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EXPERIENCE SCENARIOS TO STIMULATE CREATIVITY - GENERATING SOLUTIONS IN THE SYSTEM OF SYSTEMS OF SEAMLESS MOBILITY

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Abstract: To develop innovative and utilitarian systems for the world of tomorrow, creative ideas are crucial. In context of system engineering, the developed products are no longer considered to be individual, independent solutions, but rather a System of Systems (SoS). With the advancing digitization and the Internet of Things the networking will continue to grow. At the same time, ethical and philosophical questions will become critical for intelligent products and systems. The networking of the products, as well as the multitude of disciplines involved, create new requirements for methods that stimulate creativity to develop innovative SoS for the future. A particularly suitable method for deriving innovative solutions for the future is the scenario technique. Here, scenarios of the exemplary System of Systems "Mobility" are presented. These will be used to show improvement potentials of classical scenario communication forms in the context of SoS with the aim of addressing further research work.

Keywords: *Scenario technique, System of Systems (SoS), Creative design processes and methods, Creativity for complex problems, Design creativity support tools*

1. Introduction and Motivation

Mobility is a highly volatile field, which evolved rapidly in the last decades; new solutions arise continuously. Individual technologies, which enable the autonomous driving, will be ready soon. This will fundamentally change society and result in unimagined difficulties: Apps are updated every hour, vehicles are developed in 7 years and laws and infrastructures exist for decades (Albers et al., 2016). Nonetheless, apps, vehicles and infrastructures should form a system that works together seamlessly in order to satisfy customers. Here, all sub-system form the **System of Systems (SoS) of Seamless Mobility** together. Seamless Mobility is understood as a mobility that is easily accessible, intermodal, interconnected, safe, secure, effective and efficient in order to be affordable, valuecreating, environmentally friendly, resilient and acceptable in a mixed mobility system of automated and conventional means of transport. Seamless Mobility requires a holistic approach covering the full spectrum of options from pedestrians to commercial goods transportation including all relevant disciplines (Albers et al., 2017).

The future developments of this exemplary SoS are totally disruptive, highly cross-linked and very far in the future. Moreover, interdisciplinary fields such as society, infrastructure, acceptancy, ethic, traffic management and driving automatization are affected: It is for example unknown what happens when driving with an automated vehicle across a border where prevails a completely different infrastructure. Or what if, for example, a hacker is impersonating an ambulance to be able to drive faster with the aim to generate new business models. (Grunwald 2015)

To be able to counteract **with innovative and creative solutions**, an interdisciplinary SoS research team is needed. Due to the complexity, the reliable development of these solutions as elements in a multidisciplinary SoS must be supported by adequate methods. With common approaches, such as trend and forecast research, short term changes can be explored, but not to this extent. By contrast, the scenario technique is very suitable for long term future-oriented and cross-linked thinking. The suitability of this method for the generation of innovative and creative products and business model has already been demonstrated in numerous scenario projects. The **SoS Seamless Mobility** differ, however, as outlined above due to its disruptive nature, the significantly higher linkage and the greater time horizon. At the same time, many different disciplines are involved in the development of the **SoS Seamless Mobilty**.

This makes a cross-disciplinary methodology research including approaches, methods, and processes necessary: The aim is to **enable the classic scenario communication forms for Systems of Systems** to strengthen the interdisciplinary understanding and to stimulate the creativity of the involved disciplines holistically (Albrechts, 2005). For this purpose, two different scenario communication forms are used. These will be placed in a mutual context in the findings of this publication. Thus, correlations between the system complexity, the modelling effort of the communication forms and the creativity of the participants are derived.

2. State of Research

The following takes a closer look at creativity and scenarios.

2.1 Creativity

There are many definitions of creativity in literature. For example, EHRLENSPIEL describes Creativity as a person's ability to produce ideas, concepts, combinations, and products that are new in essential characteristics and were previously unknown (Ehrlenspiel et al., 2013). Creativity thus expresses itself as a creative force, to create new ideas or solutions and to redesign old structures (Albers et al., 2015), (Backerra et al., 2007). It can be broken out of straightforward, rational thinking. Another characteristic of creativity is that it occurs spontaneously and cannot be produced by order. However, it is possible, using so-called solution-finding methods, to stimulate creativity. Thus only average creative persons. can generate original and innovative ideas, which makes it possible to make better use of the existing creativity potential. Another advantage is to formalize the process of generating ideas in parts, which increases its predictability and controllability.

