

A Collaborative Digital Platform for Root Cause Analysis in a Value Chain

Adriana ITO^{a,1}, Dan LI^a, Malin Hane HAGSTRÖM^b, Jon BOKRANTZ^a,
Anders SKOOGH^a, Maja BÄRRING^a, Johan STAHRÉ^a

^a*Department of Industrial and Materials Science, Chalmers University of Technology*

^b*Manufacturing Engineering Development, Volvo Group*

ORCID ID: Adriana Ito <https://orcid.org/0000-0001-5608-2306>, Dan Li <https://orcid.org/0000-0003-1636-9745>, Malin Hane Hagström <https://orcid.org/0000-0003-1118-1129>, Anders Skoogh <https://orcid.org/0000-0001-8519-0736>, Jon Bokrantz <https://orcid.org/0000-0003-4930-7786>, Maja Barring <https://orcid.org/0000-0002-8763-0843>, Johan Stahre <https://orcid.org/0000-0003-2256-0079>

Abstract. Collaboration among actors is necessary to create and develop resilience in value chains. However, collaboration tends to be quite restricted when companies are dealing with disturbances and looking for their root causes. With the objective of increasing collaboration among companies in the same value chain in the process of root cause analysis, this article proposes a high-level design of a digital platform. To develop the high-level design, a design science research approach was taken, with the participation of ten different companies. The proposed design is based on identified problems and requirements regarding root cause analysis in the value chain. This study contributes both practically and theoretically. Practically, the proposed high-level design can be used as a direct input for the actual development of a collaborative digital platform. Theoretically, in this study, problems and requirements regarding root cause analysis at the level of the supply chain are identified, adding to existing knowledge in the field.

Keywords. root cause analysis, value chain, collaboration.

1. Introduction

In a globally competitive market, collaboration among companies is necessary to foster resilience at the level of the value chain [1], [2]. Through collaboration, suppliers and their customers might identify risks, define joint efforts to eradicate or minimize them, and come up with mitigation and prevention plans [2]. Furthermore, through collaboration practices, companies might also nurture stable relationships, leading to higher levels of trust in the value chain [1], [2].

However, it is rare to find a deep level of collaboration regarding root cause analysis of disturbances in value chains. Root cause analysis is an investigation performed by companies after the occurrence of a problem, with the objective of identifying and eradicating its primary causes (root causes), instead of only mitigating its symptoms and effects [3], [4]. In situations of production disturbances, manufacturing companies might focus on internally finding and dealing with issues even if external actors might be related somehow. Not surprisingly, companies miss the opportunity to learn from their suppliers and customers to understand external influences and possible consequences of

¹ Corresponding Author: Adriana Ito, adriana.ito@chalmers.se.

their processes in different locations in the value chain. Therefore, collaborative root cause analysis at the value chain level might be a promising solution for companies, since it allows them to learn from experienced issues, avoiding their reoccurrence, which leads to greater resilience.

Considering this background, the objective of this article is to propose a high-level design for a collaborative platform for root cause analysis that can be used by different companies in the same value chain. To do so, a series of workshops, focus groups, and interviews were carried out with three manufacturing companies in the same value chain and seven technology providers, following a design science research (DSR) approach. To the knowledge of the authors, no similar platforms have been proposed by previous research regarding root cause analysis in a value chain.

2. Methods

The main purpose of this research is to propose a high-level design of a collaborative platform to be used for root cause analysis among different companies in the same value chain. To do so, the authors deemed design science research (DSR) as the most suitable strategy. This is considered a pragmatic research strategy that focuses on designing artifacts aiming to improve a specific situation [5]. In the case of this work, the situation aimed to be improved is the root cause analysis process of experienced disturbances in a value chain, being the artifact the conceptual solution for the collaborative platform.

The research process was greatly influenced by [2], [3], and it can be divided into four main phases: (1) identification of the problem, (2) definition of the objective of the solution, (3) design and development of the solution, and (4) evaluation. Different activities were performed in each of the different phases, as summarized in Figure 1. The numbers in parenthesis represent the number of sessions carried out. The research process was started in September 2021 and finished in December 2022.

