Towards a Comprehensive Understanding of Stakeholder Requirements for Automated Road Transport Logistics

PETER FRÖHLICH, AIT Austrian Institute of Technology, peter.froehlich@ait.ac.at

MICHAEL GAFERT, AIT Austrian Institute of Technology, michael.gafert@ait.ac.at

LISA DIAMOND, AIT Austrian Institute of Technology, lisa.diamond@ait.ac.at

MARTIN REINTHALER, AIT Austrian Institute of Technology, martin.reinthaler@ait.ac.at

MATTHIAS NEUBAUER, University of Applied Sciences Upper Austria, matthias.neubauer@fh-steyr.at

FLORIAN HAMMER, Linz Center of Mechatronics, florian.hammer@lcm.at

SAMI KOSKINEN, VTT Technical Research Centre of Finland Ltd, sami.koskinen@vtt.fi

The logistics domain promises to be a first ground for the roll-out and business integration of automated vehicles, but so far the needs and expectations by the manifold stakeholders have only been analyzed to a limited degree. This paper describes a framework for capturing the requirements for automated road transport logistics, which integrates a comprehensive stakeholder taxonomy, operational factors and key scenarios, as well as a tailored acceptance factors model. We conclude with considerations for mixed-methods data capture and an outlook towards next steps of research.

CCS CONCEPTS • Social and professional topics → Automation.

Additional Keywords and Phrases: automated vehicles, requirements gathering, automated road transport logistics

1 INTRODUCTION

Automation is introduced in just about any domain, and some of the most prominent examples are currently demonstrated in transport and workplace environments [4]. The area of logistics has been affected by this trend since a long time, and already now many specialized areas operate with systems for automated loading or warehouse management [8]. A wide introduction of automated vehicles could be achieved sooner in freight transport and logistics than in passenger transport, because environments are more controllable and thus suitable for the operation of connected and automated vehicles within different parts of supply chains (e.g. factories, warehouse, airports, ports and other logistics hubs). Fewer vulnerable road users, low driving speeds and a well-defined layout of logistics areas are typical and useful characteristics of such areas. Furthermore, autonomous commercial vehicles aim at increasing freight transport capacity through 24/7 driverless operation. Acceptance by various stakeholders has been widely recognized as an overarching requirement for a successful and responsible introduction of automated road transport logistics (ATL), asides managing risks of reduction of operational flexibility, high initial costs, security and vulnerability [1]. First approaches towards a systematic investigation of requirements have been undertaken, and test fields and innovation laboratories have been set up that specialize on automated road transport logistics use cases, their further development and certification [6]. Apart from these preliminary research efforts, a comprehensive and systematic level of understanding the requirements for automated driving within this field of interwoven stakeholder groups and

Workshop proceedings *Automation Experience at the Workplace*
In conjunction with CHI'21, May 7th, 2021, Yokohama, Japan

Website: http://everyday-automation.tech-experience.at

value chains has only partly been achieved. The European research and development project AWARD[1] has set out to close this gap. The project gathers 29 leading institutions who develop and deploy safe and efficient connected and automated heavy-duty vehicles in real-life logistics operations. The requirements for such novel systems are explored within a range of real-world applications and with different types of purpose-built vehicles and fleet management system prototypes. The knowledge gained from real-world operations shall help to validate solutions for example in terms of functional safety, availability, efficiency, scalability, or cost-benefits for hub operators or fleets.

This paper outlines the underlying considerations and methodological approach for a stakeholder requirements analysis within AWARD that systematically integrates three key dimensions: stakeholder types, operational scenarios and acceptance factors. Section 2 introduces open issues and remaining challenges for a holistic, systematic and comprehensive analysis of stakeholder requirements for ATL. Section 3 presents a taxonomy of ATL stakeholders and section 4 introduces the considerations and cross-relationships with use cases and the defined operational design domain. Section 5 then describes a framework for investigating expectations and future acceptance. The paper concludes with an outline on the ongoing data capturing activities and issues encountered in times of COVID-19.

