Disruption Management in One-Off Production with Collaborative Digital Assistance Systems

Benefits of an Integrative Approach with a Generic Data Model

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1. Introduction

Disruptions inevitably occur in the project execution of complex one-off projects (Fischäder 2007). They cause effort and costs and, in many cases, delay the progress of the project. Nevertheless, in practice, disruption management is often inadequate because disruptions are only recorded locally and disruption information is not documented in a structured manner. A large part of the disruptions is solved by the interaction of several operational roles, such as workers and foremen (Gruß 2010). However, access to disruption information is not easily available for all affected roles. One-of-a-kind manufacturers are also confronted with a lack of information between the operational level and project control (Wandt 2014), so that disruptions can rarely be related to the overall progress of the project.

By using digital assistance systems, disruptions can already be reduced or even avoided on the operational level. The reason is an improved presentation of information (Friedewald et al. 2016). Nevertheless, unavoidable disruptions occur, such as quality defects of installed parts or delays due to environmental influences (Steinhauer/König 2010). A potential for improvement is to reduce the effort caused by such disruptions and to reduce or completely prevent consequential disruptions by reacting quickly. Furthermore, information about disruptions and the knowledge gained from them should contribute to future avoidance in follow-up projects and should be transparently available (Gronau et al. 2019).

This article shows how digital assistance systems will play a key role in the future in order to improve disruption management in one-of-a-kind production. The basis is a generic data model that can map different disruptions and enables structured storage for the many participants in disruption management. We assume that digital assistance systems will already be well integrated into the work processes and will thus avoid system and context changes at the operational level, while supporting in disruption management activities.

The paper is structured as follows:

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First, the importance and handling of disruptions in one-off production is exemplified (Section 2). Subsequently, the state of the art in relation to the use of IT systems in disruption management (Section 3) is discussed.

The development of digital assistance systems (Section 4) and data models are examined in regard of disruption management requirements (Section 5). In the process, opportunities and deficits are highlighted. Following, the concept of a generic data model for disruptions is presented (Section 6).

The integration with a digital assistance system and a web application incorporating value-added features is described in Section 7. Especially we show how to use the solutions to improve disruption management.

The paper concludes with a summary and an outlook, which gives a perspective on the use of the obtained disruption information in follow-up projects.

2. Significance of Disruption Management in One-off Projects

Disruptions are any kind of unintentional deviation from the normal process (Lehmann 1992). Typical sources of disruptions observed in one-off projects at different branches of industry are problems with (Rost et al. 2019):

- Construction acceptance, e.g. open items at quality gates
- Complaints in the customer acceptance phase
- Material supply, e.g. a shortage of material
- Assignment of tasks, e.g. unclear task definition
- Resource conflicts, e.g. building site reservations and closures
- Construction ambiguities

These problems cause rework, clarification efforts and waiting times. Good handling of disruptions can increase the quality of a product and thus its longevity. For a more sustainable production, more products can also be produced while using the same amount of resources by reducing scrap and rework efforts.

One-off productions are particularly sensitive to above mentioned disruptions for two reasons:

1. The execution of one-off projects requires a high degree of interdisciplinarity through the interaction of many disciplines and multiple project-to-production interfaces. A disruption in one discipline therefore in many cases affects other disciplines as well as the project management.

2. Different one-off production projects usually share the same production resources at the same time in terms of disciplines and also partly space. This can lead to cross-project disruptive effects due to lack of resources or space as a consequence of a single disruption.

Therefore, high demands are placed on the cooperation as well as on collectively managing disruptions to maintain a smooth project and production execution (Rost et al. 2019). If disruptions occur, they require a rapid response and often also a rescheduling of production. Therefore, up-to-date information about disruptions is just as important as knowing about the current project progress and situation.

Our studies in shipbuilding industry have shown that construction managers and foreman play a key role in communicating and resolving most disruptions. For example, 43 individual disruption cases taking up the majority of working time were observed during a single shift, see Figure 1.

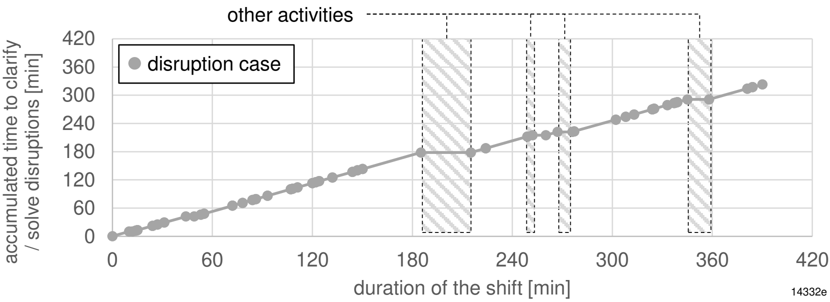

Figure 1: Example of the accumulated clarification time for disruptions of a construction manager during a shift

