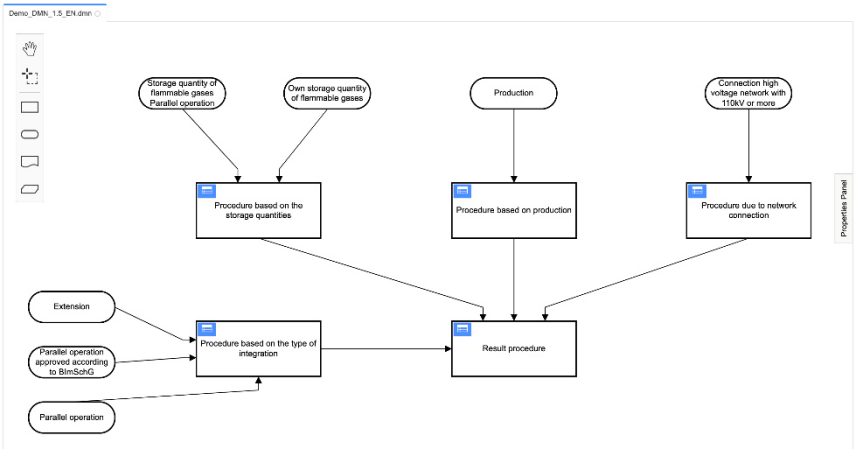

Fig 4. DMN structure of the decision support demonstrator

Fig. 5 shows an example of the queries within the decision tables.

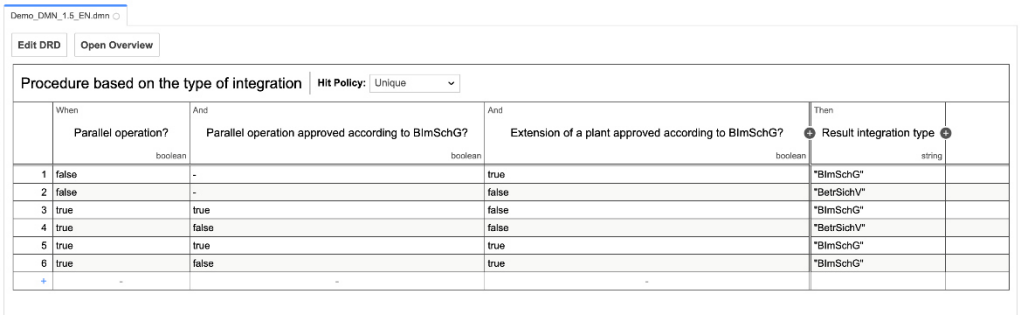

Fig 5. DMN decision table „Procedure based on the type of integration“

Within the “Result procedure” table (see Fig. 6), the results of the four other decision tables are evaluated and, after confirmation, output as the final result for the approval procedure to be applied for.

With the procedure shown, the demonstrator offers applicants the opportunity to classify the time and financial effort of their planned project. In addition, with the help of the demonstrator, the user can take the opportunity to modify the setup of his hydrogen filling station, e.g. by changing the storage capacities, so that it runs into a simplified and less complex approval process. The form of the demonstrator presented can be further expanded and adapted to the various configurations of hydrogen filling stations presented in Chapter 3.3. Furthermore, this type of DMN analysis can be transferred to other applications inside and outside of the hydrogen infrastructure and can be incorporated into the processes and programs of the application authorities as an upstream decision-making process through further modifications. Feedback on the use of the demonstrator referred to its simplicity on the one hand and to suggestions to clearly indicate the critical values in the input step instead of just deriving the resulting legal procedure on the other hand. This suggestion will be implemented in the next version of the demonstrator.

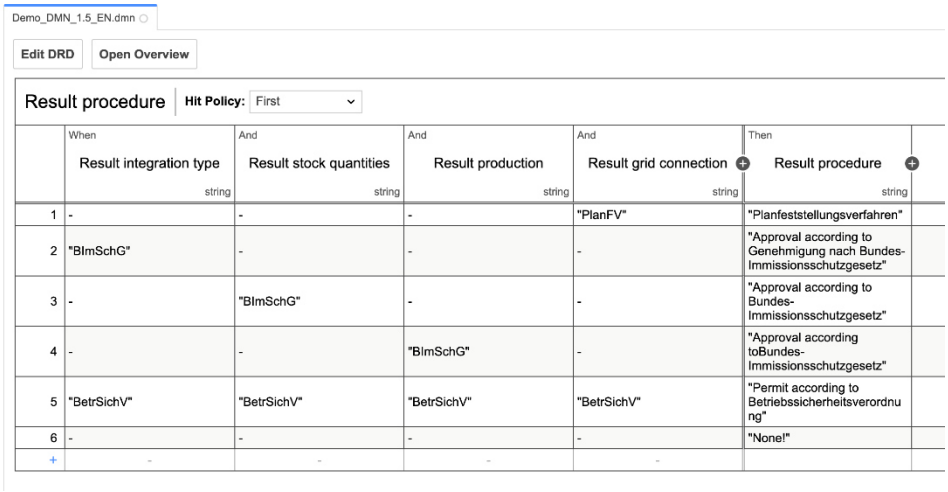

Fig 6. DMN decision table „Result Procedure

5. Discussion / Conclusion and Future Outlook

The results of the project are twofold. First, aiming at deriving a standardized approach in respect to the approval process of hydrogen filling stations in the model region of Metropolregion Nordwest, a taxonomy delivers a systematic overview regarding potential configurations of hydrogen filling stations. The taxonomy enabled a depiction of the most commonly used setup today. This forms the basis for the ongoing research work to arrive at a standard To-Be process model. Second, looking at our progress in terms of the digitization, the crucial first step in the approval process, in which the main configuration is defined and the resulting legal procedure is identified, can now be supported using an automated decision model. Further research within this project will concentrate on the design of a To-Be process, including a clear representation of the information needed in each process step. The document analysis, therefore is continued and deepened and a mapping with the process steps will finish up the project work. In the area of digitization, the above mentioned mapping that will take place in a two-dimensional table will be translated into a XML-statement that can be directly included into the Camunda-representation of the process model. The modeling approach is planned to be used for the digitization of a variety of other business and administrative processes.

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