In addition, the high number of solutions results in a rational and objective selection of the best ideas. Furthermore, the use of these methods increases the likelihood of obtaining good solutions compared to a procedure without a method (Albers et al., 2011), (Deigendesch, 2009). Basically, it is thus possible to solve problems in an intuitive way, or by means of a systematic, analytical approach.

With its component model of creativity, AMABILE has identified three main factors that make a person responsible for how creative the result of an effort is (Amabile, 1996). The component model/framework of creativity was designed in research on the social psychology of creativity; it uses a Venn diagram to describe three factors and dimensions that focus specifically on creative personality and personal creativity.

The following three necessary, but in itself insufficient variables, are central:

- **Expertise:** The professional skills and competences
- **Creativity Skills:** Skills and competences with regard to creativity
- **Task Motivation:** Motivation with regard to the task

All three variables can be influenced very well and thus also the creative output of a person. The advantage of AMABILE'S three-component approach is that it subdivides the modality "creative personality" into individual selected submodalities, which can be further subdivided and controlled in terms of ability to act.

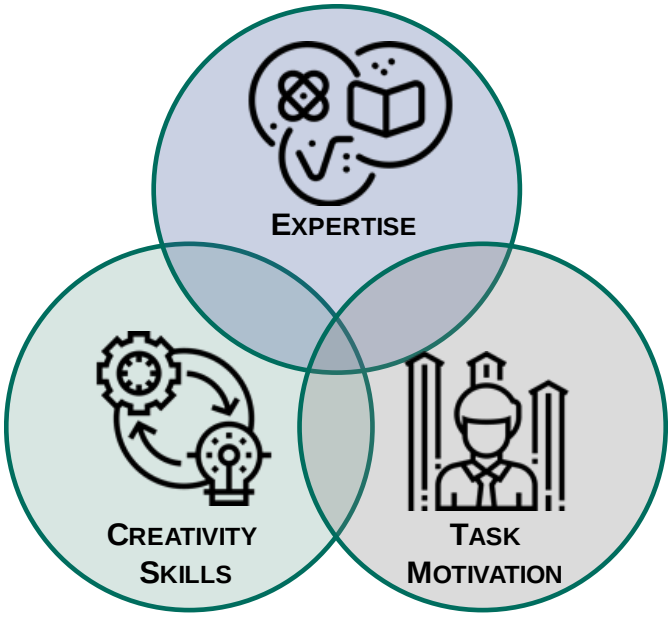

Figure 1. The three influences on creativity

2.2 Scenarios in Product Engineering

Scenarios play a very important role in product development and are frequently used to generate innovative and creative product ideas and business models (Albrechts, 2005). A special importance is associated with the scenario technique. The objective of the scenario technique is to create as many alternative developments as possible with a high degree of consistency by linking future-oriented, networked and strategic thinking (Fink et. al, 2016), (Gausemeier et. al, 2009).

The scenario technique is a deductive method. So, the scenarios are developed bottom-up starting with the decisive key factors. Then, possible, alternative developments of the key factors, also called projections, are systematically linked to consistent future scenarios. The linking of consistent projections is based on a pairwise consistency comparison of two projections. The projection space of the projections, which is mostly stretched by two axes, provides a nearly complete description of all consistent and continuous future developments. For this reason, the use of the scenario technique is very helpful in context to the SoS mobility: The derived scenarios provide a valid basis to discuss creatively about seamless and continuous mobility solutions (Fink et. al, 2011).

With the help of specific and adequate methods, different communication forms of scenarios are possible. They range from matrix presentations to scenario stories or a deep interaction in a virtual reality environment depending on the degree of immersion. Up to now, it is not proofed that a higher degree of immersion of the communication form increases the creativity of the participants.