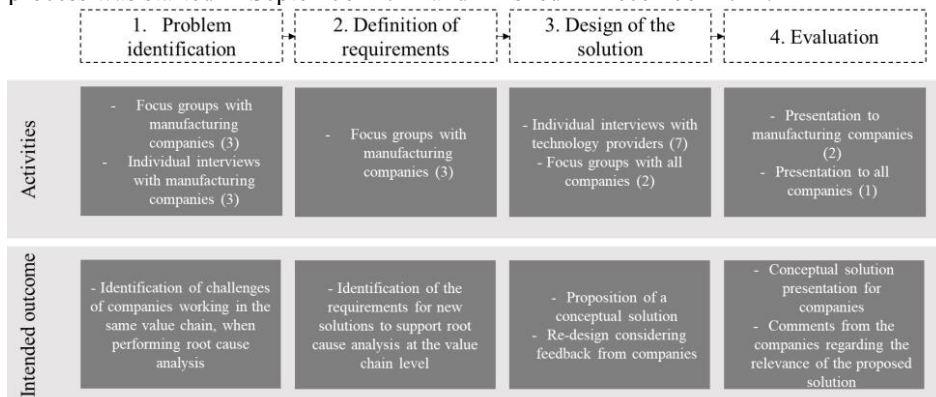


Figure 1. Research process

A qualitative approach was chosen for data collection and analysis, based on interviews and focus groups. Qualitative research is usually used to answer questions about experience, meaning and perspective, most often from the standpoint of the participant [8], [9]. In this study, the authors aimed to explore the different problems, requirements, and possible solutions for root cause analysis from a practitioner's standpoint, so a qualitative approach was considered adequate.

Focus groups and semi-structured interviews were performed for the collection of data (see Activities in Figure 1). Focus groups is a flexible method frequently used in research to better understand a collective issue [10]. On the other hand, semi-structured interviews allow researchers to explore in-depth the opinions and experiences of individuals [11]. The combination of those two methods for data collection provided the chance of understanding both individual and collective problems, requirements and solutions for root cause analysis.

Two different types of companies were involved in the study: manufacturing companies and technology providers. Table 1 provides information about the companies. To choose the manufacturing companies, the authors looked for those that were part of the same value chain and were willing to improve their joint root cause analysis. For the choice of technology providers, the authors looked for those interested in developing digital and collaborative platforms. For the selection of participants from the companies, the authors looked for those directly involved either with root cause analysis (in the case of the manufacturing companies), or with the development of solutions related to root cause analysis (in the case of the technology providers). At least one person from each company was involved in this study.

Table 1. Participating companies in the study (MC: manufacturing company, TP: technology provider).

Company	Main product/service/ technology	Size of the plant/office
MC1	Connecting rod	50-250
MC2	Motor	>250
MC3	Truck	>250
TP1	Cloud-related solutions	>250
TP2	Internet of things and business intelligence solutions	<50
TP3	Quality management software	<50
TP4	Data analytics services	>250
TP5	Traceability software	<50
TP6	Data analytics solutions	<50
TP7	Connectivity applications	<50

3. Results

3.1. Problem identification

Finding the root causes of disturbances at the level of the value chain is a difficult task. Internally, manufacturing companies already struggle to understand their processes and establish the relationship between cause and effect for the experienced disturbances. At the value chain level, this problem is exacerbated since the complexity is much higher with the involvement of suppliers and customers. Additionally, with a significant number of disturbances (internal and external) being experienced on a daily basis and the lack of systematic ways of working, manufacturing companies end up spending their energy primarily on mitigating the disturbances' symptoms and effects. In this scenario, often

the root causes for disturbances in the value chain are not found. The following statement was collected during the interviews:

“The problem is that we don’t have a structured way to deal with the disturbances, we just act. We have daily discussions, but we just firefight the disturbances.”

When a quality disturbance happens in the value chain, communication among companies tends to be established between sales and purchase teams. This means that often, it can be challenging to connect experts from different companies for collaboration in finding the root causes. Those experts might belong to different departments other than sales or purchasing, such as quality, maintenance, or production, for example. The interviewees expressed that they have encountered communication problems when investigating the causes of quality disturbances.

“It is a bit embarrassing to say this, but many times we need to hunt our suppliers if we want to understand a specific problem.”

Additionally, the interviewees pointed out that one problem when collaborating to identify root causes concerns the rise of rumors among the companies about the disturbance. This can lead to a greater stress level in the process, and reduce trust among the different actors.

“When such things [referring to disturbances] happen, there is a risk. You need some kind of communication plan because there will be rumors around. It does not even have to be a big thing.”

When the root cause analysis process is started, and employees from different companies can begin cooperating to analyze quality disturbances, a challenge that can be encountered is that the communication is not structured, making it hard to manage the information that is exchanged.

“Because today we are typically using emails, and we send them to a distribution list... And then when they answer, they answer to some of the people and not to everybody... And then, in the end, you have a mess.”