Figure 2 uses a simplified example from customized aircraft cabin production to show how different types of disruptions are handled with the involvement of different roles. Minor disruptions (1) can be solved bilaterally between a worker and his foremen. Bigger disruptions (2) require further escalation and involvement of superior roles. Our observations show that usually the following activities are performed after a disruption occurs:

1. Initial message by a worker (documentation)

2. Assessment by a foreman, incl. finding a solution

3. Further escalation, if necessary for finding a solution and deciding on a counter-measure

4. Communication of solution instructions from foreman to worker (counter-measure initiation)

5. Documentation of countermeasures and evaluation or feedback on effectiveness from worker to foreman

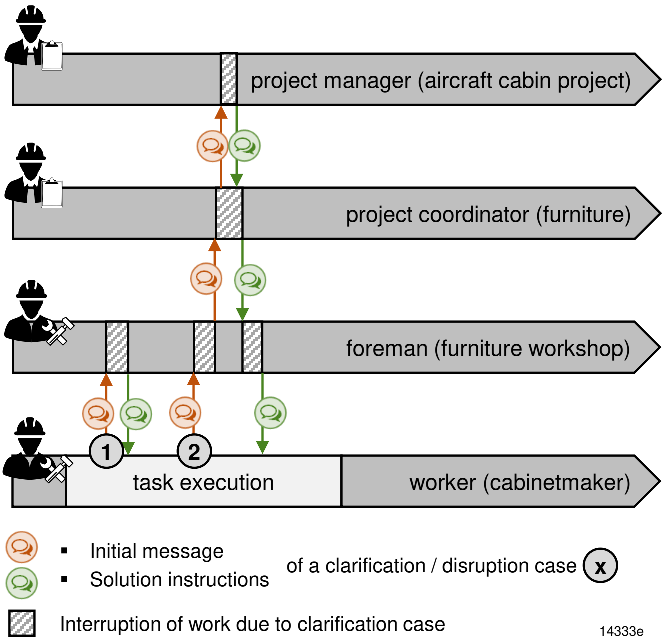

Figure 2: Management of disruptions in one-off production, based on (Rost et al. 2019)

These activities of dealing with disruptions are typical for a reactive disruption management, because they take place after a disruption has happened and aim at reducing their effect. There are two basic strategies for managing disruptions, namely prevention and reaction strategies (Schwartz 2004), see Figure 3.

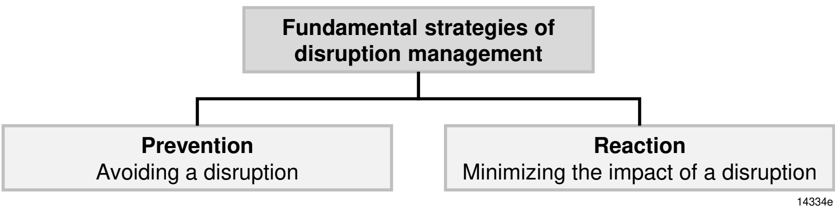

Figure 3: Fundamental strategies of disruption management, based on (Schwartz 2004)

Prevention requires assessment of possible disruptions and implementing measures to either eliminate their cause or protect against their occurrence beforehand (Schwartz 2004). Preventive activities in one-off production are performed mostly within a discipline or on project management level by regular meetings of domain experts. They typically collect potential lessons learned from their discipline-specific disruption documentation solution.

Previous analysis and evaluation of disruptions during planning are however especially challenging in one-off projects since design can occur even late in the production process and there is a constant lack of information, especially in the early planning phases. Disruptions and their treatment are usually not immediately reflected on extensively in the sense of lessons learned, but instead the order contents are further processed so that no further delay occurs. As a result, preventive measures tend to take place downstream, and there is a tendency to postpone a large number of these until the end of the project. The problem is that in the end preventive measures and lessons learned are usually carried out in a rather rudimentary manner, if at all, since a new or parallel project usually ties up the resources immediately. Because preventive disruption management often is rudimentary in one-off projects, reactive activities are especially important.

3. Information Technology Used in Disruption Management

Disruptions are typically managed and tracked individually per discipline with a variety of methods, often with generic IT tools, such as Excel sheets with different layouts, digital Kanban boards as in Microsoft Teams or messenger apps like WhatsApp. Sometimes, instead of IT tools, paper is still used for notes on disruptions and to-do lists are created to keep track of the troubleshooting process.

Usually, reactive activities and underlying disturbances are not transparent and accessible across disciplines and projects. In consequence reaction efforts are slowed down along the communication chain. If a disturbance affects other disciplines, it regularly is observed as an isolated disturbance by this discipline, triggering isolated disturbance management activities where a collaborative approach would be required.

The criticality of a disruption is strongly determined by the scope of consequences, which can be individual, discipline-wide, cross-discipline, project-wide or cross-project. However, when a disruption occurs, often the consequences cannot be determined solely by the person noticing it. Therefore, it is important that disruptions can be easily accessed by all affected parties to see far-reaching consequences. Consequentially a company-wide organizational and IT infrastructure is necessary.