3. Preliminary Work: Scenarios and the System of Systems Mobility

To be able to stimulate the influence factor imagination, four different mobility scenarios, that describe the future of **Seamless Mobility in 2035**, have been derived with the usage of the scenario technique in an interdisciplinary team consisting of 18 experts from different disciplines. The approach of the scenario development was based on the phase model according to GAUSEMEIER and PLASS (Gausemeier et. al, 2009). During the scenario development, the relevant factors, such as safety, reliability, social and user acceptance and the role of intermodal mobility solutions in mixed traffic were considered, analyzed and populated with varying values. These resulting scenarios were subsequently mapped into concise scenario stories for a typical urban area like Karlsruhe. The possible futures were pictured with the help of a positive and negative scenario video. The positive scenario video describes a desirable world and should trigger necessary development and research activities (see figure 2). The negative scenario video describes a future, in which autonomous mobility is present but not seamlessly linked and connected (see figure 3). Thus, possible problems are identified. It is the task of science and research to prevent and solve them before they occur. The complete videos can be found on the KIT Mobility Systems Center page and can be accessed via the printed QR codes or links (KIT Mobility Systems Center, 2017).

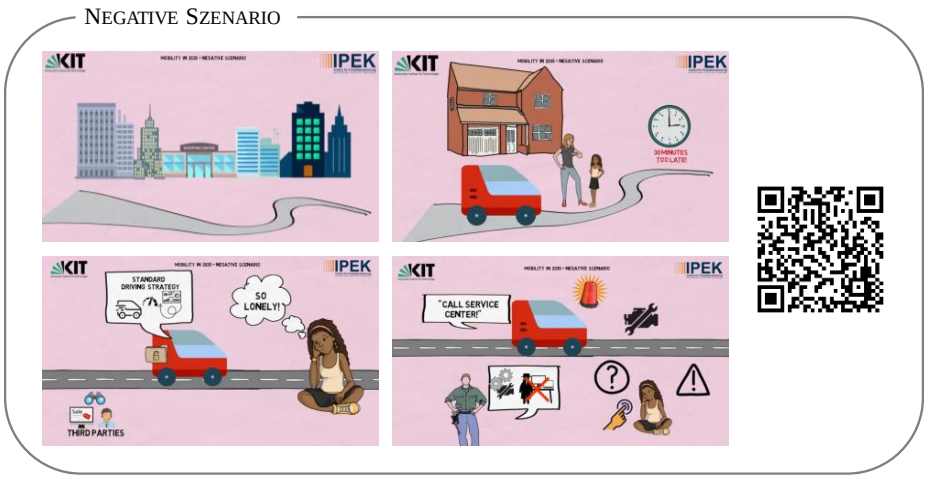

Figure 2. Inconsistently networked Mobility in 2035– Negative Scenario (https://youtu.be/d7alA7OXWHg)

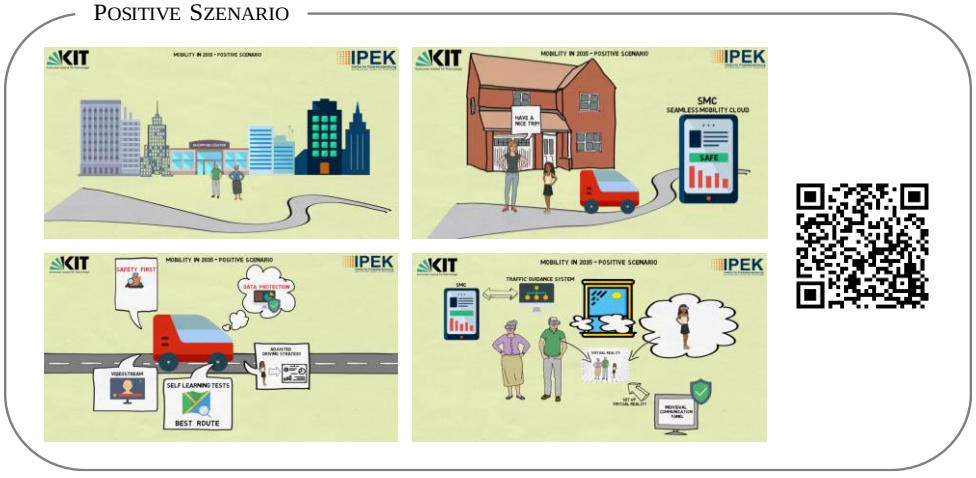

Figure 3. Seamless Mobility in 2035 – Positive Scenario (https://youtu.be/UyjQnUjo_AY)

