Validation of a Failure-Cause Searching and Solution-Finding Algorithm in Production based on Complaint Information from the Use Phase

Validation using an industrial example from the field of precision machining and cold forming

Nadine Schlüter
University of Wuppertal
Product Safety and Quality Engineering
Wuppertal, Germany
Email: schlueter@uni-wuppertal.de

Marius Heinrichsmeyer
University of Wuppertal
Product Safety and Quality Engineering
Wuppertal, Germany
Email: heinrichsmeyer@uni-wuppertal.de

Fynn Kösling
University of Wuppertal
Product Safety and Quality Engineering
Wuppertal, Germany
Email: fynn.koesling-hk@uni-wuppertal.de

Amirbabak Ansari
University of Wuppertal
Product Safety and Quality Engineering
Wuppertal, Germany
Email: aansari@uni-wuppertal.de

***Abstract* — Nowadays, constantly increasing demands on products lead to great opportunities, but also major challenges. Complaint management, in particular, is also affected by this, as the high complexity of products and production systems can often lead to failures. In connection with digitalization, companies face the challenge of having to handle complex and extensive information. In the field of complaint management, not only the amount of information increase but also the number of sources, channels, formats, etc. While the companies act more and more globally and digitally, the complaint management in German mechanical engineering is still predominantly carried out manually. In order to improve the processing time and the analysis of complaints, as well as to implement the automated processing of complaint information, the fundamental research project FusLa [funding code: SCHL 2225/1-1] funded by the German Research Foundation (DFG) was launched. The aim is to develop an algorithm that automates the evaluation of relevant complaint information from different types of complaint texts. This paper evaluates the functionality of the algorithm in the context of a validation example from the field of precision machining and cold forming.**

Keywords-Algorithm; Complaint Management; Business Process Re-Engineering for Manufacturing; Decision Support

I. Introduction

Due to the increasing internationalization of our time, the complexity of products and their producing companies is constantly increasing. The need for a higher individualization of products inevitably leads to new challenges for the company's requirements management, as product requirements become more and more complex [1]. Although this increases the opportunities on the market, it also means that the failure risks increase significantly. Therefore, a direct relationship exists between the complexity of a product and the failures that occur. An increasing number of complaints automatically accompanies an increasing number of failures. Complaints mean additional costs for a company, which have to be minimized in the context of increasing complexity.

To eliminate failures and thus avoid complaints, companies rely on different approaches, including the software-supported 8D report. However, these approaches show numerous weaknesses when it comes to dealing with the complexity that prevails in production systems. There is no model integration that enables the traceability of causes of failure within the production system. To process the flow of information generated by complaints and master the complexity of the production system it is necessary to use a model approach. For this particular problem, the current approaches, as demonstrated in section II, reach their limits or do not yet focus on complaint management. In order to solve this problem, an algorithm based on the current state of the art was developed [2] and validated in the industry. In the following section II, this paper deals with the current state of the art and examines which findings have been gained in science as well as in industry with regard to failure-cause searching and solution-finding based on complaint information. Within the framework of this paper, future-oriented approaches will mainly be considered and examined for interfaces to the topic. Section III describes the developed algorithm with its functions and methods as well as the applied validation. Finally, the results of the validation carried out previously are being used for an evaluation in section IV. Moreover, it gives an outlook for upcoming research fields.

II. State of the Art

Considering the field of science, there are some research projects that focus on failure-cause searching and solution-finding in production systems. However, it turned out that these research projects either are not related to complaint management, do not function algorithm-based and thus are not automated, or just subjective evaluations take place. At this point, some of the already published works of the research group Product Safety and Quality Engineering can be referenced, which have already dealt with this topic and in which the current state of science and technology has been analyzed in detail. These include the ICONS 2019 Paper [3]. In addition, the state of the art was examined in detail in the