The digital processing and IT support of disruption management in one-off production has been subject of research since the 1990s (Eversheim 1992; Lehmann 1992; Bamberger 1996). IT systems proposed or used for disruption management are adapted shop floor management systems or workflow management systems as well as dedicated disruption management systems, such as assist^{IT} (Wünscher 2010). As a link between planning systems and production, Manufacturing Execution Systems (MES) are also able to identify disruptions and initiate countermeasures (Schumacher 2009). So far, these have mostly been established in the context of highly automated production with extensive use of machines, which can be monitored with sensors and controlled digitally. For companies that perform one-off production, which is characterized by a high number of manual activities within production orders, there is still no suitable MES (Jericho et al. 2022). However, there are already approaches to connecting the shop floor in one-off production with MES systems or with a Digital Twin in particular with the aim of improving disruption management (Jericho et al. 2022). Yet the exact digital integration of the particularly important workers is not described in detail.

We could see that the acceptance for the aforementioned systems is low in practice of one-off production. This is due to different reasons: the systems are not integrated well into standard processes or tools, they are often not designed to be user-friendly for non-experts and they often run on stationary computers, resulting in walking distances and additional work for the user. Our observations show that a natural starting point to report a disruption for the workers is the link with components, product structure, location and ideally a products 3D model. Most disruptions have a component reference and a reasonable link saves workers the search effort when trying to resolve a documented disruption.

Digital assistance systems for production workers are a promising alternative to the systems described before due to their focus on the product and its 3D representation as well as their availability on mobile devices. Unfortunately, they are not entirely adapted to be used in disruption management. In the following it will be shown how adapted digital assistance systems combined with a generic data model can overcome present deficits and lead to more integrated disruption management.

4. Digital Assistance Systems

Digital assistance systems are a special type of information systems, which are designed mainly for use at production level and run on mobile devices such as tablets or mobile phones. They are intended as the main source of information for operators performing their work. Studies show that the use of such assistance systems can reduce assembly errors and improve productivity (Friedewald et al. 2016). The main functionalities provided by digital assistance systems in one-off production are (Friedewald et al. 2016; Halata et al. 2014; Rost et al. 2019):

- Easy and quick access to product and work package related information:
    - CAD model of the product or the relevant parts for a work package
    - Additional attributes, such as geometric measures or process parameters
    - Digital documents, such as data sheets
- Visual 3D deviation check of an installation situation (actual state vs. target state) by means of comparison to reality via augmented reality (AR) or CAD view.

- Basic documentation and feedback of
    - Work progress
    - Disruptions

For several reasons, digital assistance systems for the worker are ideal and useful in disruption management:

- Digital assistance systems reduce the effort required to document because the documentation is made with the same device and software that is used for the value-adding activities. Important points of the documentation can be deduced from the tracking function of the AR function (location) or from the workflow (part numbers of affected parts).
- Studies indicate that digital assistance systems enjoy a high level of acceptance among employees and are therefore likely to establish themselves as the primary information system in manufacturing. They are characterized by high availability and easy accessibility because they run on mobile devices.
- Digital assistance systems bear the potential to sense disruptions (via user input / feedback / context) and reach out to individual users for immediate reaction with counter-measures.
- Digital assistance systems can be connected to an MES or a digital twin and thus integrated into the comprehensive disruption management across several company IT system levels and together with machines.

However, there are still some deficits besides the aforementioned chances that need to be solved in order to achieve a comprehensive disruption management:

- **Vertical integration.** Current digital assistance systems often address only the operative roles and lack integration with information systems for foreman, production and project managers and engineering (see Figure 4).
- **Horizontal integration.** Digital assistance systems currently focus on dedicated disciplines and do not function across them, which would be needed for a bilateral information exchange.

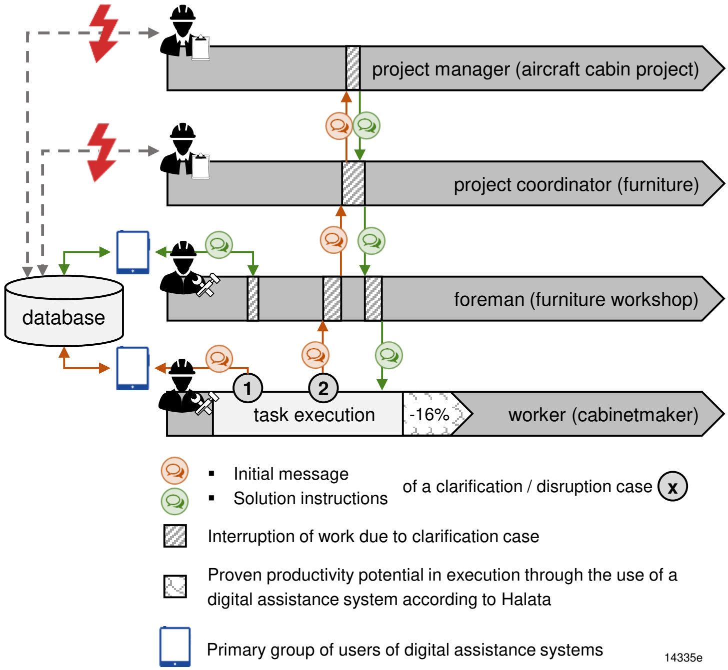

Figure 4: Motivation and improvement potentials for using digital assistance systems in disruption management, based on (Rost et al. 2019)

Moreover, current disruption management functionality in digital assistance systems suits user groups that can share a fixed and standardized data model in a database. In the following, this data model is described in more detail and its problems and limitations are shown as soon as more than one discipline as well as project management and engineering are to work collaboratively with it.

