An Expert Survey on the Use of Informal Models in the Automotive Industry

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Abstract. Currently, the automotive industry shifts from classic Cyber-physical Systems (CPSs) development to the development of CPSs with digital twins. However, while most digital twins assume formal/formalized models, in practice many engineers stated to employ informal models or sketches during the development of CPS with digital twins. Thus, to investigate the purpose and use of informal models in the automotive industry, we conducted an expert survey within the SofDCar project. In detail, we set up an online questionnaire asking participants from industry and academia about the way they employ informal models in their contexts. The survey indicates that informal models are widely used during the conception phase and for communication and documentation. Thus, we maintain that digital twin architectures for the automotive industry must incorporate informal models, as additional artifacts documenting and communicating design decisions.

Keywords: Informal Model · Survey · Automotive · Cyber-Physical System · Digital Twin.

1 Introduction

There currently are huge shifts in the automotive industry from the classic development of Cyber-Physical Systems (CPSs) to the development of/with digital twins, to reduce development costs and time-to-market [3]. Among other projects, in *Software-Defined Car (SofDCar)*[4], partners from industry and partners from academia *collaborate to research the challenges of E/E and software*

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[4] https://sofdcar.de

architecture in vehicles. While academics generally assume that all models in digital twin are well-defined formal (or formalized models), from industry experts, we learned that informal models play an important role during the development of an automotive system. Nevertheless, today's digital twin platforms do not support informal modeling [7,8]. In general, *informal models* are hand-drawn, e.g., Whiteboard, or digital, e.g., PowerPoint, box-and-line diagrams and sketches of models. In sum, although informal models are widely used in practice, they are rarely integrated into a digital twin architecture, such that sketches can be persisted and mapped to existing formal models.

For software development, we already know that informal models are widely used [5], as they ease the communication and documentation of software and can help in multiple software development phases [1,10]. Consequently, research on approaches to deal with informal diagrams and sketches often focus on development and developers or architects, e.g. [6,9,11,13]. Notably though, the use of informal models for the development of CPSs or the development with a digital twin is rarely studied.

Conversely, we focus on the CPSs developed by the automotive industry— automobiles—as they involve many disciplines ranging from engineering over electrical engineering to software engineering. In particular, we want to answer the following research question: *(RQ) How relevant are informal models for the design and use of digital twins in the automotive industry?* To answer this question, we conducted an expert survey among the participants and affiliates of the SofDCar project, surveying the specific purpose, frequency of use, specific kinds, and reuse of informal models in current development practice. We provided an online questionnaire and collected 45 responses.[5] In sum, we confirmed that informal models are mainly used for communication and documentation. However, most informal models are drawn in digital tools, like PowerPoint, rather than on an analog medium, like a whiteboard. Moreover, informal models are mostly employed during the conception phase. Furthermore, most employed informal models denote behavioral descriptions of the CPS, e.g., business process models, activity diagrams, state diagrams, rather than structural descriptions, e.g., database schemes or architecture models. In conclusion, digital twin architectures for the automotive industry should be able to incorporate informal models, as additional artifacts used for the conception, communication, and documentation of behavioral and structural aspects of the CPS under development.

The paper is structured as follows: In Section 2, we describe the conduction of the expert survey. After that, we present the results of the survey in Section 3 focusing on general trends and found correlations. In Section 4, we discuss our findings and threats to validity. In Section 5, we discuss related work, whereas Section 6 concludes the paper.

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[5] Please note that while the questionnaire was in German, for this paper we translated the results to English.
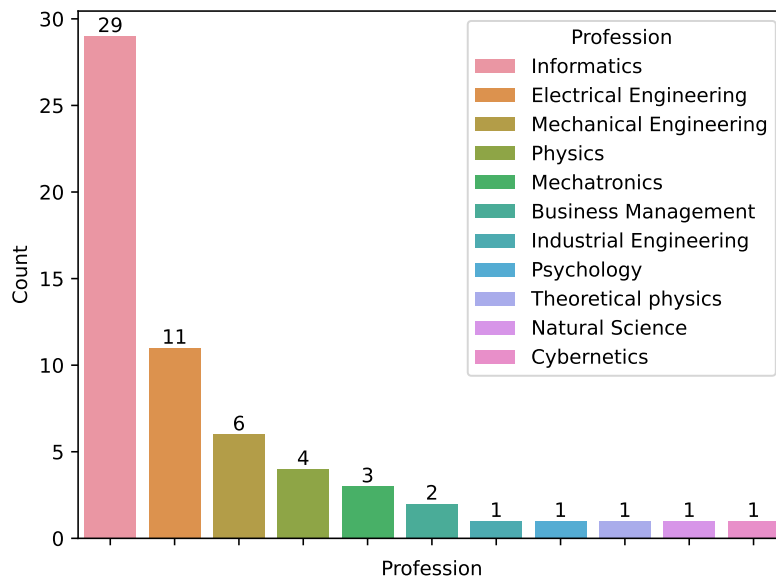
Fig. 1. Participants of the Survey