 ISBN: 978-1-61208-771-9

GQW Paper 2019 [4] for the probing as well as in the QMOD 2019 Papers [5] for the prioritization and in [6] for the failure cause localization of the algorithm. In this paper, the focus shall be on the future-oriented approaches and validation of the algorithm in the sense of an extension of the previous publications. These are explained and examined in the following. Especially at the present time, the relevance of Artificial Intelligence (AI) for the processing of large amounts of information is increasing. However, a distinction must be made between AI, big data, and Machine to Machine communications (M2M) [7]. AI has the goal to enable cognitive-like functions of a machine to analyze and interpret data and to solve problems on this basis. It is, therefore, a better fit for decision making [8]. The purpose of big data, however, is to process and analyze large amounts of data and a large variety of data in order to achieve a specific result. That means that the potential of AI in the area of complaint management is enormous in order to be able to react to failures and eliminate them. AI could develop the possibility to learn from known complaint information in order to be able to exert a preventive effect and prevent future complaints. In order to analyze how far the current future-oriented approaches are when dealing with the mentioned problem, some service platforms were examined and evaluated for this purpose. The investigated platforms are IBM Watson Compare & Comply [9], Apache Spark [10], Amazon Comprehend [11], Microsoft Analytics Platform System [12], Google BigQuery [13], PrediCX [14], CEMax [15], and Adobe Analytics [16]. All these platforms work based on machine learning. They are able to identify, structure, analyze, and evaluate information in text sources. This would also make them suitable for processing complaint texts if they were programmed for this purpose. However, the evaluation of the platforms showed that the analyzed platforms are currently not able to perform a comprehensive failure-cause search and solution-finding in production based on information from the use phase. However, it is necessary to develop such applications in order to deal with the ever-increasing complexity of production systems. In order to enable the use in complaint management, concepts are needed that define how the service platforms are to deal with complaints and which information is relevant. At the same time, such a concept can provide the procedure for failure-cause search and solution-finding for the platform.

III. FUNCTIONALITY AND VALIDATION OF THE ALGORITHM

The algorithm for failure-cause search and solution-finding was developed after the acquisition of various requirements regarding the current state of science and technology. These requirements led to the fact that the algorithm had to consist of the following modules:

- information probing of complaint information [4]
- prioritization of complaint information [5]
- localization of failure-causes [6] and
- solution-finding for failure-causes.

A. Functionality of the Algorithm

As can be seen, the complaint information from the use phase of the product is accessed and filtered within the information probing, so that only the relevant information is being used further. Relevant information can be, e.g., product names, company name, technical drawing number, etc. That information is then being used by the algorithm to determine across several dimensions within the prioritization which complaint has the highest priority. Thereby necessary resources, such as time, personnel or costs can be used in the best possible way for the failure-cause localization. The basis for failure-cause localization is a previously developed model of the corresponding production system. Here, correlations between the essential views of the production systems are stored according to the eDeCoDe model (enhanced Demand Compliant Design) developed by Winzer [17] and Nicklas [18]. These views can be, e.g., components, functions, processes, persons or requirements. An example of such a model of a production system is shown in Figure 1 below. This Figure visualizes all relationships of R1.2, i.e., requirement 1.2 has relationships to the other requirements, functions, processes, persons, and components.

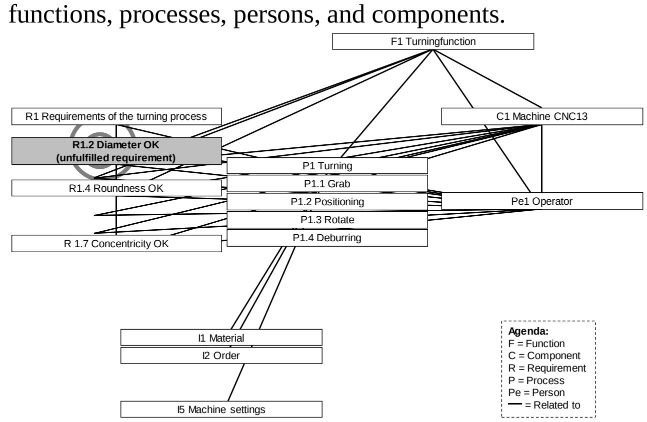

Figure 1. Example of a model of a production system according to [17].