5. Existing Data Models for Disruptions

Data models are the backbone of digital assistance systems. The data relevant for disruption documentation and management can be summarized as follows:

- Identification key, e.g. a GUID
- Textual descriptions and categorizations
- References to product, location and work order
- Processing and meta information (status, dates, author, responsible)
- Descriptive attachment references (documents, images, …)

Rost et al. introduce a data model for documenting issues in 3D with Augmented Reality based on the IFC and BCF formats, which originate from the Building Information Model (BIM) used in the construction industry (Rost et al. 2018). Since most construction projects are similarly complex as production projects in shipbuilding and aircraft cabin modification, the data model can be applied in principle. However, it has a few shortcomings, which are to be discussed.

First, the data models lack flexibility in terms of information content of the topic to match discipline-specific needs, of which some examples are shown in Figure 5. Second, the data models are not integrated into the global project scope, e.g. the project plan but also the global production scope, e.g. the production plan.

Many data models are based on the assumption, that a one-size-fits-all solution in the form of a rigid data model can be explicitly formulated. However, there are multiple situations in which this assumption is wrong, since it requires that standardization is possible with reasonable effort.

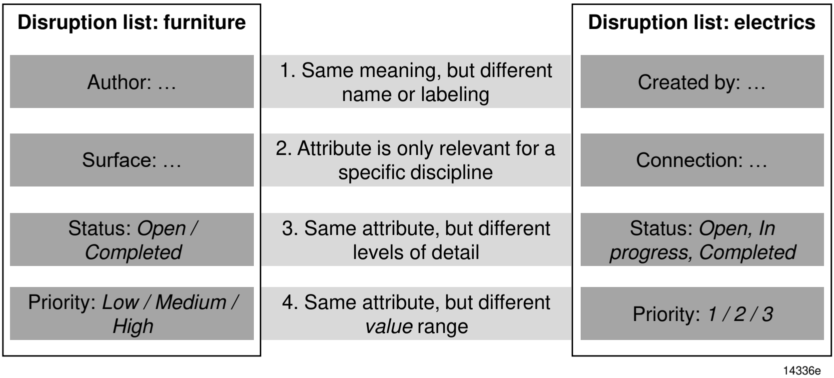

Figure 5: Differences between disciplines in disruption documentation

Reasons that problematize standardization and the aforementioned assumption for one-off production are:

1. Different disciplines have individual requirements regarding the visual presentation of disruption data, e.g. label based on a discipline- or process-specific expression ("author" vs. "created by" vs. "responsible").

2. Different disciplines require custom attributes and categories to document their disruptions, which are not needed by others.

3. Different disciplines require the use of individual status definitions for their disruptions internally, which only partially matches with overall project / production status definitions, because a finer division is required.

4. The same case as in 3., but different division of the status is required.

It is not feasible to combine the lists of the different disciplines into one, since:

1. Different designations are absolutely justified, since they e.g. are common in technical language and are therefore easier to understand.
2. Since there will be too much and also irrelevant additional information when simply merging the lists, the disciplines would have to make an effort through manual filtering to keep an overview, which impedes usability.
3. Having unnecessary additional choices can cause confusion.
4. Same argument as 1. Even with a compromise in which both attributes remain to coexist in a merged list (e.g. priority 1, priority 2) this is at the expense of clarity.

The example shows that, despite initially obvious differences, there are similarities and intersections in terms of content. This favors the plan to find a generic model that meets the different needs of the processes and disciplines and could thus lead to a cross-process standard. A concept for this is developed below.

6. A Generic Data Model for Disruptions

This section presents the concept of a generic data model for disruptions derived from requirements arising from the previously identified deficits in disruption management. The purpose of the proposed data model is to store all data describing and related to a single disruption in a way that serves all stakeholders in disruption management during associated activities.

Requirements for a data model derived from the previously elaborated problems and deficits are:

1. Allowing a definition of discipline-specific disruption types with custom attributes and individual status.
2. Maintaining comparability of different types of disruption records.
3. Being able to derive disruption management performance indicators from the data model for all disruption types from any source.
4. Allowing customization of the visual representation of the disruption data, without the need of changing or extending the data model itself.

The concept of the generic data model for disruption consists of two parts: the first part considers the requirements 1 to 3 and the second part covers the fourth.

