Effect-oriented Requirements Elicitation and Specification

Torsten Ronneberger¹, Ozguer Uenalani², Michael Eisenbarth², Anne Gross²

¹Audi Electronics Venture GmbH
Gaimersheim, Germany
torsten.ronneberger@audi.de

²Fraunhofer IESE
Kaiserslautern, Germany
{anne.gross,michael.eisenbarth,ozguer.uenalan}@iese.fraunhofer.de

Abstract—To support the early evaluation of the effects of a novel system on its environment, it is important to understand and analyze current deficits and problems within the application domain and to derive hypotheses on the potential impact of the system. An emerging application domain of such cause-effect oriented requirements engineering methods is the automotive domain. New upcoming functionalities in automobiles and traffic systems do not only require accurate development and consideration of safety-related aspects, but are also more and more constrained to proving their positive effect on existing traffic systems, ecological and sociological aspects, as well as, e.g., future reduction of the number of traffic deaths. Based on a systematic elicitation and refinement of system requirements, explicit measures can be derived to evaluate the achievement and coverage of envisioned system goals and to identify further optimization goals. In this paper, we will introduce a requirements engineering method and specification guideline that supports the deductive derivation and specification of measures from a causal chain of goals, deficits, hypotheses and solutions for evaluating a system’s effect on its application environment. We already applied this approach in a research project in the automotive domain and will exemplarily describe the realization of a concrete vehicle function that interacts with the environment. At the end, we will provide a general conclusion regarding our first experiences with the described method and with the specification guideline.

Requirements Engineering, Effect-oriented Requirements Engineering, Requirements Specification, Automotive Domain, Cause-Effect Chains

I. MOTIVATION

A major proportion of current innovations in the context of automotive systems is implemented and realized in vehicle functions (VF). The development of these functions is motivated by the construction of safer, more efficient, and more comfortable vehicle systems. Driven by this motivation, a lot of research is going on to identify solutions with the potential to address and fulfill these expected effects.

Some of these solutions are based on novel technologies that are integrated into a vehicle by extending its basic functionalities. To increase the safety of a vehicle, for example, communication technology can be used and integrated to realize car-to-car communication, which ultimately enables the vehicles to exchange up-to-date information on traffic flow, traffic blocks, and road states [1].

Besides the integration of novel technologies, the improvement of existing VFs themselves, and/or the combination with other existing VFs, provides the possibility to achieve the effect of safer, more efficient, and more comfortable vehicle systems, which again increases the satisfaction of customers or road traffic associations as another positive effect [2].

Therefore, the aforementioned effects on both the customers and the environment are of tremendous relevance for the development of innovative VFs. For example, the intended effect of the Adaptive Cruise Control (short: ACC, see Figure 1) function is to increase safety by reducing rear end collisions. Via radar sensors, other vehicles are detected that are driving in front of your vehicle (ego-vehicle) in the same lane. If the ego-vehicle is faster than another vehicle, the ACC function decelerates the ego-vehicle automatically with the help of adjusted minimum distance [3]. However, imprecise detections implemented in the ACC can lead to misinterpretations and false activations of the ACC, resulting in unexpected hard braking of the ego-vehicle. This effect could scare the driver and the traffic behind him in such a way that the result could be additional collisions [4].

Figure 1. Adaptive Cruise Control (ACC)

As already mentioned, in automotive engineering the development of VFs is typically driven by the idea of achieving an intended effect (such as to increase safety in case of the ACC function). Based on this functional goal, function characteristics are derived that are specified in the form of functional and nonfunctional requirements. Such a requirements specification then initiates and provides the baseline for subsequent development processes. However, if the initial idea, i.e., the intended effect, is not explicitly included in the requirements specification, the development process does not include the effect verification either.

This may result in the implementation of functions that fulfill the specified requirements but fail to achieve the
intended effects, as for instance, the false activations of the ACC mentioned previously fail to achieve increased safety. In the worst case, this failure is detected during final evaluations of the functions, such as field tests or customer studies, which ultimately results in increased costs due to cost-intensive change processes and/or more time required for development.

Requirements engineering can solve this dilemma by explicitly eliciting and specifying the intended effects during requirements engineering activities.

This paper introduces a deductive method based on a meta-model that allows systematically eliciting and specifying intended function effects during requirements engineering. The artifacts resulting from the application of this method provide a verification baseline during functional development to support the evaluation of the function against its intended effect. After a short discussion of related work in Section II and some background information provided in Section III, Section IV introduces the process underlying our method. In Section V, this process is illustrated on a concrete car-to-x function implemented in the scope of the simTD project. Finally, the paper concludes with a summary and an outlook on intended future work in Section VI.

