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Unraveling the Social-Technical Complexity of Dashboards for Transformation

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Abstract. The need for standardized and visualized performance monitoring on a wide range of topics has become apparent in recent years. In the public sector, there has been an increase in the number of dashboards to create transparency into the progress. Yet, the design of dashboards encounters many challenges ranging from technical to social. The goal of this research is to unravel the social-technical complexity of dashboards and outline their basic requirements and a process for creating dashboards. In addition to explicit project milestones, these also visualize digital implementation programs at the policy level.

Keywords: Dashboard · Performance Monitoring · Stakeholder · e-Government (eGov) · Digital Government · Complexity · Design Dimensions

1 Introduction

A crucial success factor in any digital transformation is a deep understanding of adequate key performance indicators and their systematic utilization. Measurements and performance indicators and the usage of data as a basis for private and public decision-making have become more important to provide insight into the progress of digital government initiatives. Public sector CIOs and ministers are requesting key performance indicators (KPI) from different public organizations to build up dashboards that can present and quickly offer information about their transformation projects for internal use or to the public [1–3].

The transformation is often guided by the development of metrics presented on dashboards [4]. A dashboard is a graphical user interface which provides at-a-glance views as well as data and information on a particular topic. The underlying data and information can often be understood as key performance indicators that are relevant to a particular objective of a process. Dashboards are used more and more as an alternative to the annual "progress report". Whereas reports are provided in discrete points in time, dashboards can always give the actual situation. A dashboard provides a means to track

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progress, however, its indicators might also easily give wrong impressions. Data might not be correct, might give a wrong picture or can be interpreted in the wrong way as they are from social-technical nature [5]. Also, people might fill in data politically [6, 7]. As such, managing digital transformation using measures such as KPIs and dashboards is challenging.

While dashboards are by no means a new phenomenon, we can nowadays observe a wide-spread and increasing proliferation and utilization of such tools throughout the public sector. For example, they are used to display use of financial resources, reform progress, health data, and geospatial and environmental data. Currently, managing government officials request measures and dashboards to make their initiated changes (such as digital strategies and programs) and their daily work more visible and transparent to the citizen. A good example is the visualization of vaccination progress in various countries in the context of the global COVID-19 pandemic [8]. Hence, consultancies are engaged and consult the relevant public institutions and set up measures that outline current situations and trail measures that mostly show obvious and biased outcomes. However, those situations will not bring digital transformation to a further stage and will not contribute significantly to the transparency requested by the citizen as they do not provide the information that is required, or only provide it in part in order to withhold information. This approach does not create change in terms of building trust and openness with governments [9].

In order to better understand these social-technical challenges and to provide dashboard creators with a targeted approach to their creation, this paper will unravel the social-technical complexity of dashboards and outline basic requirements for dashboards to understand the complexity and counteract existing challenges to make them successful.

In Sect. 2, we provide the conceptualization of the development of a dashboard from its data generation to implementation based on five expert interviews to put the information provided in the interviews into an overall structure. In Sect. 3, at first, we will have a look at two different cases and outline the results of the five expert interviews regarding the outlined challenges for the development of a dashboard by introducing and presenting an overview of generic challenges. We finish the paper with a conclusion in Sect. 4.

Our suggested generic overview of challenges in the development of current dashboards is based on evidence from a short literature review, an analysis of two presented cases (Sect. 3) and, furthermore, evidence from five anonymous personal open expert interviews – each one hour – that we have conducted in Germany and the People's Republic of China (PRC). The interviewees are senior practitioners in the development and implementation of dashboards and specialists in the R&D sector on a national and European level.

The five experts were identified according to their experience in the national and international context as well as their involvement in the process of creating a dashboard. The respondents included people involved in the conceptual design of dashboards, experts involved in the technical implementation and creation of the data engine, and experts focused on the creation of the interfaces.

In the area of dashboard conceptualization, the experts were two German senior business analysts who are involved in the creation of public dashboards (1) and the

creation of public and private dashboards (2). For the analysis of technical questions, a Chinese data scientist from a public research institute in Guangzhou was interviewed (3), who deals with the provision of utility data. Furthermore, a German data engineer was interviewed who deals with the development of system architectures of the data engine based on the data of the dashboards to be used (4). Finally, a German frontend designer of a private research institute was interviewed, who deals with the creation of interfaces (5).