Combination of standardization and customizability. The data model consists of a set of default attributes, to allow for comparability and common analysis of different types of disruptions, and a set of customizable attributes, which enable flexible definition of different disruption types in a discipline-specific manner.

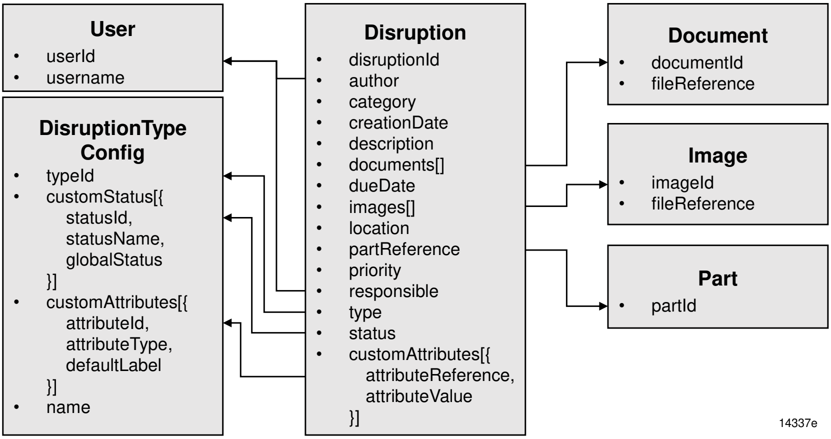

Figure 6: Entity-relationship model of the generic data model (simplified)

Figure 6 shows the entity-relationship model of the generic disruption data model. The properties identified in the previous section as necessary for documenting a disruption are present as default attributes for all disruptions. In addition to a unique identifier and the creator of the disruption documentation, these attributes also include references to a product or part, relevant images and documents, and a location of the disruption. Information on creation and due dates, priorities, and status enable a uniform and joint evaluation of the disruptions regardless of their discipline-specific application.

Every disruption contains a reference to a discipline-specific type configuration that defines custom attributes and status. In this configuration the data type and a default label for the custom attributes are defined. In the model of the disruption itself, only a reference to the attribute definition and the attribute value are stored. The situation is similar with the statuses. Here, too, the discipline-specific statuses are defined in the configuration and only a reference is stored in the disruption model itself. To enable uniform evaluation and derive performance indicators, a type-specific status must be mapped to a global status, e.g. "open", "in work" or "done".

Separation of data model and visualization model. A core idea of the data model concept is making use of the software design pattern called model-view-viewmodel, short MVVM, which separates the business logic related model from the visualization in user interfaces. The reason for this is a gain in flexibility to display the same disruption data in different customizable visualizations and even customize the default attributes of the data model at the user interface layer.

Figure 7 shows the entity-relationship model of the visualization model. It defines which disruption types are to be considered in the visualization. Thereby it is possible to create discipline-specific or combined views of disruptions.

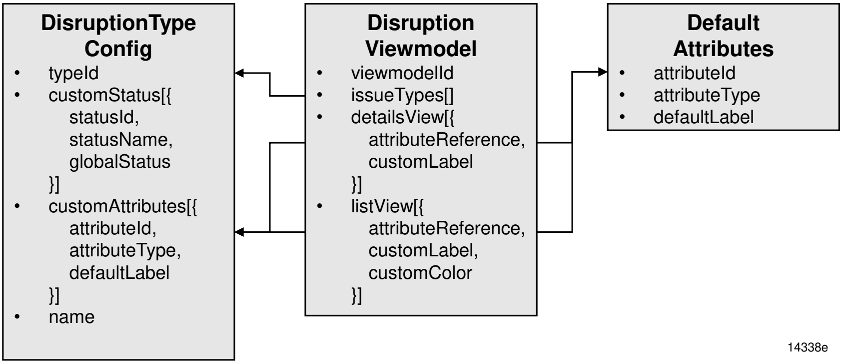

Figure 7: Entity-relationship model of the visualization model (simplified)

Customization of a detailed view of a single disruption and a list view of multiple disruptions can be done independently of each other. In both cases, an array is defined that contains references to the default attributes or custom attributes of the selected disruption types. If a custom attribute label is assigned, it will be used at the user interface layer instead of the default label. As an example, it is possible for the default attribute "author" to have the label "author", "created by" or any other designation for different viewmodels. Furthermore, column colors can be defined for a list view.