II. RELATED WORK

Embedding functions in a vehicle aims at making the product more innovative. Here, the innovation process is the most important thing. [5] sketches such an innovation process.

In most cases, an innovative idea is generated when current vehicle systems are analyzed in terms of problems caused by various influence factors such as market evolution / market trends, technological progress, or legal requirements (cf. [14]). These problems (e.g., slow traffic flows, increased number of accidents) mainly occur in certain situations or contexts (e.g., crossroads). We consider this combination of problems and situations / contexts respectively, as areas where innovative VF development mainly takes place (effect area). An effect area is thus a self-contained area where actions are taken in the sense of adding/modifying VFs in order to solve the problems in a particular situation / context.

The innovation process illustrated in Figure 2 very clearly illustrates the incremental flow from the problem to a new product or method. It is shown that, in addition to the customer requirements, the problem and the solution idea are the basis of the requirements specification. What the process model does not illustrate is the goal definition phase, which enables proceeding in a goal-oriented manner. Hence, the innovation goals and the innovation strategy – in alignment with the business strategy – must first be known, defined, and communicated before the search for suitable solutions can begin. The innovation goals are one level of abstraction above the concrete problem and are thus affected directly by the influence factors (cf. W-Modell [15]). Furthermore, the process model also does not take into account that the effect of a solution idea on the respective problem and/or the goals must be checked.

Figure 2. Innovation Process

Following the development of the product or method, which ends with the validation of the realization regarding the requirements from the requirements specification, the implemented solution idea must thus be evaluated in terms of its effect on the problem. In other words, there must be a feedback loop in the innovation process back to the influence factors in order to be able to evaluate a problem solution or its effect on the problem. Ultimately, the evaluation result must be validated with the target requirements (to-be situation) in order to be able to make a statement regarding the success of an innovation for one particular VF.

A. Cause-Effect Relationship

In all of this, the term “effect” plays a crucial role. It is part of the causality describing the relationship between cause and effect and is of essential importance for the understanding of technical systems [6]. The reason for this lies in the deterministic behavior exhibited by technical systems. A change in the state of a system, for instance, is the effect of a cause [7]. The effect describes the goal that is achieved with the developed system. It relates to the system itself, since the state changes and the environment notices this change of state. This results in effects on various system abstractions, which can be determined objectively in the form of measurements or subjectively on the basis of emotions [8].

Since an effect presumes one or several causes, it is important for technical systems to validate this relation. To do so, it is necessary to capture and evaluate variations that cause a system reaction, respectively a change in state. In the case of complex systems in real environments, such as in VFs, this is only possible by means of empirical studies, due to the great variation in causes and effects.
B. Evaluation

According to [9], the effectiveness of an action or intervention – such as the introduction of a new VF – can be checked with the instruments of evaluation research. This means employing empirical research methods to evaluate these actions. The use of empiricism counters the complexity of the evaluation caused by the variation of causes and effects. With the help of empirically captured data, inductive conclusions can be drawn regarding the effect of actions that can be generalized [10]. In order to obtain generally valid results from empirical studies, the analytical science theory draws, among others, on the deductive-nomological model by Hempel-Oppenheim [11], which handles the interaction of cause and effect in a formal way [12]. A VF developed in such a way, which is based on a theoretical solution idea and has been developed deductively, can then be evaluated with the help of empirical studies regarding its goals and the problem solution (see Figure 3).

C. Task- and Goal-oriented Requirements Engineering

As mentioned in the previous section, the project goals and the problem space are part of the key starting points of a successful and systematic innovation process. Thus, a goal-oriented requirements engineering approach will be an essential building block of our proposed solution.

In our case, we used the TORE Approach [16] as a baseline for the development of our elicitation and specification method which is presented in more detail in Section IV. TORE is a decision framework that encapsulates 18 decisions on four different levels of abstraction that typically need to be made during requirements engineering for interactive (information) systems (see Figure 4). The benefit of thinking in these decisions is that this can serve as a conceptual model independent of the processes and notations actually used, allowing it to be applied in many different contexts. For more details on TORE see [16].
information (see Figure 5). Therefore, it is necessary to specify what the cause/trigger for the output information of a VF is. This cause/trigger occurs right before the execution of a VF, which also represents a cause-effect relationship. Thus, not only is a cause-effect relationship analyzed, but a causal chain can be identified, too (see Figure 6). This is more complex and harder to evaluate but also offers a bigger cause-effect range, which includes the source cause of the causal chain.