With the help of this model, the algorithm is able to make assumptions based on probabilities about which part of the production system is responsible for the failure that led to the complaint. Once the cause of the failure has been localized, a possible solution will be found by pointing out the necessary measures. This is based on the STOP principle, whereby substitutional, technical, organizational and person-related measures can be offered [19]. Once the measure has been determined, it is up to the producing company to implement it, adapt it, or not use it at all. Due to the focus of the paper, a more detailed description of the algorithm is deliberately omitted. A detailed explanation of the theoretical concept of the algorithm can be found in the papers IEEE QR2MSE [2] and ICONS 2019 [3] published by the research group Product Safety and Quality. After the theoretical concept was completely developed, the algorithm was programmed with Microsoft Office - Visual Basic Application (VBA) and turned into a usable software. In section B of this chapter, the validation using an industrial example is described and evaluated in detail.

 ISBN: 978-1-61208-771-9

B. Validation in Industry

The validation in the industry is used to determine whether the algorithm provides meaningful information and assessments and how the different quality of the complaint information affects the results of the algorithm. At this point in the project, only the feasibility of the theoretical concept and also the effect of the quality of complaints on the result of the algorithm have been examined. A long-term study to measure the performance of the algorithm has not yet been carried out but is planned for the future. While the current validations were only carried out based on a requirement evaluation, the time, cost and personnel expenditure of the algorithm should also be measured and evaluated as parameters in the coming months. This should also contribute to the reproducibility of the results and transparency of the evaluation. Starting with the validation, the company of the industry example will be presented. In order to preserve the anonymity of the company and to protect internal know-how, all company-related information was deliberately concealed. The validation was carried out using the example of a company in the field of precision machining and cold forming. This area is used among other things for the production of strain-hardened and cold-formed parts, e.g., shafts or spindles, which are predominantly manufactured for the automotive industry. This industrial example is noteworthy because the complaint handling is subject to the high standards of the automotive industry. This demonstrates that the algorithm can meet such high standards. In order that the algorithm can carry useful results for the failure cause searching and solution-finding, it was first necessary to create the appropriate information basis. This means that first, all necessary customer information, product information, or order information had to be localized and then a model of the production system had to be created and also prepared for access as part of the evaluation. In this paper, this process is referred to as "preparation for validation". This is essential because it cannot be assumed that a company has all the necessary information in the required format.

1) Preparation for Validation

The preparation of the validation was divided into three steps. In the first step, all information systems of the company were examined for available information about customers, products, and orders. Since the company used very different systems for the respective information, the required information was prepared by the algorithm in Excel sheets and compiled for evaluation. This meant that it was not necessary to program the interfaces for each specific information system. However, at this point, it should be noted that for the practical implementation of the algorithm in industry, exactly such an interface to the existing information systems of the respective company must be programmed and set up by software developers. After the successful mapping of the information systems, in a second step, a model of the socio-technical production system with the eDeCoDe approach was developed. Besides the use of existing documents (e.g., technical drawings, test plans) and the discussion with the process managers of the company as well as the testing, this industrial example offered the possibility to go through all processes for the claimed product systematically with the production manager. It allowed to link the requirements, components, functions, and persons. This not only contributed to a better understanding of the connections within the company but also showed that the company was very interested in the implementation. The correlations between the elements were mapped using Design Structure and Domain Mapping matrices. The result of the collaboration was a production system that comprised 69 requirements for a product under complaint, 21 functions, 22 processes (25 inputs/11 outputs) as well as 11 components and 9 persons involved. With the acquisition of the production system and the associated system elements, the third step in the preparation of the validation could take place. This clearly defined the relationships between the type and importance of the failure and the previously collected requirements. This step is necessary in order to determine for the algorithm which type of failure is the non-fulfilled requirement and what significance this non-fulfillment has. In order not to manipulate the result of the algorithm with regard to the evaluation of a non-fulfilled requirement, the definition of the relationships was discussed based on documents (e.g., Failure Mode and Effects Analysis) and in conversation with the company's experts (e.g., production/complaint management). The result of this elaboration is two matrices for the correlations between the requirements to be fulfilled and the type of failure as well as the significance of the failure. After the three steps for the preparation of the validation had been completed, the actual validation of the algorithm could take place. The validation was based on a very detailed customer complaint relating to an unfulfilled requirement for the SGW product. The SGW product is usually installed in passenger cars and is a critical component of safety. In this case, the complaint text was available in digital form so that it was possible to transfer the complaint text to the intended surface within a few seconds (Figure 3).