2 Conceptualizing Dashboards: From Data Generation to Implementation

In order to obtain a clear and unambiguous definition of a development process of a dashboard and corresponding terms (e.g., the types of dashboards identified), the information provided is conceptualized based on literature, interviews and the authors' own knowledge.

To meet the main goal of a dashboard, the automated and visualized provision of reports should be based on available resources (and thus enable a significant reduction of effort for the creation of those reports). A generic process should also be created which represents the development of a dashboard. Based on the authors' personal experience, interviewees were asked to comment on and expand a given high-level process in a joint conversation with the authors. During the interviews, clear process steps for the overall development of a dashboard emerged.

Based on the conducted expert interviews, a generic process for the development of dashboards was derived. In the process, two different approaches for the public sector were identified that make necessary a distinction necessary in the development of a dashboard, i.e., open-oriented dashboards and goal-oriented dashboards:

- *Open-oriented dashboards* are the visualization of data that show a development without a previously defined goal. Good examples are the presentation of infection figures and the vaccination rate during the COVID-19 pandemic. Likewise, dashboards that show the distribution of age cohorts and population development can be classified as open-oriented.

- *Goal-oriented dashboards* are visualizations of data that work towards an explicit goal. For example, policy efforts can be visualized and the extent to which policy goals have been achieved can be recognized. These dashboards usually show the development of thematic projects such as digital transformation or the fight against poverty among the elderly. However, this requires a clear definition of the measurability of these goals.

Both identified types of dashboards differ in the framework of information provision and the extent to which transparency is created, as goal-oriented dashboards are located within predefined frameworks. Depending on the user orientation, the data provided can be used to visualize information on the fulfillment of goals. However, the user should be responsible for evaluating the visualized data of the dashboard. In the case of open-oriented dashboards, the creation of transparency is purely dependent on the information provided and is not influenced by a defined target direction.

It is not necessary to define the user groups for one of the identified types of dashboards. Depending on their content, both types of dashboards can address the same or different user groups at the very same time.

In the case of open-oriented dashboards, the first step is to define the correct measures after the major question and objective has been posed. It may be that already existing data sets and indicators must be visualized, or that new data sets and logics have to be developed, which enable a visualization of the major question and objective with the help of data.

In the case of goal-oriented dashboards, a translation from policy goals, characteristics or milestones that should be achieved must take place at the beginning to enable data-driven measurability to subsequently merge these two types of dashboards and facilitate a clear definition of the targeted audience.

The following step focuses on the involvement of different stakeholders. Some of the relevant stakeholders can be found in Fig. 1.

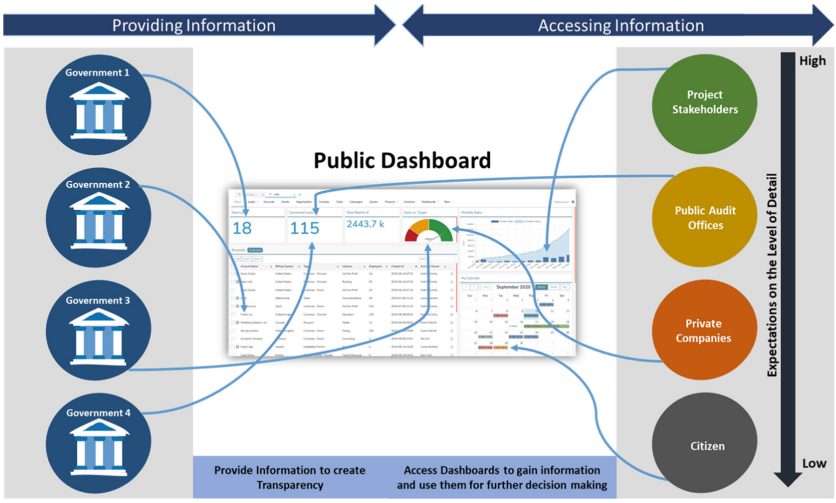

Fig. 1. Example of a dashboard: the provision of dashboards and the different expectations at the level of information provided for different user groups.

Here, it is important to involve not only the participating institutions but also future users and audience. In the conducted interviews, clear comments were made in this regard, which referred to the fact that the involvement of stakeholders was primarily concerned with setting goals and user centeredness. The focus in this step is not yet on the provision of data and the close involvement of data suppliers, so as not to jeopardize or restrict the creative and iterative process for answering the major question and objective.