In the example of the VF for autonomous braking, other detected vehicles in the environment are entities of the context. If for example an autonomous braking occurs caused by the detection of a vehicle on the opposite lane, the intended effect of the VF is not reached, because the VF does not work correctly. Thus, the driver of the vehicle will not be satisfied and devaluate the VF of autonomous breaking because it does not reach the intended effect.

The effect is consequently a sequence of detected causes that is composed of the context entities of the VF and the output of the VF. Since the number of context entities and their states can be arbitrary, a deductive evaluation of all these possibilities is not possible.

Research in evaluation methods shows that this problem can be solved by using summative evaluation studies for a VF regarding its effectiveness [9].

Testing the correct processing of the input data of a VF to the resulting output data is usually done using established development methods in the validation phase.

Equally important is the validation of the effect of a VF for the customer/driver within its context and how this can be evaluated. Therefore, the effect of a VF has to be integrated and specified in the development process.

B. Meta-model for effect-oriented specification

The established development phase (see Figure 7) for VF includes a specification and implementation phase, which then results in an implemented VF. Here, the main characteristics and requirements of the system are described. [13] groups these specification artifacts into product requirements and component requirements. However, the requirements concerning the market requirements with goals and needs are often not considered during the development process of VF. Furthermore, general solution ideas are also not specified but mainly exist in the minds of the system engineers. Solution ideas are abstract descriptions of a VF in the context of their application (see Table V in Section V as an example).

Based on the market requirements, the overall goals, and the general deficits of the as-is situation, general solution ideas can be derived (see Figure 8). Goals are specified as measurable results, which can be described with values that need to be reached in comparison to the as-is situation (see Table XI in Section V as an example). The description of the as-is situation consists of the specification of the current effect context. The to-be situation describes the desired state after the VF is implemented in the specified effect context. The deficits of the as-is situation are described and thus the to-be state is reached. The bridge between the market and the system requirements, respectively between the context analysis and the development phase, is represented by the association between the deficits and the solution idea. The hypothetical effect that the solution idea has on the deficits is made explicit by specifying an effect hypothesis. This has to be verified after the VF has been implemented to prove that the initial solution idea really had the desired effect on the deficits of the as-is situation.

By extending the requirements specification with market-driven requirements, a basis for validation is created for the test phase. This can be used to test whether the specified VF meets the functional specification. Additionally, it can be evaluated whether the desired effect of the VF in the real environment has been attained. In order to perform an evaluation, validation goals have to be defined. From these validation goals, parameters can be identified that can be quantified with values in the evaluation phase. A parameter may be a measurable physical parameter or a subjective impression of a test driver. Therefore, the design of the tests and trials has to consider these parameters. During the tests and trial phase, results are produced that can be used to draw valid conclusions regarding the validation goals.
Whether the produced results are significant regarding the validation goals can be evaluated by using significance tests (see Figure 9). A complete view on the meta-model can be found at the end of this paper (Figure 11).

Figure 9. Evaluation phase

IV. METHOD

Figure 10 illustrates an Event-driven process chain (EPC) diagram [17] of the process that underlies our method. We used this process diagram to visualize the flow of activities, the relationships between particular activities by means of input / output relations, as well as the assignment of the activities to one of three phases: (1) the context and solution analysis phase which initiates the process, (2) the development phase, and (3) the evaluation phase. In the following sections, we provide detailed descriptions of each of these phases. In order to see concrete examples of results related to each of the phases, please refer to section V, which describes a case study where we applied the method described in the following. Further descriptions of the artifacts that are derived during the process including their relationships can be found in the description of the meta-model introduced in the previous Section III.B.

A. Context and Solution Analysis

One of the main goals of the context and solution analysis phase is to derive solution ideas as well as effect hypotheses that formalize the expected effect of the solution ideas on an identified effect area.

In order to systematically derive solution ideas and effect hypotheses, our method suggests starting with an analysis of the context of the identified effect area (activity analyze the context) which represents the trigger for applying our method. This context can be restricted and defined by the goals associated with the effect area, such as project goals. The output of this context analysis activity consists of a description of the current situation, i.e., the as-is situation in which the identified effect area is located.