2 CHALLENGES FOR THE REQUIREMENTS ANALYSIS OF AUTOMATED ROAD TRANSPORT LOGISTICS

Trends such as digitalization, automation and Industry 4.0 also transform the work roles in the logistics sector. Cimini et al [2] introduce the paradigm of the “Logistics Operator 4.0”, who is highly skilled and is supported by various advanced technologies, such as smart supervisory control of increasingly automated functions as well as by task assistance and augmentation. However, at the current stage most innovations are focusing on automating single vehicles, which leaves uncertainty about where, how often, and how humans should be enabled to configure, monitor, or intervene with automated vehicles. When integrating automated vehicle fleets, it is likely that also here the automation paradox can be observed: the less humans are involved in automated processes, the more crucial is their involvement in the planning, refinement and intervention [1]. Another aspect that is specific to the logistics sector, is the highly specialized and multifaceted appearance and behavior of vehicles and machinery used for a large variety of mobility and goods handling tasks, ranging from long-haul transport to small distances between hubs and intralogistics operations. Here, also other automated tasks such as loading and unloading and warehouse robotics are extending and interfacing with transportation tasks.

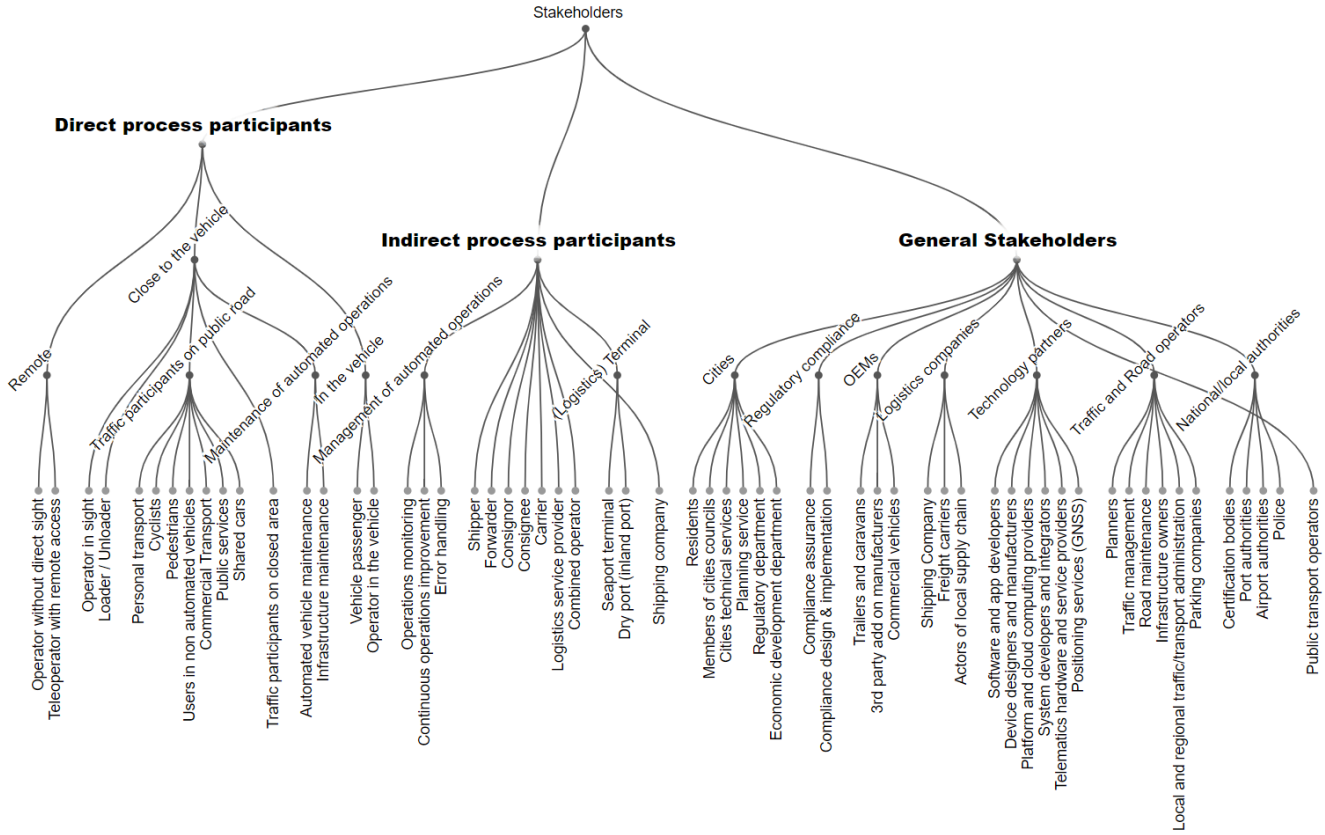
Given these novel developments and transitions of new work roles and use cases, we are missing a sufficiently systematic analysis on the requirements from different operators and stakeholders of automated road transport logistics. Most fundamentally, no reference frame is available that could help to categorize involved ATL stakeholders of the dynamically developing ecosystem, value chains and work role models, in order to enable a common ground for communication. Furthermore, so far, the structured empirical analysis of expectations of future users towards automated road transport logistics, has most often been restricted to singular use cases such as the future workplace in a truck. As a notable exception, Neubauer et al. [9] investigated different stakeholder groups on the institutional level, but they did not break this further down towards the need for direct operation of the system.