3.2. Definition of Requirements

In the second phase of this research, the focus was given to the identification of requirements for the intended collaborative digital platform. As an overall objective, the manufacturing companies pointed out that the value chain as a whole should be more agile in dealing with issues so that problems can be solved fast and the right countermeasures can be taken to avoid them from happening again in the future.

“We need to increase our agility and reduce our inertia in the value chain.”

Another identified requirement is that the solution should enable knowledge sharing. Through knowledge sharing, disturbances that would have consequences for an individual company can be avoided at a different point of the value chain (for example, at the customers). Knowledge, in this case, might refer to understanding the upstream and downstream processes, how the different production and product variables in a specific point affect the rest of the value chain, the most frequent disturbances and their causes, and the quality checks that are performed along the production steps.

Additionally, knowledge might refer to best practices identified in the different companies to deal with disturbances and their ways of performing root cause analysis.

“...maybe you can come out with different controls and can get information from another company that you didn’t know they have it. Learning from other companies is necessary to survive in a competitive environment.”

“We need to make knowledge available from the expert to everyone.”

Additionally, a requirement regarding the need for visibility in the process of root cause analysis at the level of the value chain was also identified. According to the manufacturing companies, it is important to know at which stage of the analysis a specific investigation is, how the work is being conducted, and to have transparency in the results. Relevant information that should be visible includes, for example, the status of the investigation, lead time for problem-solving, reoccurrence of disturbances, and people involved in the investigation.

“I mean, we need some kind of place where you can make sure everybody has the latest updated information about the quality problem we are trying to solve together.”

The final identified requirement regards secure applications. The manufacturing companies mentioned that it is critical to establish security protocols, so they can trust that the data they share will be made available only for the intended people and that other companies will not misuse it. Additionally, when sharing data, it should also be ensured that critical databases and systems are not put in a vulnerable position where they might easily be hijacked.

“I think that we must understand from the technology providers how we can use different protocols for the information to be safely shared.”

“Cyber-security is needed.”

3.3. A High-Level Design of a Collaborative Platform for Root Cause Analysis

Based on the identified problems and requirements for the solution, a collaborative platform for root cause analysis was designed. In this section, the final design is presented. However, different versions were developed and presented during the project to the involved companies, and their feedback was considered for re-design. Specifically, the feedback from the technology providers helped the authors in designing a solution that is feasible to be implemented in practice with currently available technology. The design of the platform is divided into two different parts: the use case diagram that presents the functionalities of the platform, and the high-level architecture that presents the different modules.

3.3.1 Use case diagram - functionalities of the collaborative platform

The intended users of the platforms are the employees from all the manufacturing companies that work with root cause analysis of production disturbances. The roles may vary among the companies, but they might include employees working in departments such as quality, production, maintenance, continuous improvement, engineering, and product development. Figure 2 presents the high-level functionalities defined for the platform, presented in the form of a use case diagram.

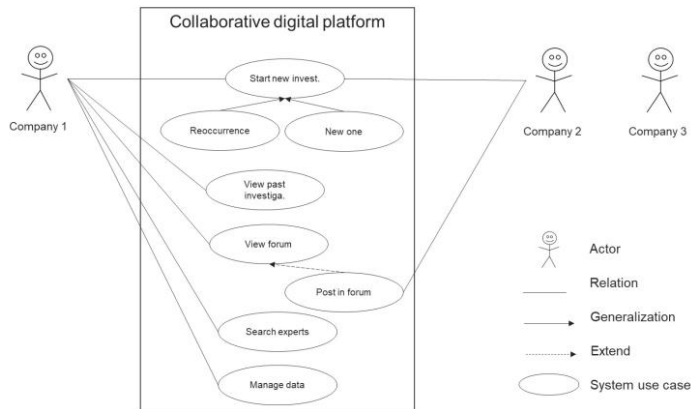


Figure 2. Use case diagram for the collaborative platform.

The users of the platform should be able to start a new collaborative investigation when a new event potentially related to the suppliers or customers is identified. Additionally, the users should be able to gain insight into possible root causes based on previous investigations, to find experts in different areas of interest, and to exchange knowledge through a forum.

a. New investigation

In the case of a new disturbance, an employee (user) in each of the plants can initiate a new investigation. The disturbance can be a completely new one (never experienced before), or a reoccurrence of a previously experienced type of issue. Based on the description of the disturbance, the digital platform returns the results of similar investigated issues that were previously registered, and the contact of the people involved in the past investigations. If no similar disturbances are found, a suggestion of the people to be involved in the new investigation is made based on a knowledge area chosen by the user. The user can then select the people from the various companies to be involved in the root cause analysis investigation group, and a notification is sent to those.

b. View past and ongoing investigations

In order to increase learning from past events, the user is also able to check the results of previous investigations, without initiating a new investigation. In this case, the found root causes are presented, as the status of the recommendations for eradicating them (for example, implemented or to be implemented). The information about the involved people from the different companies is also presented as the data and information shared during the investigation. The user can then judge if the identified root causes are applicable to their own experienced issue, as the proposed recommendations. Also, the user has the information of relevant employees involved that can potentially help in a specific event.