In a second step, deficits need to be identified (activity identify deficits) that currently exist in the as-is situation and that hinder / negatively influence the achievement of the intended goals associated with the effect area. The output of this activity is twofold: (1) a list of deficits, and (2) a description of the to-be situation outlining a future situation within the context of the effect area, where the deficits of the as-is situations are solved. So basically, one can consider the deficits to describe the delta between the as-is and to-be situation. Finally, in order to address these deficits and to reach the intended to-be situation, suitable solution ideas have to be identified that are capable of handling these deficits by means of appropriate vehicle functionality that needs to be implemented (activity derive solution idea). Besides a list of solution ideas that will be dealt with in the development phase regarding further specification and implementation (see Section IV.B), effect hypotheses are to be identified and specified that formalize the expected effect of the derived solution idea on the context of the intended effect area and that will be tested during the evaluation phase (see Section IV.C).

B. Development Phase

The development starts with identifying solution ideas within the scope of the previous context and solution analysis phase. The goal of this phase is to specify the solution ideas by means of concrete system function specifications (activity specify system functions), which will then serve as input for the implementation of the system function (activity realize system functions). The implemented system functions will finally be handled during the evaluation phase (see section IV.C), where they will be tested in terms of the fulfillment of the intended effects as well as in terms of the defined validation goals.

Figure 10. EPC process diagram
C. Evaluation Phase

The evaluation phase aims at preparing and executing the evaluation of the implemented functions regarding their fulfillment of the intended effect. Similar to the development phase, this phase is triggered by the outcomes of the context and solution analysis phase - in particular the to-be situation and the effect hypotheses – and may be conducted in parallel to the development phase. One of the first activities that are to be performed within the evaluation phase is to derive validation goals based on the to-be situation that reflect particular improvements of the to-be situation compared to the as-is situation of the effect area.

In a second step, characteristic parameters and measurements have to be derived from the validation goals that represent measurable data that can be used to test whether the validation goals are fulfilled or not (activity derive parameters). This will later be done by means of suitable test trials, which need to be prepared accordingly (activity prepare trial). As soon as the preparation is finished and the implementation of the system functions has been completed (see development phase in Section IV.B), the trials need to be run (activity run trials). Finally, the test results delivered by the trials can be used to check whether the validation goals have been fulfilled. Moreover, significance tests on the test results analyze whether the effect hypotheses derived during the context and solution analysis phase can be approved or have to be rejected (activity test hypotheses). In the latter case, one might consider thinking about new solution ideas. If the effect hypotheses can be accepted, it has been proven that the implemented solution positively affects the deficits related to the as-is situation of the effect area.

V. CASE STUDY

The project in which our case study was performed is called simTD [18]. The project’s goal is to integrate existing and new car2x-functionalities into a large, integrated system and evaluate the effect of this system on project goals such as increasing road safety and contributing to more efficient traffic flow.

Car2X-functionalities are basically vehicle functions that communicate with other cars, traffic infrastructure (e.g., traffic lights), and other external communication partners. For this purpose, realistic traffic scenarios are addressed in a large-scale test field infrastructure around the city of Frankfurt, Germany. Currently, both the specification of the context and solution analysis and the preparation of the test and trials are already completed. The implementation, integration and execution of the tests and trials will be done during the next year.

The cause-effect-oriented approach was performed by 15 development teams in the project whose task is to engineer and develop VFs that have a positive effect on the high-level goals of the project. To present our approach we will describe the concrete application of our method with one of the simTD VFs. We will depict each step using the example of the “Traffic light phase assistance” function (TLPA), which informs the driver what the optimal speed (within traffic rules) is for passing the next traffic lights during a green-phase and warns the driver about possible red-light violations. The requirement artifacts were specified in structured tables representing the structure of the meta-model of our approach described in the previous section IV. By deriving and linking the requirements artifacts to one another, we assured that each of the requirements artifacts can be traced back to its original project goal and serve as guidance for the deductive derivation of each artifact.

A. Context and Solution Analysis Phase for TLPA

It is important to know that there exist key project goals such as increasing road safety. Each development team had to state high-level goals they want to address with their function. Table I shows the goals related to the TLPA.

<table>
<thead>
<tr>
<th>ID</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>Increase traffic efficiency</td>
</tr>
<tr>
<td>G2</td>
<td>Increase road safety</td>
</tr>
</tbody>
</table>

To keep the example intelligible, we will focus on G2 and perform subsequent steps based on this goal. Since the goal (G2) “Increase road safety” is at a very high level, it is important for each development team to translate this goal into the context of their function. For the TLPA, this would mean that increasing road safety only in the context of street lights is relevant and should be addressed.