To illustrate as many views as possible, the scenarios are told in four consecutive chapters. The story of the positive scenario is described below:

"**Chapter 1 – Transport of persons, who are unable to drive**: Emily is a girl who intends to visit her grandparents, but her mother Anika is busy and has no time to take her to see them. The family's individual mobility behaviors are managed in a secure Seamless Mobility Cloud (SMC). Based on their profile, individual solutions for their mobility needs are offered as Mobility as a Service. With one click, Anika orders a single sustainable mobility system for her daughter which conveys one person automatically without any emissions. The SMC ensures for Anika in the background that the mobility system for her daughter is operated by a trustworthy service provider. At the same time, the SMC transfers a profile with Emily's interests to provide an interactive video stream to make her trip more entertaining. This data, as well as the telemetry and the user profiles, are protected optimally due to data protection solutions embedded in the SMC system. Using the best route and driving strategy, considering the special situation that a child is being transported alone, the vehicle automatically drives to the planned meeting point." (KIT Mobility Systems Center, 2017)

"**Chapter 2 – Ideal traffic flow (societal and individual)**: Paul and his friends from different parts of the city intend to visit a soccer match. On the basis of analyses of existing data, the traffic system has pre-calculated the expected traffic loads and patterns for such a major sports event and reroutes the traffic appropriately to ensure comfortable access to the stadium. The suggested solutions consider that one of the six friends is using his own non-automated vehicle and another friend values comfort and privacy. The SMC offers a single compartment in the tram pre-configured with his favorite entertainment and communication content. Another friend, who comes from afar, leaves his car at a parking hub and travels together with a further friend to the stadium by train. During the game his car takes advantage of the light traffic to travel automatically to the stadium´s pick-up point just in time after the thrilling match. Still excited from the match, Paul decides on a scenic route for the return trip, which was suggested by his SMC, to enjoy the fun of manual driving as soon as he has automatically left the crowded city center. In this scenario proper planning and safe handling of real-time traffic data allows the adaptation of the traffic flows and enables automated coordination between private transport, which still constitutes a certain portion of the traffic, and public transport. One challenge is to include expected large numbers of not yet automated vehicles in a mixed traffic scenario with automated, interconnected vehicles." (KIT Mobility Systems Center, 2017)

"**Chapter 3 – Individual and automated mobility solutions**: Peter, still a passionate driver at 80 years old, lives in Karlsruhe. In order to preserve his individual mobility, Peter's modular and optionally automated car has continued to automatically adapt to his changing needs (ergonomics and capacity of reaction). Modification of the application profile was possible because the vehicle technology, based on agile development techniques, had already anticipated the need during the design of the car. These agile techniques also enable for the integration of his new mobile device, even though it has been introduced to the market much later than his car." (KIT Mobility Systems Center, 2017)

"**Chapter 4 – Intelligent transport of goods**: Monika is doctoral researcher at KIT Campus South, together with Jens she is investigating new materials for batteries. However, Jens is working at another location (Campus North). Monika wants to send a sample for a structural analysis to her colleague. She calls a Personnel Logistic System (PLS) to her office and hands over the sample addressed to Jens. The PLS autonomously passes the package to the Urban Transport System (UTS), which connects the campuses via public roads. In addition to the goods, the UTS also transports people with high priority to an important Senate session. This information of the demand for transport at KIT is available in the SMC. The SMC automatically prioritizes the needs of stakeholders and drives first to the senate hall. Monika and Jens receive immediately the information about the planned arrival of the package at the Campus North at 10.23 a.m. First the senate members were brought to the meeting on time, then the UTS delivers the goods to a PLS at Campus North. Via fingerprint Jens identifies himself and receives the important sample by PLS in his lab. Due to the Senate session, the SMC expects little traffic between campuses and decides to use its available capacity for the transportation of goods between the central hub at Campus North and to bring essential hardware from Campus North to the institutes at Campus South." (KIT Mobility Systems Center, 2017)