7. Integrated Disruption Management with a Digital Assistance System

The integration concept for the generic data model for disruptions addresses native augmented reality based digital assistance systems as well as web-based applications. In total three applications for different purposes have been developed in order to make use of the shared generic data model and to cover support during core activities in disruption management (see Figure 8):

- An augmented reality based digital assistance system on a tablet, which serves as the main work package and production information source for production level (Subsection 7.1)
- A web-based disruption dashboard with additional tools for situational awareness and decision making for disruption management on production and project management level (Subsection 7.2)
- A web-based tool especially for the purpose of disruption documentation and remediation for production level via mobile devices, when the use of AR is unfeasible, e.g. due to a lack of 3D models (not shown here)

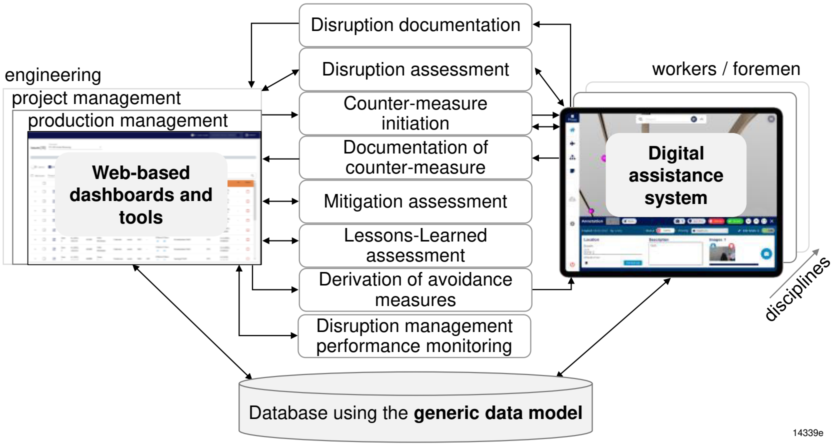

Figure 8: Digital support of core activities in disruption management with an integrated generic data model

7.1. Digital Assistance System with Disruption Management Functionalities

The integration of advanced disruption management capabilities into digital assistance system represents the core idea of this article. The main challenges and solutions which will be presented hereafter lie in user interface (UI) and user experience design, especially when Augmented Reality visualization takes place. On the technical side, the adaptability of the user interface to the generic data model described in the previous section also introduces challenges in software development. However, these will not be discussed in detail but instead the resulting user interface will be presented. The user interface of an existing digital assistance system for manufacturing has been extended by two additional functional areas focused on disruption management:

- a UI for a single disruption that is related to a 3D or alternatively AR view and which can either display an empty state for documenting a new disruption or to review an already documented one, e.g. for processing (Figure 9)
- a UI which presents an overview of all recorded disruptions in a list and includes a 2D layout with the location pins of disruptions, filter functionalities for processing and meta information like author, processing responsible and status (Figure 10)

Figure 9: Individual display and input mask for documenting a disruption

Documenting a new disruption consists of up to 3 steps:

1. Setting a 3D-pin in CAD / AR at the affected location of the product
2. Specifying description and additional information (e.g. priority)
3. Capturing photos of the disruption (optional)

Automated context-sensitive functionalities enrich the quality of the disruption records. Setting the location pin (1.) will automatically detect the related part and derive further information about its location based on the product structure (e.g. zone / deck, parent assembly). The photos (3.) are automatically tagged with information about the parts and disruption it refers to or which are visible in it. These tags are linked to exact 2D positions (markers) on the photo.

As shown in Figure , the digital assistance system supports not only documenting the disruptions but also facilitates processing them until they are solved completely. Solution progress, counter-measures and their success can easily be tracked, documented and reviewed on spot or remotely. A 2D layout and a 3D navigation function accessible in AR help to quickly find locations where disruptions occurred.

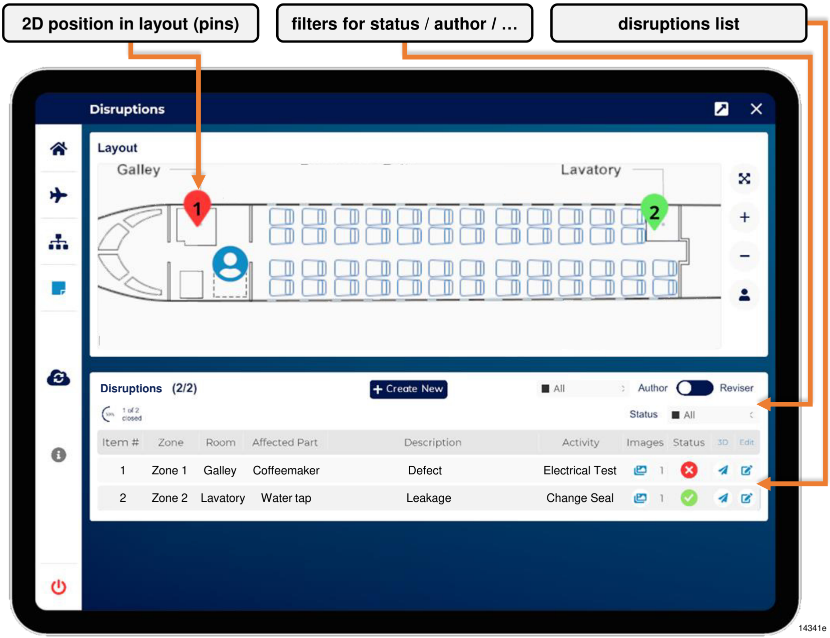

Figure 10: Disruption overview in the digital assistance system for processing

7.2. Web-based Disruption Processing

The developed web-based tools for disruption management use the same generic data model as the digital assistance system described before. However, they are intended for use in decision making by providing an overview and the possibility to review and extend the disruption information for initiation and tracking of reactions. Besides assigning priorities and due dates, users can define countermeasures and delegate them to a responsible discipline, department or employee.