After completion of this process step, various activities are carried out in parallel. The definition of the individual steps is usually carried out in interactive workshops with all stakeholders and various methods such as design thinking [10] and co-creation [11, 12]. In addition to the definition of the user journey, the determination of relevant data and the form of visualization of corresponding data, multivariate tests are carried out in

this step in order to achieve a satisfactory result for the user. After completion of this phase, the result may differ significantly from the objectives that were defined at the beginning of the process.

In the following step, the necessary data quality is defined together with corresponding data providers and appropriate data sources are identified to ensure the development of the key elements of a dashboard, i.e., the data engine. From the developer's point of view, the preparation and participation of the data suppliers are fundamental, since they have an overall view of the data available to them and at the same time also have the knowledge regarding the data quality, according to the statement of one interviewee (4).

The development of the data engine is described by the interviewees (3–5) as the key element of the process. The development of the data engine includes the definition of the system architecture, whose structure is dependent on the data provided. System architectures that exclusively process static data differ from those that also process dynamic data. At the same time, the data engine also serves as a data storage to enable the manual provision and storage of non-dynamic data from corresponding data-registers. A data-register is a data storage or set of data that can be assigned to a variety of functions by a data engineer. To merge these data-registers in a meaningful and value-creating way, a corresponding data-register linking takes place within the data engine. To check the plausibility and quality of the data provided, the data engine also includes a data plausibility logic and a data linking logic. A data linking logic only becomes significant if different raw data sets are merged to obtain new insights and create new indicators for statements. This is especially necessary when goals have to be made measurable within goal-oriented dashboards. The same procedure can be seen when developing complex indexes. Some of the data that is made available and processed within the data engine may not be public. For security reasons, appropriate data security measures must therefore be considered as early as in the stage of creating the data engine to guarantee the security of the data. According to the interviewees (4–5), this process step poses challenges, since access to the final interface for visualization is usually protected, however the security of the data engine has not been sufficiently considered.

After the basic development of the data engine, the implementation of previous results and decisions on the strategic orientation, the results of the user tests as well as the definition and creation of relevant data together with their quality take place in a major visualization interface designed for this purpose. Many different visualization tools are available for this purpose. Besides commercial providers, there are also open-source libraries with ready-made visualization options and interfaces. The selection of the appropriate visualization tool depends on the requirements of the interface. The use of open-source interfaces makes it possible to improve the visual design, the standardization and professionalism of the representations and to enable a better user experience.

After the first visualization of data, an important milestone within the project implementation can be achieved with the go-live of the visualization interface as a minimal viable product (MVP).

With the help of user feedback and further usability workshops, further requirements and design elements can be implemented in the interface following an iterative process to increase its quality. With this step, the basic process for the development of a dashboard is completed.

During the interviews, an expert (2) offered the thought of a "next generation" development of dashboards. With this statement, she underlined the further development and decoupling of interfaces with further reference to the already existing major data engine. This spin-off serves the possible representation of regional specifics and is to be fundamentally dependent on the main dashboard. One interviewee (2) emphasizes that in the private sector, spin-off dashboards could be the upgrading of a supply chain process, which could be enriched with internal company data and thus offer new possibilities for presentation and, in addition to a better basis for management decisions, could also enable a competitive advantage.

The interviewee (2) affirms the provision of different spin-off minor visualization interfaces with the statement that the necessary data and representations must be brought to the place where they are needed. One interviewee (1) supported this with the statement: *"The data has to follow the citizens and not the citizen its data."*

For the public sector, this development of a "next generation" dashboard could be a trustworthy, comprehensible, region-specific visualization of information for citizens, especially in the context of responsibility and provision of valid data and information. An example of this could be the creation of a major dashboard, which would visualize general information about the infection rates and general regulations in the context of the COVID-19 pandemic at the national level. Possible spin-off dashboards would be specific dashboards at the regional and municipal level, showing targeted information and regulations in the regions and thus improving the comprehensibility for users and ensuring that the data are up-to-date.

Public institutions are enabled to provide up-to-date information at low cost and thus create added public value due to open-data. At the same time, this also means a reduction in the complexity of corresponding interfaces since those spin-offs are tailored to the requirements of the users.