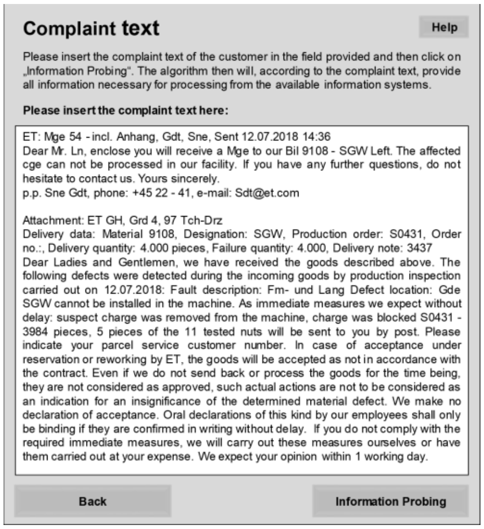

Figure 2. Complaint text of the product SGW according to [20]

2) Information probing of the complaints

Based on the present complaint text, the algorithm recognized the first and last name, organization, and address of the customer and transferred them, as shown in Figure 3, to the fields provided for this purpose in the surface of the information probing.

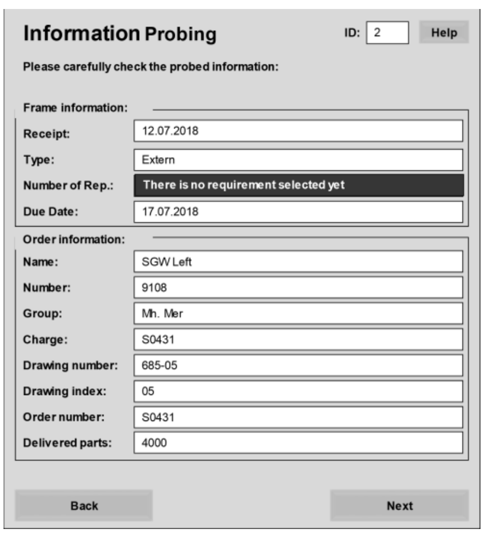

Figure 3. Information probing of the complaints of the product SGW according to [20]

With the help of this information, the algorithm filled in the other fields within the interface. In addition to collecting the date information, the algorithm was also able to identify relevant complaint information relating to the product. The algorithm not only correctly examined its name but also its number, group, and drawing details. The number of products delivered could also be determined via the interface to the ordering system and entered in the field provided for this purpose. Despite the more detailed failure description in the complaint text, this step showed that the algorithm could not assign exactly which unfulfilled requirement was actually involved. Although the algorithm recognizes the product and thus assigns all recorded product requirements to the unfulfilled requirement field as a selection, this is not an automated process. In addition, the user must manually select which requirement was actually not fulfilled. The background of this problem is the lack of standardization of the complaint texts. With the execution of the first step of the validation, the second step started.

3) Prioritization of the complaint

In order to check how the prioritization is influenced by the quality of the complaint text, two prioritizations were performed based on the previously prepared complaint information, as shown in Figure 4.