2   Approach

Our expert survey about the informal models was conducted in the context of *SofDCar*. We describe informal models as "hand-drawn (e.g., Whiteboard) or digital (e.g., PowerPoint) box-and-line diagrams and sketches of models". The survey has been sent to the members of the SofDCar project. Thus, we include experts from the automotive industry and academia that deal with digital twins. We also encouraged the participants to forward the survey to colleagues that are interested in the development of digital twins. The survey was conducted as an online survey using LimeSurvey. We provide the survey questions and answers of the participants in our replication package [4]. In the following, we describe the questions that are related to informal models.

Participants

First, the participants had to answer, what their professions are. The participants were able to select multiple professions. Thus, we get a better understanding of the different backgrounds of the participants and the different perspectives on informal models. Figure 1 shows the composition of the participants.

The majority of the participants have a background in informatics. The second-largest group consists of participants with a background in electrical

engineering. We also included participants with backgrounds in mechanical engineering, physics, and other fields.

Purposes of Informal Models

Our first question about informal models targets their purpose in the automotive industry: *Q1: How often do you use informal models for the following purposes?* From literature, we know that informal models are used by software developers for communication [5]. Nevertheless, we were interested in the purposes of informal models in the context of digital twins and automotive. We proposed four purposes and asked the participants to rate the frequency of each purpose: (1) Communication in meetings (e.g., development meetings), (2) Documentation, (3) Design of the digital twin, and (4) Requirement analysis of the digital twin.

We assumed that there will be the typical purposes of informal models like communication and documentation. Additionally, we provided options about the design and requirement analysis of the digital twin. In order to allow the participants to enter further purposes, we also provided a free text field. For the rating of the frequency, we used a five-point Likert scale: *very often*, *rather often*, *rather rarely*, *very rarely*, and *never*.

Informal Models in Phases of Development

We were also interested in the phases of development, in which informal models are used: *Q2: How often do you use informal models in the following phases of development?* Since our project deals with digital twins in the automotive domain, the questions focus on phases we know from our project members. We asked the participants to rate the frequency of informal models in the different phases of development. The options were the following: (1) Conception: Profile- and requirement analysis, (2) Development: Prototype development, design and analysis of the cyber-physical system, Testing of design decisions, (3) Production: Monitoring of production, tracking of production steps, (4) Use and Support: Gathering of information about the current and historic system state in use, predictive maintenance, and (5) Retirement: Transfer of knowledge to future system generations.

Analogous to the purposes of informal models, we used a free text field to allow the participants to enter further phases of development and used the same Likert scale. The conception phase refers to phase where the requirements of the system are analyzed. The development phase covers the development of prototypes, the design and analysis of the cyber-physical system and the testing of decisions. Afterward, the production phase covers the monitoring and tracking of the production steps of the CPS. The use and support phase deals with gathering information about concrete system states and also predictive maintenance. Finally, the retirement phase focuses on the transfer of knowledge to future system generations.

Persisting Informal Models

Our next question deals with the way of persisting informal models: *Q3: How do you persist informal models?* From previous meetings within the project, we gathered four options for persisting informal models. We asked the participants to rate the frequency of the different ways of persisting informal models. The options were the following: (1) Digitally created and persisted (e.g., Power-Point), (2) Photos are taken and persisted, (3) Manual transfer of models to a suitable tool (e.g., Enterprise Architect), and (4) They stay on the flipboard / whiteboard.

Analogous, we used the same Likert scale as before. The first option refers to the creation of informal models using a digital tool like PowerPoint. The second option deals with the case that photos of informal models are taken and persisted. With the third option, we refer to the case that informal models are manually transferred to suitable tools. Finally, the last option refers to the case that informal models stay on flipboards or whiteboards and are not persisted in another way.

Kinds of Informal Models

As we were also interested in the kinds of informal models, we asked the participants to select the kinds they use in their context: *Q4: What kinds of informal models do you use?* The options were the following: (1) CAD/3D models, (2) E/E architecture diagrams, (3) State charts, (4) Activity diagrams, (5) Database (scheme), (6) (Business) process model, and (7) Development (process) model.