<table>
<thead>
<tr>
<th>ID</th>
<th>As-Is Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS-IS1</td>
<td>The drivers of vehicles should follow the rules of the traffic light and its current state (green, yellow, red).</td>
</tr>
</tbody>
</table>

The current state in the context for the function TLPA is that there is no support for the driver to judge how long a traffic light will stay in its current state and what the optimal (allowed) speed is to pass the traffic light while it shows green (see Table II). This leads to the identification of deficits (see Table III).

<table>
<thead>
<tr>
<th>ID</th>
<th>Deficit</th>
<th>Affected Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Drivers may overlook light signals. The driver may overlook a red light or might not catch the green phase in time and drive through the light when it has already changed to red. Overlooking a red traffic light can lead to dangerous traffic situations and cause accidents. Therefore, the goal of increasing road safety is compromised.</td>
<td>G2</td>
</tr>
</tbody>
</table>
By specifying the deficit and the affected goal, it could be assured that the requirements were specified in a deductive way. In order to address this deficit, a desired to-be situation needed to be specified (see Table IV).

**TABLE IV. TO-BE SITUATION**

<table>
<thead>
<tr>
<th>ID</th>
<th>To-Be Situation</th>
<th>Addressed Deficit</th>
<th>Related AS-IS Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB1</td>
<td>The driver should not overlook a red traffic light anymore and thus we assume that the goal of road safety is addressed.</td>
<td>D1</td>
<td>AS-IS1</td>
</tr>
</tbody>
</table>

The to-be situation is a desired state that needs to be reached when the system is implemented. From this we could derive validation goals, whose attainment can be proven in the evaluation phase (see Section V.C).

In order to realize the desired to-be situation, a solution idea needed to be derived to assure that the driver does not overlook a red traffic light. The solution idea derived in our case is shown in Table V.

**TABLE V. SOLUTION IDEA**

<table>
<thead>
<tr>
<th>ID</th>
<th>Solution Idea</th>
<th>Addressed Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI1</td>
<td>Warning the driver in the event of a possible failure to heed a light signal. The driver is warned if the red display of the traffic light is not adhered to or heeded.</td>
<td>D1</td>
</tr>
</tbody>
</table>

The solution idea is a generic, high-level idea on how to address the deficit. We assume that our solution idea will have an effect on the deficit we want to address. This we call an effect hypothesis. Table VI shows the effect hypothesis related to the TLPA.

**TABLE VI. EFFECT HYPOTHESIS**

<table>
<thead>
<tr>
<th>ID</th>
<th>Effect Hypothesis</th>
<th>Addressed Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH1</td>
<td>If the function provides a correct display in time, this will impact the corresponding deficiency.</td>
<td>D1</td>
</tr>
</tbody>
</table>

Once the solution ideas are implemented, trials and tests need to be performed. The result of the trials must be empirically evaluated in order to prove the effect hypothesis.

**B. Development Phase for TLPA**

After the context and solution analysis phase, the concrete implementation for a solution idea had to be specified as a system function. Each of the system functions (see Table VII) could be traced back to the original goal of increasing road safety. The traces assure completeness in the deductive derivation of the system functions and related requirement artifacts.

**TABLE VII. SYSTEM FUNCTION SPECIFICATION**

<table>
<thead>
<tr>
<th>ID</th>
<th>System function</th>
<th>Addressed Solution Idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF1</td>
<td>Warn the driver of an imminent red light violation.</td>
<td>SI1</td>
</tr>
<tr>
<td>SF2</td>
<td>Inform the driver about the duration about the current green state of the traffic light.</td>
<td>SI1</td>
</tr>
</tbody>
</table>

**C. Evaluation Phase for TLPA**

So far, the building blocks were just logically derived but in order to prove the correctness of the cause-effect chain, metrics need to be defined to measure the goals, effect hypothesis, deficits, and system functions.

In our example, the goal was to increase road safety, which can be reached by the to-be situation that the driver does not overlook a red traffic light. One means to validate the attainment of the to-be situation in the evaluation phase is to state validation goals for the to-be situation as shown in Table VIII.