Figure 2 shows the open- and goal-oriented approaches from their beginning, which results in two different steps for the further creation of a dashboard. The process visualization was designed using the Business Process Model and Notation (BPMN 2.0), which is a graphical specification language in business informatics and process management [13].

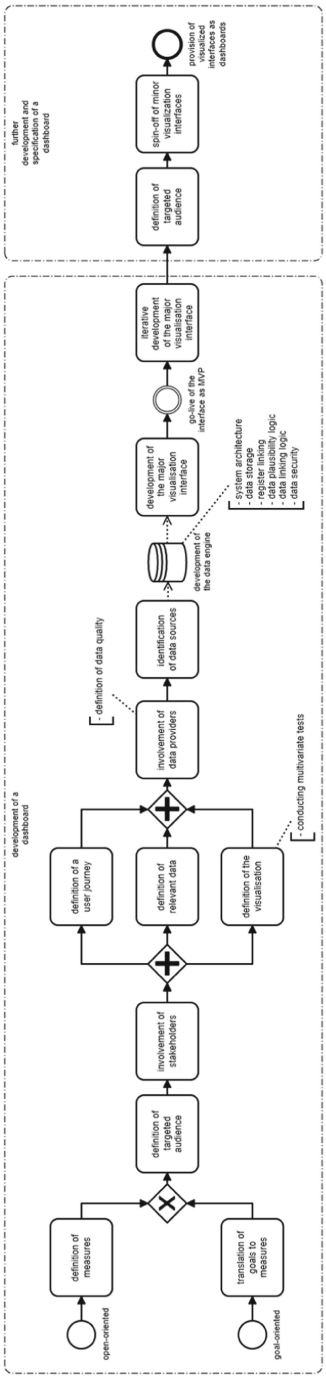

Fig. 2. The development process of a dashboard.

3 Challenges

For the analysis of challenges in the creation of dashboards, the authors conducted interviews as well as an examination of two cases. Here, the purpose and the framework conditions were elaborated and special aspects during the development were analyzed. The analyses were carried out on the *OZG Dashboard Germany* and the *Dashboard "Digital Made in Germany"*. These dashboards were chosen explicitly because the corresponding background information was available and because they were open-oriented and goal-oriented dashboards.

OZG Dashboard Germany (Open-Oriented) [14]
The dashboard on the implementation of the Online Access Act in Germany (OZG) presents the development of administrative digitization based on a uniform federal law. The law, which was passed in 2017, regulates the legally binding provision of digital administrative services by the end of 2022 [15, 16]. The initially very slow implementation of the law is also reflected in the provision of a dashboard. It was not until 2020 that the Federal Ministry of the Interior, Building and Community began providing an initial version of a dashboard. This dashboard, which initially had a strong goal-orientation, was heavily criticized by experts in the field of administrative digitization and misinterpreted by third parties (e.g., newspaper publishers). The misunderstanding was based on the visualization of data regarding the provision of administrative services in Germany. At the beginning of the implementation of the law, 575 OZG-services were set. The visualization showed that the provision of OZG-services was progressing rapidly. However, a closer look at the data showed that the provision of a digital service was already considered complete as soon as the service was available in just one municipality in Germany. This is highly controversial in the federal context and distorts the provision of the actual information.

Based on the criticism expressed, the ministry started to relaunch the dashboard at the beginning of 2021, taking a clear turn and focusing on an open-oriented format of the dashboard provision. This has the advantage that changing goals based on a possible deprioritization of services during the implementation process and the dedicated presentation of regional aspects of the Länder (term of the German federal states) can be better presented without focusing on direct goals. While the analysis for this paper was still underway, the ministry has been working to further provide information within a new dashboard on the OZG-implementation for its citizens. This will focus primarily on the general provision of OZG-services in the Länder, listing the provision of technical services and basic functionalities of the portal network, and at the same time clearly showing the corresponding go-live dates of individual OZG-services on a timeline.

Dashboard "Digital Made in Germany" (Goal-Oriented) [17]
The "Digital Made in Germany" website is the information portal for the German government's "Shaping Digitization" [18] implementation strategy. The website provides interactive and data-based access to the German government's digital policy priority projects and to the federal policy players in digital policy. The core of the site is the Digital Policy Dashboard, which has been under development since March 2019 and was published in September 2020.