The participants were able to select multiple options. Additionally, we used a free text field to allow the participants to enter further kinds of informal models. The options cover typical kinds of informal models like CAD/3D models, E/E architecture diagrams, state charts, activity diagrams, and database schemes. Additionally, we also included business process models and development process models.

Reuse of Informal Models

The final question was about the reuse of informal models. We asked the participants how they rate the following statements: (1) Informal artifacts were not reused, because they were not persisted, (2) The informal artifacts were not reused, but they were persisted, (3) The photos of informal artifacts were reused at a later point in time, (4) The photos of informal artifacts were saved but not used later, (5) The manual transfer of informal artifacts was time-consuming, (6) The manual transfer of informal models was useful for later work, and (7) The retained models were hard to access/find.

The participants should rate the statements on a four-point Likert scale: *agree completely*, *rather agree*, *rather disagree*, and *disagree completely*. Additionally, they had the option of *not specified*.
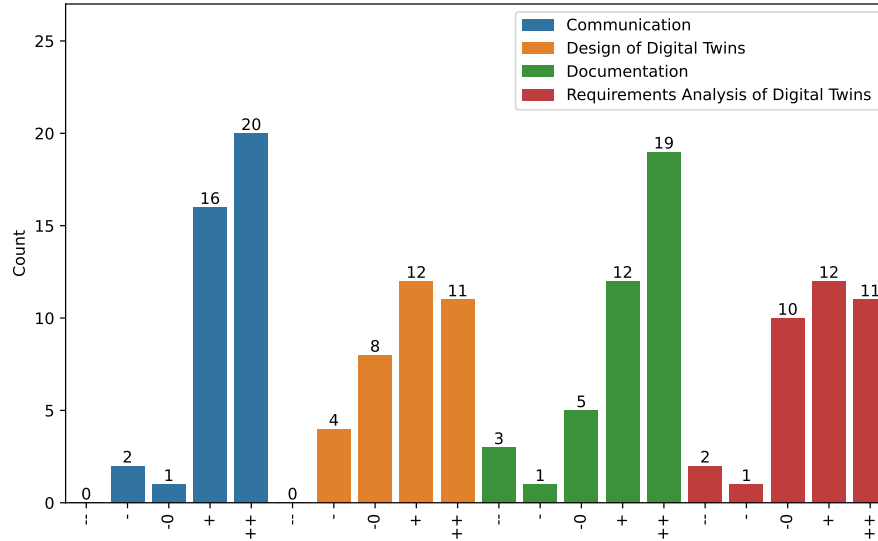
Fig. 2. Purposes of Informal Models

3 Results of the Survey

This section summarizes the results of the different questions of the survey from Section 2. We denote the five-point Likert scale as follows: *very often* (++), *rather often* (+), *rather rarely* (-0), *very rarely* (-), and *never* (--). The four-point Likert scale is denoted as follows: *agree completely* (++), *rather agree* (+), *rather disagree* (-), and *disagree completely* (--). The symbols in brackets were not part of the survey. They are used to make the results better readable.

Purposes of Informal Models

The first results are about the purposes of informal models. One important question was the purpose of informal models or models. We proposed a list of purposes and asked the participants to rate the frequency of each purpose.

Figure 2 shows that the most important purpose of informal models is the communication of ideas. No one stated that this purpose is never used, whereas the majority of the participants stated that this purpose is used very often. The second most important purpose is the documentation. Most participants stated that in this case, the informal models are used very often. Additionally, the purposes of design and requirement analysis of digital twins have no clear outcome. There are participants, who stated that these purposes occur very often or rather often (that was the majority), but there are also participants, who stated that these purposes occur rarely.
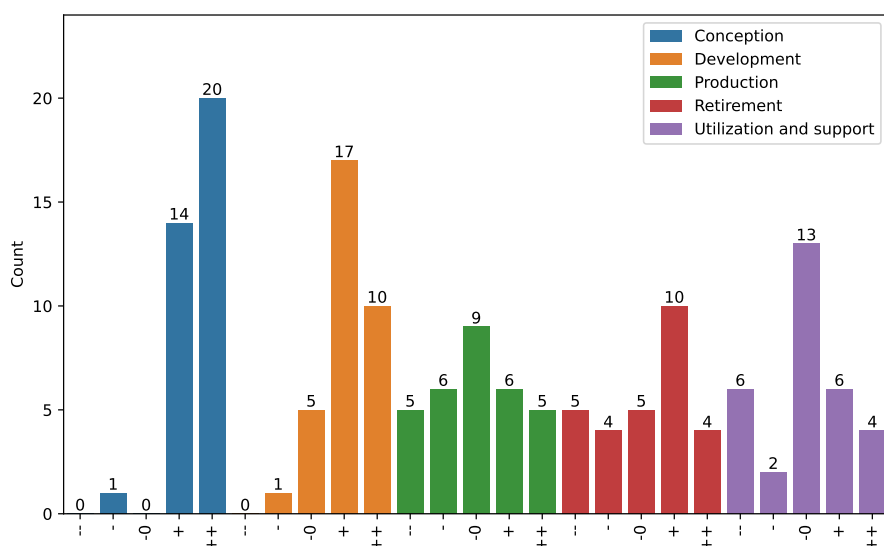
Fig. 3. Phases of Development