Additionally, the user can also check the status of an ongoing root cause analysis investigation. In this case, it is possible to verify the different people that are involved and in which phase the analysis is (for example, if data is being collected or if the root

causes were already identified or handled). All data and information already exchanged among the different members of the investigation group is also visible.

c. Search experts

In some cases, the user might just want to connect to different specialists without formally starting a new root cause analysis investigation. Therefore, another functionality of the platform regards the search for experts. In this case, the user can choose an “area of knowledge” (such as maintenance or product development, for example). The platform retrieves then the relevant employees from all companies in the value chain that are related to the selected area. The user has access to the contact information of the experts.

d. View forum

If the user has a specific question but is unsure of who to contact, or wants a more holistic perspective of the matter involving people from different areas of knowledge, it is also possible to post on a forum. Once a question is posted, different people from all companies will get an automatic notification, and will be able to comment and answer the posted question. Previous posted questions are stored in the platform, so it is also possible to search for specific questions and see the provided answers and comments.

e. Manage data

In the course of the root cause analysis process, different types of data from the different companies can be shared through the platform, being the assigned employee in the team responsible to give access to the data to other companies. In the platform, it is also possible to visualize all shared data and information. In this case, the user can check the data/information that has been shared and different people across the value chain that has access to it, granting or revoking access if deemed necessary, enabling higher data security.

3.3.2 A high-level architecture for the platform

The designed platform enables collaborative root cause analysis of problems involving more than one actor in the value chain, connects experts from different manufacturing plants, provides consistent information regarding the status of the root cause analysis, enables information and data sharing among companies, and promotes knowledge sharing. A high-level design of the platform is presented in Figure 3. The different manufacturing plants are connected through the platform, being able to collaborate in a digital environment. A demonstration of how the platform can look like as a web application is also provided in Figure 3.

3.4. Evaluation of the Collaborative Digital Platform

In the final phase of this study, the proposed conceptual solution for the collaborative digital platform was presented to the participants from the manufacturing companies and technology providers on different occasions. After the presentation, their feedback was asked on if they considered the solution as relevant to their practices. The participants mentioned that this type of solution could help in reducing the time for root cause analysis, once it enables relevant people from the different companies to connect more easily. A new root cause analysis investigation at the level can also be started more

rapidly. The participants also mentioned that they thought this type of solution could be beneficial even in other contexts, such as in between plants of the same manufacturing companies.

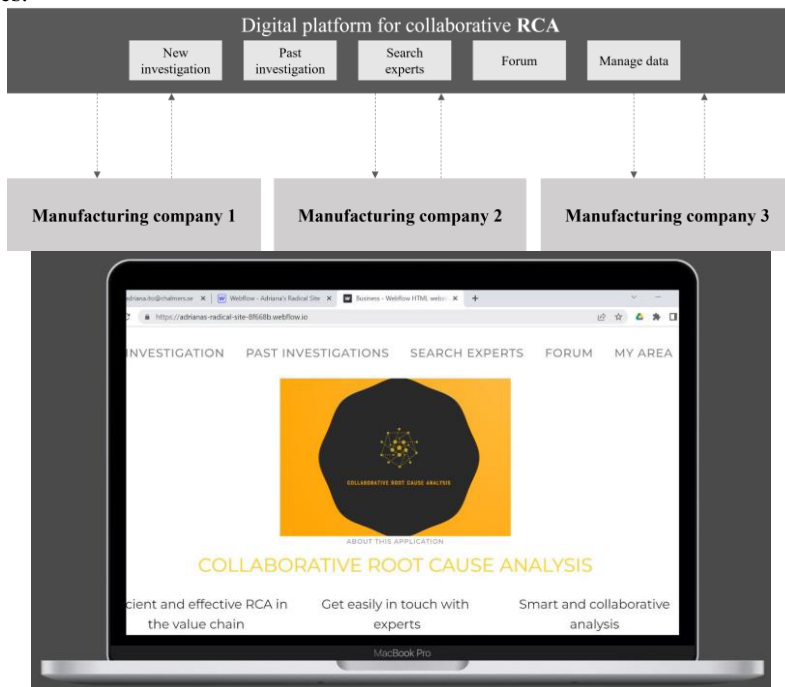


Figure 3. A high-level design for a collaborative platform for root cause analysis.