4. Research Question and Research Approach

Creative discussions with the involved domains are absolutely necessary to generate holistic, seamless and continuous solutions for the SoS Mobility. As already motivated above, this SoS differs due to its disruptive nature, the significantly higher linkage and the greater time horizon from conventional systems. Thus, the research question using the exemplary SoS Mobility is:

- How can creativity be stimulated in the context of a radical increase in complexity and a great future openness, so that holistic future seamless mobility solutions can be generated?

Therefore, the methodical approach shown in figure 4 is used. The first step is to define the task of the workshop: Here, the goal is to define as many seamless, cross-linked and future-oriented key research challenges (KRC) as possible. For this, scenario stories are presented to the involved experts in a first workshop (step 2). The results are then recorded for later comparison (step 3). In a second workshop, scenario videos are shown to the participants (step 4). Subsequently, the quantitative and qualitative comparison of the results is carried out in the last step. In the quantitative analysis, the number of identified research ideas is compared. In the qualitative comparison, the results are analyzed in terms of interconnectivity, future openness and farsightness.

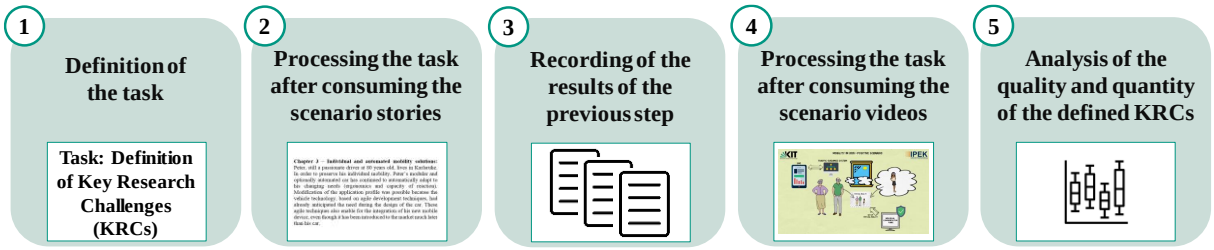

Figure 4. Methodical Approach

5. Results

Within the framework of the case study described in Chapter 4, interdisciplinary expert groups, consisting of 5 domain experts each, had the task to identify key research challenges (KRC) of the future of mobility research. This process can be understood as a highly creative process, since all the dimensions of creativity described in the state of research were necessary.
Observations have shown that the results differ markedly depending on the chosen communication form of the scenarios.

Despite the same group size and processing time, three times more ideas were generated after consuming the videos (step 4) in comparison with the results of step 2.

The use of scenario stories as a scenario communication form resulted qualitatively in significantly lower quantity and less mature results during editing, such as the use of videos as an impulse for the creative process.

In conclusion, the results were much better both quantitatively and qualitatively. Altogether, 19 interdisciplinary KRCs were generated within the workshops of which 15 were inspired by the scenarios videos.
These are highly crosslinked, continuous and very open to the future. Some examples which are addressed by research results from numerous disciplines are presented for the first time below:

- KRC 1) Manage coexistence of automated and non-automated vehicles (in mixed traffic)
- KRC 2) Criteria for an ethical and sustainability assessment of Seamless Mobility concepts
- KRC 3) Consider big differences in the development and usage cycles of the SoS elements

6. Findings

To interpret the results, the creativity model shown in figure 1 is related with the degree of immersion (see figure 6). As characterized previously, the creativity of the participants is influenced by expertise, creativity skills and task motivation. These three influences can be differentiated in affected and unaffected target variables. The expertise of the participants can be assumed to be constant and cannot be directly influenced through scenarios, as the shortness of the workshop does not allow any greater manifestations of the gained experience within the discussion sessions. In contrast, the task motivation and the creativity skills of the participants can be increased by using the scenarios as follows:

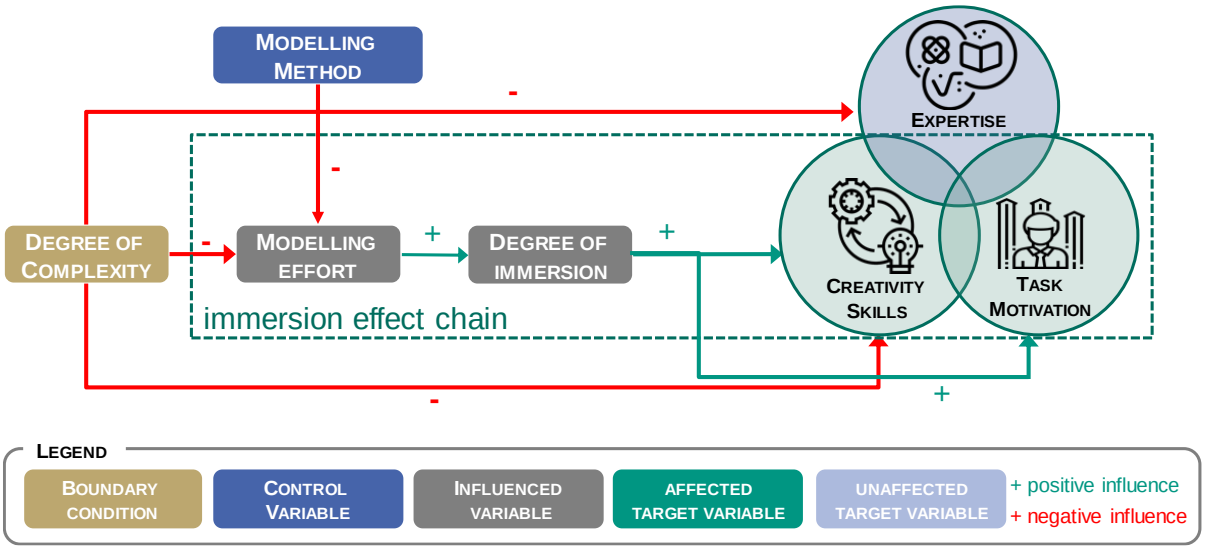

Figure 6. Creativity in the context of SoS and Scenarios

For the description of these causal connections, we begin with the complexity of the SoS. With an increasing number of independent influences and interactions the SoS becomes more and more complex. The degree of complexity has a direct, negative influence on expertise and creativity skills. On the one hand, it becomes much more difficult to understand the entire system and on the other hand the number of involved systems increases the likelihood that some of them are unknown to the participants. In order to stimulate the creativity of the participants despite the complexity of the system, measures must be taken. Here, the immersion effect chain is used: The higher the degree of complexity of the system is, the modelling and creation effort of the scenario communication becomes. If more effort is then additionally invested in the modelling of the scenario communication, what depends on the used communication form (modelling method), the modeling effort continues to increase. But: This also increases the degree of immersion (as shown in figure 5) and has thus a positive influence on the two affectable target variables creativity skills and task motivation. That shows that with the help of the appropriate modeling method, the necessary measures and counteractions against the higher complexity of SoS can be successfully processed.

7. Outlook

The results and findings outlined in this paper, using the exemplary SoS Seamless Mobility, clearly show the general suitability of the classic scenario technique for the development of consistent scenarios of complex SoS. Within the interdisciplinary communication and understanding of the scenarios, however, strong limitations can be observed. A key research challenge is therefore the effective communication of SoS scenarios to stimulate the creativity of the involved disciplines. In order to sustainably discuss about creative solutions for the future, the results of this paper show that the involved parties need to be stimulated holistically. One way to do this is to build a virtual and augmented reality experience room which makes the future mobility scenarios experiencable and allows users to actively influence them through interactions. The format is aimed at a broad public. The explicit goal is to reach also groups of people, who usually have no direct access to research and development.

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