Three of the participants provided additional purposes, which are not part of the list. One participant stated that informal models are used for the design of methods for continuous improvement and for updates. Another participant stated that they use informal models are used as development (process) models or that they are used to evaluate the use cases. The third participant stated that informal models are used to develop software architectures.

In summary, we can say that informal models are mostly used for communication and documentation, but they are also used for the design and requirement analysis of digital twins.

Phases of Development

In the next question, we investigated the phases of development, in which informal models are typically used.

Figure 3 shows that informal models are used in all phases of development. Nevertheless, the survey shows that informal models are used more often for conception and development. In regard to both phases, no one stated that informal models are never used and the majority of the participants stated that informal models are used very often or rather often. Regarding the production, retirement, and utilization phase, no clear trends can be seen. There are participants, who stated that informal models are used very often or rather often, but there are also participants, who stated that informal models are used rarely, very rarely, or never for these phases.
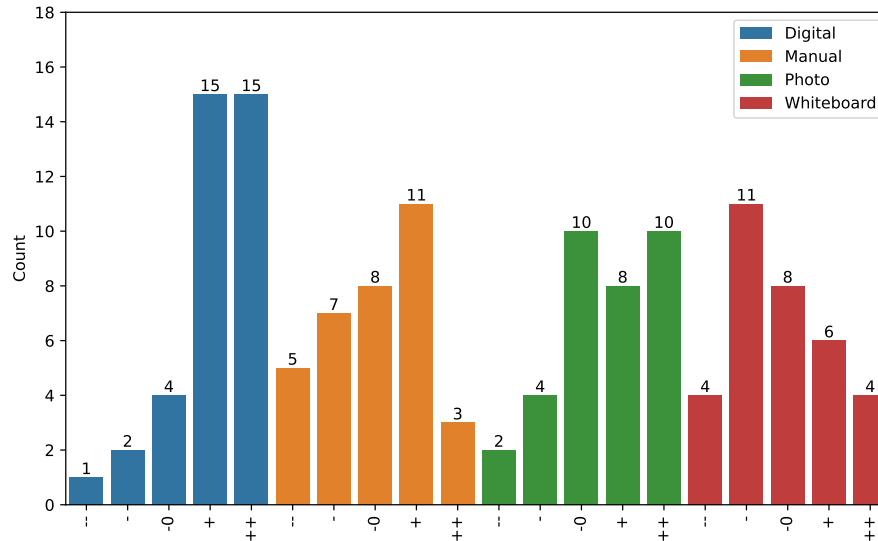
Fig. 4. Persisting Informal Models

Persisting Informal Models

The next question was about how the participants persist their informal models in practice. The results are shown in Figure 4.

Regarding the four options, the participants stated they mostly create informal models using digital tools like PowerPoint. The second most common way is to persist informal models by taking photos. Additionally, the option that the informal models simply stay on the whiteboard seems to be very rare. Lastly, the option that informal models are transferred manually is more common than keeping them on the whiteboard.

Kinds of Informal Models

The next question was about the kinds of informal models the participants use in their daily work. The results are shown in Figure 5. The additional kinds of informal models are directly taken into the figure.