With the help of a process similar to that described above for the creation of a goal-oriented dashboard, 140 central digital policy projects in five fields of action were brought together and made measurable on the basis of the "Shaping digitization" implementation strategy. For the first time, an interactive dashboard on the German government's digital policy was developed for the website. The dashboard is a visual progress indicator for the implementation of digital policy projects in the implementation strategy. It supplements the strategy and underpins the projects with current data where quantitative visualization and measurement is suitable. It is intended to improve the visualization of progress in individual projects and make it more comprehensible. Further indicators on the topics of digital policy in the implementation strategy have been added. Hence, the dashboard is the entry point to the measurability of the federal government's digital policy.

Right at the beginning of the creation of the dashboard, a particular challenge arose in the supply of measurable data relating to the individual initiatives in the various federal ministries that were involved. It became apparent that the number of data suppliers posed a particular challenge in order to obtain an overall view of the implementation of the strategy and the individual initiatives. Over time, it also became apparent that less and less data was available from the relevant ministries or that there were no longer any updates to the information. In the run-up to the September 2021 federal elections in Germany, a decrease in information within the dashboard became clear. Thus, the information provided was reduced and it was not visible whether corresponding initiatives were ended earlier or were completed. This may be an example of a recurring challenge that arises from the provision of dashboards [6]. Institutions are now subject to direct external monitoring, as information is proactively provided that can lead to poor results in the context of a review of past years (e.g., before the end of a legislative period) and put political parties and ministers under pressure.

During the development of the generic process for creating a dashboard as described in Sect. 3 and visualized in Fig. 2, various challenges and requirements emerged during the expert interviews and were subsequently clustered by the authors. Based on the analyses of existing dashboards and the interviews conducted in Germany and the PRC, various design dimensions have been identified.

The design dimensions have been consolidated and defined in Table 1. Six dimensions emerged that the interviews identified as particularly important. These are (1) the *strategic* orientation of dashboards, (2) the holistic consideration of *stakeholders*, (3) the targeted *use of data*, (4) the form of *visualization*, (5) the provision of a *feedback* component, and finally also (6) the *technical* requirements for the subsequent visualization of data.

In addition to the consolidation of challenges into corresponding design dimensions, a prioritization could be carried out. This means that, depending on the urgency or weighting in the overall process of creating a dashboard, a particular dimension is assigned a special priority. The analysis showed that the complexity of implementing dashboards results from the evaluation of the design dimensions, which can vary greatly in some areas. The main factors here are the type of a dashboard, its strategic alignment, the user group it will refer to, and the technical requirements for the data engine.

During the analysis following the interviews, it was found that interviewees (1–2) who had an overall view of the process of creating a dashboard were the most likely to indicate that the defined design dimensions are mutually interconnected and that there are

Table 1. Design dimensions for the development of dashboards.

Priority	Design dimensions
1	Strategic
	How will the dashboard support or challenge the current strategic alignment of the institution? What type of information will be provided? Will the information provide insights? What is the intention of the information provided? Is the information relevant and does it integrate into the political sphere? What will be the cost for collecting the data, the development of a data engine and the interface?
2	Stakeholder
	Are future users, data suppliers and data owners involved? Will the dashboard have an internal or external benefit for the stakeholders? What are the internal and external requirements for the dashboard from the perspective of the individual stakeholders? What should the dashboard be used for by each stakeholder? Who is the addressee of the dashboard from the perspective of each stakeholder? How can the different requirements of the stakeholders be consolidated and aligned in a user-centric way?
3	Use of Data
	Is the data publicly available? Do data sets need to be merged? What is the quality of the data? Who collected the data? How was the data collected? In what format is the data provided and how often is it updated? How valuable is the data? Is a description and source of data sets available? Who is the owner of the data?
4	Visualization
	Is the purpose of the visualization more informative or interpreted as a control element? Which data must be visualized in which form and is it relevant to visualize all available data? Does the visualization create transparency? Is the visualization an exclusive pre-selection or should users have the possibility to choose the visualization themselves? Should there be the possibility to visually display comparisons, and can data sets be merged by the user for this purpose?