4. Discussion

In this study, a high-level design for a digital platform for collaborative root cause analysis in a value chain is proposed. The design is based on the identified problems and requirements that are experienced by manufacturing companies in the same value chain, which were identified through a series of focus groups and interviews with ten different companies. The presented high-level design can be used as an input for the development of concrete instantiations of an application for root cause analysis, enabling greater collaboration, information and data sharing, visibility in the process, in a secure environment. Once a concrete instantiation of the application is built, the proposed high-level design can be tested in real cases of root cause analysis among different actors in a value chain.

The authors of this study believe that such a platform can help manufacturing companies be more effective and efficient in the root cause analysis in a value chain. However, trust among the companies in the value chain is critical, so that data, information and knowledge can be shared. In this study, focus was not given to identify strategies to enhance trust, being this therefore suggested as a future work, due to its importance in this context.

5. Conclusion

In this study, inspired by a design science research approach, a collaborative platform for root cause analysis in the value chain is proposed, based on problems and requirements of manufacturing companies working in the same value chain. The platform enables great visibility in the process and knowledge sharing in a secure environment, allowing greater collaboration among companies. The authors hope that this can be used by practitioners to improve their processes of root cause analysis in the value chain and for the development of new solutions.

Acknowledgements

The work presented in this paper has been supported by the Area of Advance Production at Chalmers University of Technology as well as the research and innovation projects “Digitala Stambanan Produktion” (grant ID: 2021-02421) funded by the Swedish Agency for Innovation Systems’ (VINNOVA) area “Sustainable Industry”.

References

- [1] M. Cao and Q. Zhang, “Supply chain collaboration: Impact on collaborative advantage and firm performance,” *J. Oper. Manag.*, vol. 29, no. 3, pp. 163–180, 2011, doi: 10.1016/j.jom.2010.12.008.
- [2] L. Horvath, “Collaboration: The key to value creation in supply chain management,” *Supply Chain Manag. An Int. J.*, vol. 6, no. 5, pp. 205–207, 2001, doi: 10.1108/EUM0000000006039.
- [3] D. Mahto and A. Kumar, “Application of root cause analysis in improvement of product quality and productivity,” *J. Ind. Eng. Manag.*, vol. 1, no. 2, pp. 16–53, 2008, doi: 10.3926/jiem.2008.v1n2.p16-53.
- [4] B. Andersen and T. Fagerhaug, *Root Cause Analysis: Simplified Tools and Techniques*, no. Second edition. 2006.
- [5] J. van Aken, A. Chandrasekaran, and J. Halman, “Conducting and publishing design science research: Inaugural essay of the design science department of the Journal of Operations Management,” *J. Oper. Manag.*, vol. 47–48, pp. 1–8, 2016, doi: 10.1016/j.jom.2016.06.004.
- [6] K. Peffers, T. Tuunanen, M. A. Rothenberger, and S. Chatterjee, “A design science research methodology for information systems research,” *J. Manag. Inf. Syst.*, vol. 24, no. 3, pp. 45–77, 2007, doi: 10.2753/MIS0742-1222240302.
- [7] B. A. R. Hevner, S. T. March, J. Park, and S. Ram, “Design Science in Information Research,” *MIS Q.*, vol. 28, no. 1, pp. 75–105, 2004.
- [8] K. Hammarberg, M. Kirkman, and S. De Lacey, “Qualitative research methods: When to use them and how to judge them,” *Hum. Reprod.*, vol. 31, no. 3, pp. 498–501, 2016, doi: 10.1093/humrep/dev334.
- [9] A. Moser and I. Korstjens, “Series: Practical guidance to qualitative research. part 1: Introduction,” *Eur. J. Gen. Pract.*, vol. 23, no. 1, pp. 271–273, 2017, doi: 10.1080/13814788.2017.1375093.
- [10] P. Gill, K. Stewart, E. Treasure, and B. Chadwick, “Methods of data collection in qualitative research: Interviews and focus groups,” *Br. Dent. J.*, vol. 204, no. 6, pp. 291–295, 2008, doi: 10.1038/bdj.2008.192.
- [11] S. E. Rabionet, “How I learned to design and conduct semi-structured interviews: An ongoing and continuous journey,” *Qual. Rep.*, vol. 16, no. 2, pp. 563–566, 2011, doi: 10.46743/2160-3715/2011.1070.