The results show that the most common kinds of informal models are *business process models*, *activity diagrams*, and *state diagrams*. All other kinds of informal models are used more rarely. Still, 13 of 45 indicated that they also sketch architectural models. The component models and deployment models are options that were added by the participants.
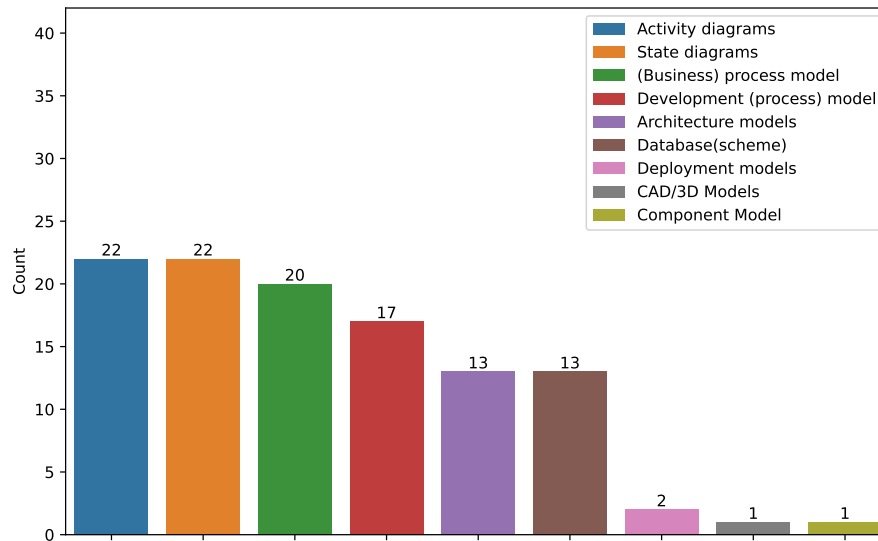
Fig. 5. Kinds of Informal Models

Reuse of Informal Models

The last question is about the reuse of informal models. The results are shown in Figure 6.

(1) The majority of the participants stated that they rather disagree with the statement that informal models were not reused because they are not persisted. Nevertheless, many participants also stated that they rather agree with this statement.

(2) The majority of the participants disagreed with the statement that informal models are not reused but somehow persisted, which is in line with the previous findings.

(3) The majority of the participants agreed with the statement that photos of informal models are reused at later points in time.

(4) Most participants disagree with the statement that photos of informal models are not reused. That is in line with the fourth statement.

(5) The fifth statement is about the time aspect of manual transfers of informal models. With this regard, most of the participants agreed that manual transfer is time-consuming. Especially, no one stated a complete disagreement.

(6) Similar to the previous statement, the participants rather agree with the statement that manual transfers were useful. That shows a potential opportunity for further research.

(7) In the last statement they rate the ease of finding retained informal models. There, most participants stated that the informal models are easy to find.
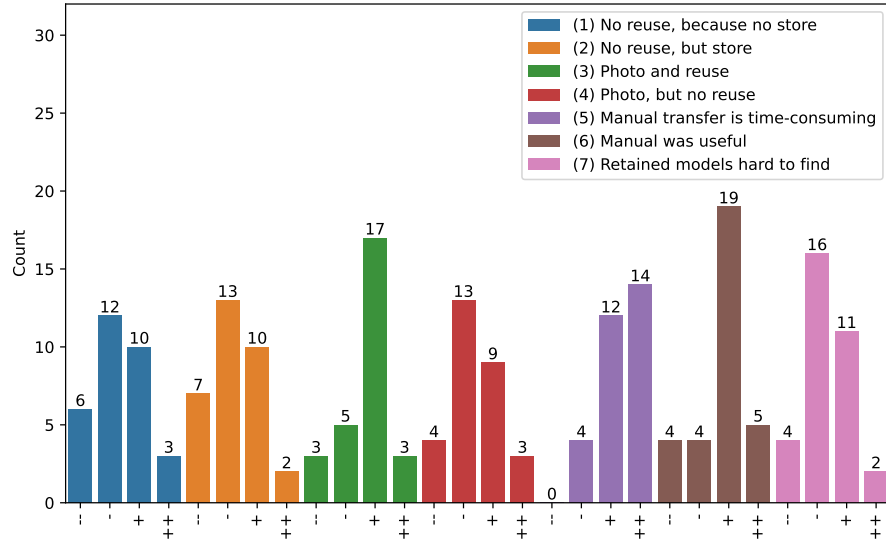
Fig. 6. Reuse of Informal Models

The final information that the participants provided is regarding further problems they see w.r.t. the reuse of informal models. Four participants provided such information. The first one stated that versioning is another problem. The second participant stated that informal models have the problem of bad analysis capability and ambiguity. The third one stated that the assumptions made to informal models are partly wrong. Finally, the last participant stated that in some cases they had to decide and learn the use of tools for transferring the model. They state that the informal model may be quickly created, but there may be a high hurdle to transfer if tools of this model type are rarely used.