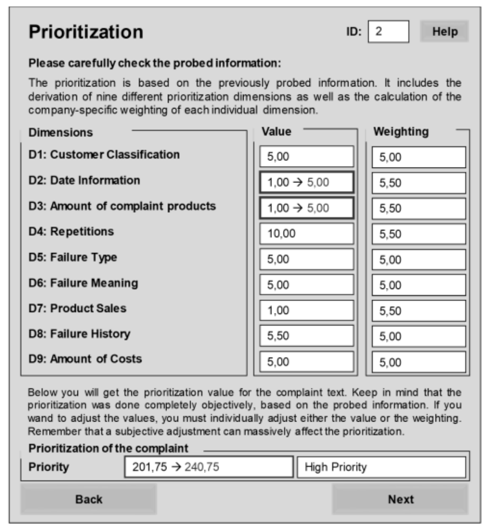

Figure 4. Prioritizing the complaint of the product SGW according to [20].

The gathered information was used to prioritize the complaint. For this, the algorithm calculates different dimensions. How this calculation is carried out is described in detail in [5]. In order to investigate how the quality of the complaint text affects the prioritization, dimension 2 and 3 were evaluated completely in the first step and incompletely in the second step. The second prioritization deliberately deleted information from the fields "ABC Classification", "Due Date" and "Amount of complaint products". The algorithm calculates and uses the reference value of 5.00 in Dimension 2 and Dimension 3 for missing information as you can see in Figure 4. This changes the dimension values and weightings. This has both advantages and disadvantages. On the one hand, it enables the algorithm to enter a dimension value and a weighting. This becomes critical when the influence of missing information becomes so great that an initially less relevant complaint becomes a complaint with high priority. In the worst case, this could lead to companies making incorrect decisions about the order in which complaints are to be processed and thus not using resources (personnel & time) in a targeted and meaningful

 ISBN: 978-1-61208-771-9

manner. The solution to this problem also lies in the standardization of complaint texts.

4) Failure-cause localization of the complaint

Since the localization of the causes of the failure is carried out similarly to the prioritization on the basis of the collected, relevant complaint information, the phase was repeatedly reviewed on the basis of a complete and an incomplete information basis. In this case, the unfulfilled requirement was deliberately deleted from the corresponding field in Figure 5. The algorithm could not make a statement about which elements of the production system were related to the requirement because there was no information about the unfulfilled requirement. This means that without a reference to the unfulfilled requirement, it is not possible to locate the cause of the failure. It seems necessary to choose a more consistent procedure, such as [21] that is developed for networks or to standardize the specification of the unfulfilled requirement. Figure 5 illustrates the complete fault cause localization. The incomplete map, which was not inserted for space reasons, looks the same, but only with empty fields. The theoretical process of localization is described in [6] in detail.

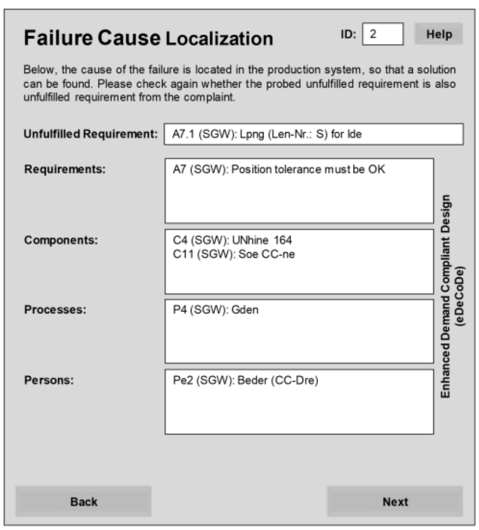

Figure 5. Failure-cause localization of the complaint of the product SGW - complete and unprocessed according to [20].

Once again, it makes sense to describe unfulfilled requirements in complaint texts, such as those stored in the technical drawing or specifications. In this case, the algorithm can identify the causes of the failure very well within the production system. This statement is because of the evaluation of the SGW product complaint included exactly those system elements that led to the cause of the failure. The company's statements about the actual cause of the defect also confirmed the statement that the algorithm could actually perform a targeted localization of the cause of the defect. At this point, it should be noted that the results of the algorithm depend not only on the quality of the complaint text but also on the quality of the production system. Only if the system elements and their interrelationships are completely captured, a targeted localization of the failure-causes is possible.