**TABLE VIII. VALIDATION GOALS**

<table>
<thead>
<tr>
<th>ID</th>
<th>Validation Goal</th>
<th>To-Be Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>VG1</td>
<td>Change the number of occurrences of dangerous traffic situations.</td>
<td>TB1</td>
</tr>
</tbody>
</table>

In order to measure the validation goal, characteristics were needed (see Table IX). The number of occurrences of dangerous traffic situations can be measured by different characteristic numbers, which are stated in the following table (“#” stands for number of “):

**TABLE IX. CHARACTERISTICS & MEASURES**

<table>
<thead>
<tr>
<th>ID</th>
<th>Characteristics</th>
<th>Validation Goal</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch1</td>
<td>#collisions</td>
<td>VG1</td>
<td>Directly</td>
</tr>
<tr>
<td>Ch2</td>
<td>“almost”-collisions</td>
<td>VG1</td>
<td>Distance to vehicle in front of the car</td>
</tr>
<tr>
<td>Ch3</td>
<td>#red-light violations</td>
<td>VG1</td>
<td>Measured by SF1</td>
</tr>
</tbody>
</table>

These characteristics can be used to measure the attainment of the validation goal (VG1) and need to be measured using measurable parameters.
The explicit derivation and specification of characteristics that can be used to reach a validation goal is one of the most important steps of this method. If these measures are not considered before the system is implemented, there might be no way to measure the characteristics of a validation goal at all. In our example, by specifying that we need to measure the number of red light violations by SF1, this measure can be implemented by the developers and thus evidence can be generated that the system reaches the desired to-be situation and thereby achieves the high-level goal of increasing road safety.

Once a function such as TLPA has been implemented, testing needs to be done in order to determine not only whether it fulfills the functional specification but also whether the validation goals have been reached. Therefore, trials were specified (see Table X for an example) that need to be performed to test and evaluate the function.

Once the trials are executed, results are produced. These results can fulfill a validation goal. Assuming that the trial TR1 is performed as many times as necessary to get a significant result then an example result (see Table XI) could be:

Finally, the results will be analyzed to check their significance. If they are significant, we have evidence that an implemented solution idea has a real effect on a previously specified deficit. Thus, we can prove our effect hypothesis EH1. The advantage we achieved compared to established software development methods is that we can not only prove a system function was implemented correctly in software development methods is that we can not only prove that a system function was implemented correctly in accordance with its specification, but we can also prove that the implemented functionality really has the intended effect to reach the intended goal.

VI. DISCUSSION AND CONCLUSION

Nowadays, new functional and technical innovations are emerging every day. Functional support from assistive systems for daily routine tasks, in particular, is increasingly being realized by means of combined technical hardware and software solutions. Although these novel functionalities provide and process an increasing number of available input and output parameters, they are often developed due to technical opportunities and do not fully address the actual goals and requirements. This can lead to irritated users or inefficient task processing and thus, to denial and rejection of new promising solutions. Traditional conventional development processes often do not explicitly address and contain the specification and analysis of cause-effect chains and the systematic derivation of the effect goals these functions have to meet. Currently, such an analysis phase is implicitly executed before the typical development processes are started that finally end with acceptance tests. This leads to the situation that the effect of a novel functionality continues to linger in the minds of the relevant stakeholders and system developers without having been explicitly specified. Hence, in the trial phase of the solution, no validation is possible with respect to an evaluation base.

Our method addresses this issue at an early stage of a project by deriving an evaluation base through the systematic specification of the envisioned effects the system should create. As a consequence, the trial phase is supported by a methodical approach designing the evaluation phase. Another positive aspect is that the trial design can run in parallel to the functional development, thus reducing the overall project schedule and supporting the iterative synchronization of the development and evaluation preparation tasks. Finally, by deriving the specification artifacts via deduction, the developer can compare the completeness and consistency of the specification during the systematic consideration of the individual specification guideline and model elements. Since the evaluation phase of the simTD project is not completed yet, one of our next steps will be to analyze the actual results of the test and trial activities in order to verify our approach. Furthermore, we want to investigate in future work how the effects of several VF’s that are integrated into a vehicle system influence one another and whether these various effects can be already considered during the requirements engineering phase.

ACKNOWLEDGMENT

This work was achieved in the project simTD funded by the German Federal Ministry of Economics and Technology (BMWi), the German Federal Ministry of Education and Research (BMBF) as well as the German Federal Ministry of Transport, Building and Urban Development (BMVBS).

REFERENCES


[18] Project sim™ „Sichere Intelligente Mobilität Testfeld Deutschland“, Projectwebsite available under www.simtd.de

---

Figure 11. Complete meta-model illustrating its main components and their relationships