4   Discussion

In the following, we discuss the findings of the survey. Furthermore, we discuss threats to validity.

4.1   Findings

The results of our survey show that informal models are widely used in different phases and purposes in the automotive domain. The survey indicates that informal models are mostly used for communication and documentation. This is in line with findings about software development processes [2]. In addition, that shows the need for the consideration of informal models in the development of architectures for digital twins. Furthermore, our study shows that informal

models are currently mostly used during the conception and development phase. Therefore, we see a change in integrating informal models into the architecture of digital twins to support the whole life cycle of the digital twin.

In contrast to past research, our study shows that informal models are mostly created and persisted using digital tools like PowerPoint. This is a clear difference from past research about software development in general, which showed that informal models are mostly created and persisted using pen and paper or whiteboards [1]. Regarding the kind of informal models, our survey shows that typically they denote the behavior of the CPS. Structural informal models are less common.

In summary, we see the opportunity to incorporate informal models as additional artifacts into the architecture of digital twins in the automotive industry.

4.2 Threats to Validity

The survey was an online survey that targeted participants that work in the automotive domain. In order to reach as many participants as possible, we used the internal mailing lists of the project and also stated that the survey can be forwarded to other colleagues. Therefore, we cannot be sure who the participants actually are. In order to mitigate this threat to internal validity, we asked the participants to state their profession. Another threat to internal validity is that the participants may have different understandings of the term *informal models*. We tried to mitigate that by defining informal models in the survey.

Regarding external validity, we have to consider that the participants may not be representative for the whole automotive domain. Nevertheless, since our project is a project with many companies from academia and industry, we argue that the participants give a first impression of the use of informal models in the automotive domain in Germany.

5 Related Work

In this section, we cover related work on informal models. Current literature mainly focuses on the use of informal models, sketches, and diagrams in the context of software development.

Cherubini et al. [2] conducted semi-structured interviews and a survey about the use of diagrams w.r.t. software developers. They found out that diagrams are mostly used for communication. Additionally, they state that diagrams are often transient i.e., they are used for a certain task and they are discarded afterwards. This is also reflected in our survey, where we asked the participants about the way of persisting informal models.

Walny et al. [12] analyzes lifecycles of diagrams and sketches in software development. They are particularly interested in the use of sketches and diagrams practices of computer scientists. Therefore, they conducted multiple interviews with researchers. In their paper, they came up with multiple diagram lifecycles. For example, they defined a lifecycle where a group of people do brainstorming,

draw a diagram, take a photo of the diagram, and finally upload the photo to a common wiki. This is reflected in our survey since we asked the participants about the way of persisting informal models.

Baltes et al. [1] conducted an exploratory study with three companies and an online survey. They aimed to find out what is the role of sketches and diagrams in software engineering. They found out that informal diagrams are valuable resources and document several aspects of the software development process. The aspect of documentation is also reflected in our survey, where we asked the participants about the use of informal models for documentation.

Störrle [10] conducted an online survey to find out whether and how conceptual modeling languages are used in software engineering practice. He observed that conceptual modeling languages like UML are used in practice, but often as informal models ($70 - 79\%$).

In contrast to the presented related work, we are focusing on the use of informal models in the context of digital twins and the automotive industry.

6   Conclusion and Future Work

In this paper we presented the results of a survey about the use of informal models in the automotive industry. We focused on the research question: *(RQ) How relevant are informal models for the design and use of digital twins in the automotive industry?* Our survey shows that informal models are mostly used for communication and documentation. They are particularly used during the conception phase, are mostly drawn in digital tools like PowerPoint, and describe the behavior of the CPS. Therefore, we see a need for the consideration of informal models in the development of architectures for digital twins. We see the opportunity to incorporate informal models as artifacts into the architecture of digital twins in the automotive industry. In summary, we can answer our research question as informal models are relevant in several phases for the design and use of digital twins in the automotive industry. Therefore, we see the need to include informal models as artifacts in the architecture of digital twins in the automotive industry. Further research should investigate how informal models can be integrated into digital twins and how they affect their architecture.

In the future, we want to investigate more about the models that are used in digital twins in the automotive industry. Additionally, we propose further research on the integration of informal models into the architecture of digital twins. Especially, we propose to investigate more companies and countries to get a better understanding of the use of informal models in the automotive industry at a global scale.

Acknowledgments

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