The upper part of Figure 11 shows the overview of all disruptions regardless of their type. In this case, only the default attributes are shown and the global status of the disruptions. In comparison, the lower representation shows the type-specific view for the "Open Items" viewmodel.

Customization allows to define the attributes to be displayed, their order, label and column color for a specific disruption type based on the MVVM approach of the generic data model. For example, the custom attribute "Connection" is only displayed in the type-specific view. Furthermore, the type-specific status definitions and labels for "author" and "status" are used.

Opening the same overview from a tablet or smartphone results in a different layout due to a responsive design, which helps improving the user experience on different devices.

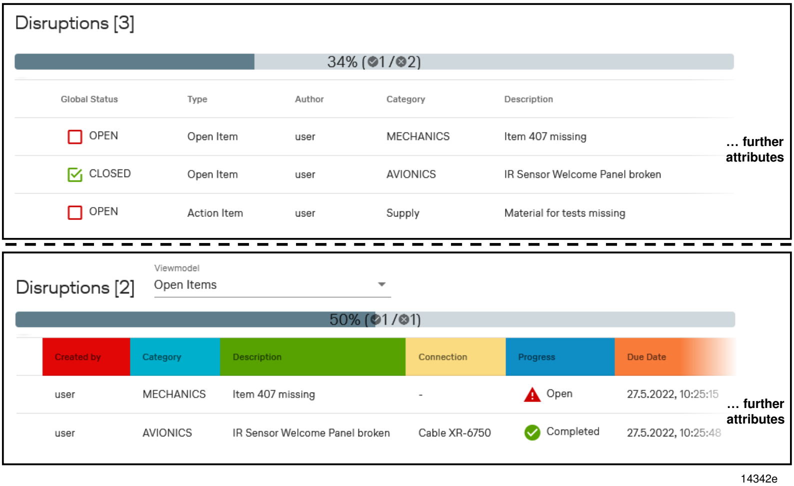

Figure 11: Comparison between the overview of all disruptions regardless of type (upper) and a type-specific view (lower)

7.3. Web-based Disruption Dashboard for Project Management

The disruption dashboard is a web-based application and forms an assistance tool for production and project management for performing analysis and during decision making. It consists of five different tabs in the user interface, each providing a specific toolset to the user for the aforementioned disruption management tasks:

- Overview and disruption distributions
- Disruption management performance indicators: schedule reliability, deviations from schedule and throughput times
- Throughput diagram
- Timeline (project-related)
- Heat map of disruption management activities

The first tab gives an overview of the existing disruptions and their distribution (Figure 12). Besides a breakdown by disruption status, bar charts show the distribution after disruption type and the number of overdue disruptions per project phase including a history over the past calendar weeks. This helps users in production control and project management to deduce trends and to adjust capacities if necessary.

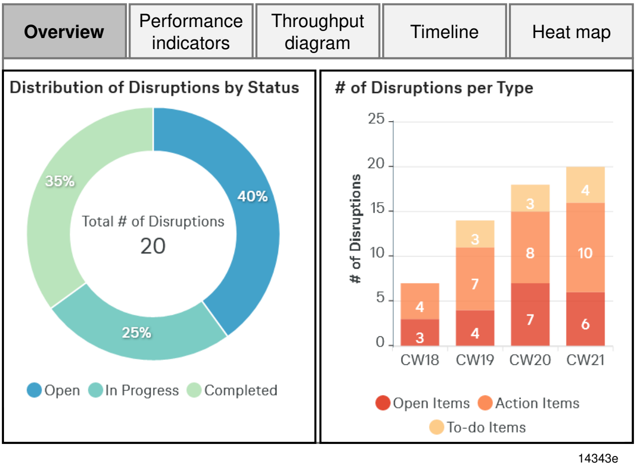

Figure 12: Disruption overview and distribution (excerpt from the web-based dashboard)

A second tab shows management performance indicators like schedule reliability, deviations from schedule and deviations between planned and actual throughput times per disruption type.

It is possible to apply the funnel model of production control to the disruptions as they have the character of an order. In this case, a discipline or department with its employees who process the countermeasures of a disruption form the workstation. As the processing time is not clearly defined for all disruption types, the number of disruptions is used as the work content. The informative value is improved by only displaying disruptions of the same priority and category at the same time. The resulting throughput diagram is part of the third tab (Figure 13).