(*continued*)

Table 1. (*continued*)

Priority	Design dimensions
5	Feedback for Continuous Improvement
	Is the possibility of user feedback desired? In which format should the user have the possibility to give feedback? (open questions, questionnaire, scale) Should there be barriers to giving irrelevant feedback? Is there a special focus for the corresponding feedback? (feedback on selection of data, visualization, handling of the interface)
6	Technical
	Is the data provided in a machine-readable and standardized form? What are the requirements for the system architecture based on the data sets used? What are the technical requirements for the data engine in terms of data-register linking, data plausibility logic, data linking logic, and data backup? What measures are taken to increase IT-security and privacy? Is a ready-made tool used to create the interface or is it a proprietary development? Are interfaces required that enable third-party access to a data engine?

various dependencies. At the same time, this also means that there is a certain potential for conflict among the existing design dimensions, which also has an influence on the complexity of developing a dashboard. This is already evident in the strategic orientation of some dashboards, as a clear decision is made in favor of exclusive visualization, the possibility of compiling one's own data sets and the associated juxtaposition of data for a self-directed conclusion of new insights, or even the possibility of proactively requesting feedback to improve data and user quality.

It has been shown that the challenge to requirements engineering also becomes a challenge in the context of deciding on a clear standardization (compare with Sect. 2). This limits the individuality and specific characteristics of representations and the provision of data. Therefore, it is important to opt for an iterative process of defining measures and corresponding data based on user requirements. Two interviewees (2, 5) clearly summarizes this in a statement saying that standardization limits innovation and individuality and thus couples the overall process to narrow framework conditions.

To counteract this, it is more important to actively involve users in the process of developing the dashboard and to focus on a further step on the development of "next generation" dashboards as proposed by an interviewee (2). In this way, the complexity of the functionalities for spin-off dashboards can be adapted according to the user groups. This means that, in addition to simplifying functionalities, citizens for example, who are solely interested in viewing the information on the dashboard, can be provided an increase in functionality in order to meet the requirements of specialists and scientists who want to merge or compare a wide variety of data sets in order to arrive at new insights [19].

Against this background, it is therefore important that the afore mentioned design dimensions are relevant, during and after the creation of dashboards. According to the

interviewees (1–3), fundamental strategic decisions play a special role here, because a decision in favor of predefined measures severely limits the possibilities for gaining knowledge. Of course, other considerations must also be made that deal with the complexity and simplicity of use. However, this is entirely up to the prior analysis of the audience and subsequent user groups. In conclusion, the analysis of the requirements shows that an imbalance can build up between the design dimensions, thus complicating the development and the not bringing the desired success when used later. One example is the recurring challenge of the misalignment of the used data and the actual data to be used to answer the previously defined questions and requirements from the users' perspective.

The overview given in this paper cannot be considered exhaustive, as the requirements for a dashboard differ greatly depending on the dashboard and the particular use case. However, the expert interviews and our own analyses during the creation of various government dashboards have shown these areas of complexity.

4 Conclusion

The creation of dashboards goes through a recurring process that has explicit characteristics and requirements depending on its particular environment and demands. The complexity of the creation process depends on various framework conditions and requirements from a social-technical point of view. The interviews have shown that in addition to the current process models, there are also future approaches for the development of dashboards. In this context, the major role of data engines will be elevated to a new level, and dashboards will become corresponding media output for the data lakes that are being created within the framework of open-data [20]. Data lakes are the future for the provision and processing of mass data. In contrast to data portals, they allow data to be made available in a timely and flexible manner [21].

We found two types of dashboards, i.e., open- and goal-oriented dashboards. The process of creating dashboards somewhat differs based on the type of dashboard, and the special requirements for user-friendliness that are neglected to cope with the mass of data. However, the advantages are the highly added value of the data used for visualization since the actuality of the data reflects the requirements of today. To address the related challenges of user-friendliness, this paper proposes the development of a "next generation" dashboard that focuses on regional characteristics and specific requirements of an audience.

These requirements are reflected in the six design dimensions and show how interconnected the various questions and requirements of the design dimensions are and how strongly they depend on each other. At the same time, it also shows how high the potential for conflict is between the individual design dimensions. These design dimensions are (1) the *strategic* orientation of dashboards, (2) the holistic consideration of *stakeholders*, (3) the targeted *use of data*, (4) the form of *visualization*, (5) the provision of a *feedback* component, and finally (6) the *technical* requirements for the subsequent visualization of data.

Based on the requirements for the creation of dashboards resulting from the process analysis, which were clustered and prioritized within the design dimensions, extensive questions about their interaction, interdependence, and potential for conflict emerged. For this purpose, it will be necessary to continue addressing these issues in further scientific research.

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