5) Solution-finding of the complaints

Validation of the solution-finding process showed that this process is completely independent of the quality of the complaint text or the information basis. By the given solutions in the form of measures, the algorithm can act also with a lower quality of the information. Figure 6 visualizes the measures proposed by the algorithm based on Organizational measures (O) for the failure-cause Component 4 (C4).

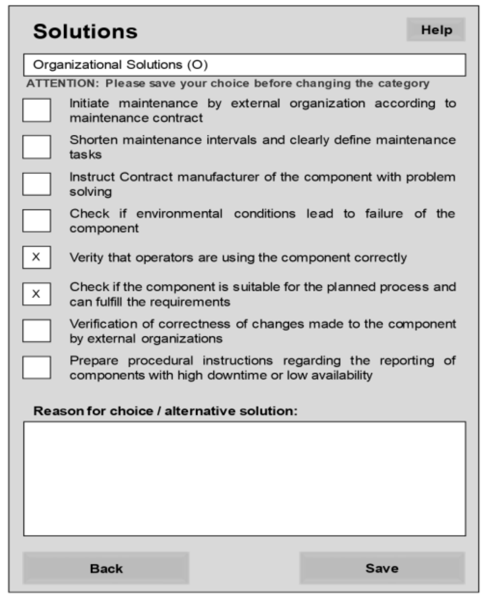

Figure 6. Measures proposed for the cause of the failure of C4 (SGW): UNhine 164 according to [20].

The result showed that it is possible to find a solution with the help of the measures, regardless of the quality of the information base or the complaint text.

IV. CONCLUSIONS

The validation using the industrial example in the field of precision machining and cold forming has shown that the performance of the algorithm is significantly influenced by the quality of the information in the input. In order to avoid a lack of information during the writing of the complaint, a standardization of the complaint text is strongly required. A lack of information would mean a high additional effort in the search for the cause of the failure and in finding a solution. This problem of probing of information could be solved by modifying the input mask of the complaint. Within the prioritization, the algorithm succeeded in compensating missing information by the formation of average values. Thereby set at least an estimated value for the prioritization of the complaint. In addition, here the impact was shown due to the quality of the complaint text, which can be improved by standardization. The validation has also shown that the quality of the complaint text has a strong effect on the localization of the cause of failure. On the other hand, it also turned out that the influence of the quality of the production system could be minimized. The reason lies in the self-developed user interface for checking the production system by the operator. A residual risk remains, however, as incorrect entries by the user are still possible. A solution for this would be the specification of the requirements in the complaint text according to the technical drawing or the specifications. With regard to finding a solution, the following findings could be gained from the validation. It has been shown that the quality of the complaint text has no technical effect on the solution-finding. However, it does affect the quality of the solution-finding. Therefore, measures can be derived at any time independently of the quality of the complaint text. The measures proposed by the algorithm led to the successful elimination of the failure-cause in the industry example. However, it was also noticed negatively that missing failure-cause information has strong effects on the probability calculation and therefore no adequate evaluation is possible without concrete information about failure rates or the competencies of persons. Furthermore, this information was not documented in the industry example. These findings follow the need for interfaces to Computer-Aided Quality (CAQ) systems in production in order to enable the algorithm to automatically access the necessary failure-cause information. Similarly, it should be examined whether alternative methods are more suitable for probability evaluation. The above-mentioned improvement potentials are now to be further investigated and implemented within the framework of future research projects.

ACKNOWLEDGMENTS

The authors thank the German Research Foundation (DFG) for the support of the Project FusLa [funding code: SCHL 2225/1-1].

REFERENCES

[1] S. Cook, “Complaint management excellence,” Kogan Page, London, 2012.

[2] M. Heinrichsmeyer, N. Schlüter, A. Ansari, “Algorithm based handling of complaints data from the usage phase,” in 2019 International Conference on Quality, Reliability, Risk, Maintenance, and Safety Engineering, IEEE QR2MSE, pp. 399–406, 2019.