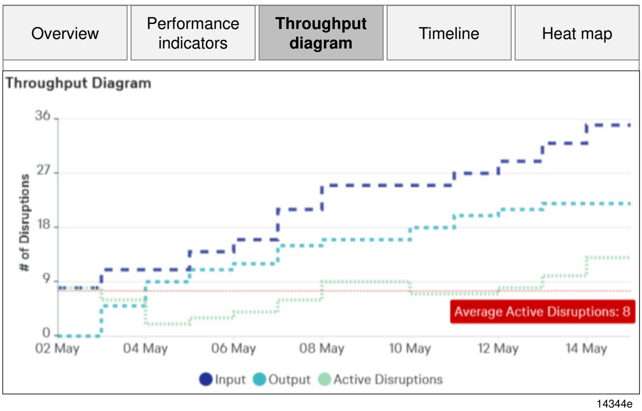

Figure 13: Throughput diagram for disruptions (excerpt from the web-based dashboard)

The disruption timeline in the fourth tab shows the individual disruptions with their scheduled or actual throughput times in the context of the project phases and milestones. Filter and grouping options complete this view.

The last tab contains an activity heat map which shows the disruption-related activities like creation, updating and closing on a timeline. Grouping options help to compare the frequencies of different groups like disruption types or categories.

8. Practical Use and Evaluation Approaches

The approach towards an integrated disruption management with digital assistance systems and a generic data model has been implemented in a demonstrator that includes synthetic data records for an aircraft cabin modification. The solution is to be evaluated via a combination of surveys with production employees, benchmarks of the user experience as well as expert interviews. Some expert interviews as well as a process simulation for the disruption documentation have already been performed, of which some preliminary results as well as expectations regarding results are presented in the following.

Production Level. Several disruption documentation and processing tasks shall be evaluated regarding usability using the User Experience Questionnaire and the NASA Task Load Index. The aim is to achieve a better rating for the digital assistance system for documentation and processing as the current heterogeneous IT landscape (MS Excel, Kanban boards, etc.), so that as many potential users as possible use the system in the sense of end-to-end horizontal and vertical integration.

As mentioned in Section 3, a variety of IT tools have been used to date for documenting disruptions. The presented digital assistance system in combination with the generic data model is able to replace a large part of these IT tools. Redundancies are avoided through the common database and transparency is increased as communication between disciplines is based on the same, up-to-date data.

In customer acceptance processes of several one-off projects, it has been possible to successfully use the digital assistance system, see 7.1, as a prototype in a process-related manner. The system has met great interest for future establishment and acceptance has been high. In addition to the user experience with the application on a mobile device, the increased documentation quality through the direct link to the product and the integration of localized photos was mentioned as advantageous. Only the setup of the tracking required for the use of the AR functionality was recognized as expandable. Therefore, tracking strategies that require even less setup effort are currently being designed and tested. Further the evaluation in customer acceptance processes focused on the documentation, while the processing that is expected to bear a significant productivity impact hasn't been covered yet. This is planned to be checked in future in an overall evaluation.

Production Control Level and Project Management. The practical implications and solution aspects for project management and production control were discussed in an expert interview with a senior project manager. His tasks consist of recording and coordinating internal and external complaints as well as the ensuring the product quality of in-house production and purchased parts.

In general, the senior project manager expresses a positive opinion with regard to a shared generic data model with a common database, since the disruption data provide information that can be decisive for capacity and control adjustments. With live data across all types of disruptions, he sees an opportunity to react more quickly to problems and, in the event of accumulations, to adjust capacities at an earlier stage. At this time, data of different disruption types is gathered manually at certain time intervals which can lead to delays in the reaction. The time histories of the disruption data shown on the dashboard can provide insight into the effectiveness of the countermeasures taken.

Even though the feedback of the senior project manager regarding the disruption dashboard paints a promising picture, the next step is to conduct a quantitative evaluation of this potential at production control and project management level.

9. Summary and Outlook

In this paper the relevance and deficits in the disruption management in one-off projects have been discussed. Further it has been shown why in digital disruption management current rigid data models are not sufficient for cross-discipline working environments.

As a solution it has been shown how a generic data model can represent different disruptions and allows a structured storage. This allows a continuous information feedback to the project management.

Based on this, it is shown how access to disruption information can be improved by a digital assistance system and web-based lists. The digital assistance system enhances information quality by locating it in the project's CAD model and general plan. It provides disruption management seamlessly integrated into the same system used to retrieve work package information and to work in collaboration, thus reducing context switching. Additional web-based tools present the project's disruption situation transparently and support project control in making decisions and gaining knowledge for future projects.

Potential for improvement exists in the form of an addition of functionalities for lessons learned assessment and derivation of avoidance measures via automated support in finding potential lessons learned by a recommender system, which analyzes disruptions for similarities with previous disruptions which were used as lessons learned and ranks them based on their attributes.

Another important aspect is the use of the extensive database of structured disruption data for automated preventive measures, e.g. similarity measurement based on the previous projects' disruption data and the current work package in the digital assistance system in order to automatically suggest and highlight potential problems and disruption risks.

In terms of sustainability, goods should be used for longer, which makes maintenance more significant and good disruption management and documentation all the more important. The data model presented can also be used in the lifecycle phases downstream of production - operation, maintenance and repair - to ensure quality and reduce resource consumption along the lifecycle.

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