[3] M. Heinrichsmeyer, N. Schlüter, A. Ansari, “Algorithm for Dealing with Complaints Data from the Use Phase,” in Proceedings ICONS 2019, Sendra C., S. Valencia, Spanien, pp. 1–6, 2019.

[4] M. Heinrichsmeyer, N. Schlüter, A. Ansari, “Algorithmus zur automatisierten Abfrage relevanter Informationen aus Kundenreklamationen,” in Bericht zur GQW-Jahrestagung, Schmitt, R., pp. Status: Accepted and will be published, 2019.

[5] M. Heinrichsmeyer, N. Schlüter, I. Lemke, “Development of an automated prioritization procedure for complaints,” in Proceedings of Quality Management and Organisational Development/ an International Conference on Quality and Service Sciences, QMOD, 2019.

[6] M. Heinrichsmeyer, N. Schlüter, F. Kösling, “Localization of failure causes in production using complaint information by the means of an algorithm to achieve sustainable quality,” in Proceedings of Quality Management and Organisational Development/ an International Conference on Quality and Service Sciences, QMOD, 2019.

[7] C.-G. Hong and C. Dietze, “Enabling Digital Excellence Through Business Process Management and Process Frameworks,” in Future Telco, Krüssel, P. Springer International Publishing Cham, 2019.

[8] A. Holz, “Artificial Intelligence in Business. Reshaping work and organizations,” GRIN Verlag, vol. 1, München, 2019.

[9] IBM Watson Compare & Comply, "*Extract data from contracts and governing documents to in-crease productivity, reduce costs and minimize exposure*," [Online]. Available from: https://www.ibm.com/cloud/compare-and-comply, 19.12.2019.

[10] Apache Spark, "*Framework for Cluster Computing*," [Online]. Available from: https://spark.apache.org/docs/latest/index.html, 10.09.2019.

[11] Amazon Comprehend, "*Natural Language Processing*," [Online]. Available from: https://aws.amazon.com/de/comprehend/, 10.09.2019.

[12] Microsoft Analytics Platform System, "*Microsoft Data Platform*," [Online]. Available from: https://www.microsoft.com/en-us/sql-server/default.aspx, 10.09.2019.

[13] Google BigQuery, "*A serverless, highly-scalable, and cost-effective cloud data warehouse*," [Online]. Available from: https://cloud.google.com/bigquery/, 10.09.2019.

[14] PrediCX, "*Complaint Handling*," [Online]. Available from: https://warwickanalytics.com/use-cases/complaint-handling/, 10.09.2019.

[15] CEMax, "*CEMax Complaint Management*," [Online]. Available from: https://www.c-m-x.com/sol-complaint-management/, 10.09.2019.

[16] Adobe Analytics, "*Digital Analysis Platform*," [Online]. Available from: https://www.adobe.com/analytics/adobe-analytics.html#, 10.09.2019.

[17] P. Winzer, “Generic Systems Engineering,” Springer Vieweg, vol. 2. Auflage, Berlin, Heidelberg, 2016.

[18] J.-P. G. Nicklas, “Ansatz für ein modellbasiertes Anforderungsmanagement für Unternehmensnetzwerke,” Shaker, vol. 1, Aachen, 2016.

[19] J. Brauweiler, A. Zenker-Hoffmann, M. Will, “Arbeitsschutzmanagementsysteme nach ISO 45001:2018,” Springer Fachmedien Wiesbaden, vol. 2. Aufl. 2019, Wiesbaden, 2019.

[20] M. Heinrichsmeyer, N. Schlüter, H. Dransfeld, F. Kösling, “Validation of a Failure Cause Searching and Solution Finding Algorithm for Failures in Production; based on Complaints of a Company in the Field of Stamping and Metal Forming,” in International Journal On Advances, IARIA 2019, International Academy, Research, and Industry Association, 2019 - Status: Accepted and will be published.

[21] Y. Shang, "*Localized recovery of complex networks against failure*," [Online]. Available from: https://www.nature.com/articles/srep30521#citeas, 10.09.2019.