[1] H2020 Project AWARD: www.award-h2020.eu/

3 THE STAKEHOLDER PERSPECTIVE

Figure 1 shows the stakeholder taxonomy that has been derived from expert-based consultations among ATL experts from the 29 partners of the AWARD project. The taxonomy is divided into three main categories. Direct process participants are those persons who get in touch with or are affected by automated vehicles. This includes staff remotely managing the vehicles, persons close to the vehicle working in a logistics hub or production site, as well as other road users on public roads. For human–computer interaction (HCI), this group is the most relevant one, as it is related to direct contact of human operators and technology. However, for a more holistic discussion of requirements for logistics processes, also indirect process participants are relevant, which go beyond those who directly are in remote or on-site contact with an automated vehicle. Then, beyond a concrete logistics process, those groups of persons and institutions are listed who should an overarching economic or social interest in (the future use of) ATL.

Figure 1: Stakeholder Taxonomy for automated road transport logistics



4 THE OPERATIONS PERSPECTIVE

In order to demonstrate and evaluate the technical improvements for all-weather operation of automated vehicles, the AWARD concept includes specific real-world use cases. The use cases address vehicle tasks in different settings, from operational area to public roadways as well as with different automated vehicles and users. The AWARD project aims at demonstrating the automated vehicles working in all weather conditions and addressing challenges related to the deployment of these vehicles in real logistics operations through several strategic use cases that meet market needs, from the factory to logistics hubs.

Figure 2 describes the general scope of the use cases and related tests planned within the AWARD project. For each use case, ODD (Operational Design Domain) elements and associated parties (users and stakeholders) are defined. Each use case is linked to several operational scenarios, where the use case will be tested in a specific situation. The purpose of a use case description is to have an initial, semi-formal description of the use of the system and the test details. Subsequently, use case support to derive formal and more detailed operational scenarios. Use cases are applicable for any abstraction level within the system hierarchy to capture the needs of the stakeholders, e.g. the AD vehicle in its environment in certain situation to fulfill a specific purpose or intended behavior. Operational scenarios are refined, more detailed, formalized and structured descriptions of the system of interest in its context (environment, situation) to validate a use case. Operational scenarios can be used to trigger for requirements elicitation, detailed system development, test case variation and test development.

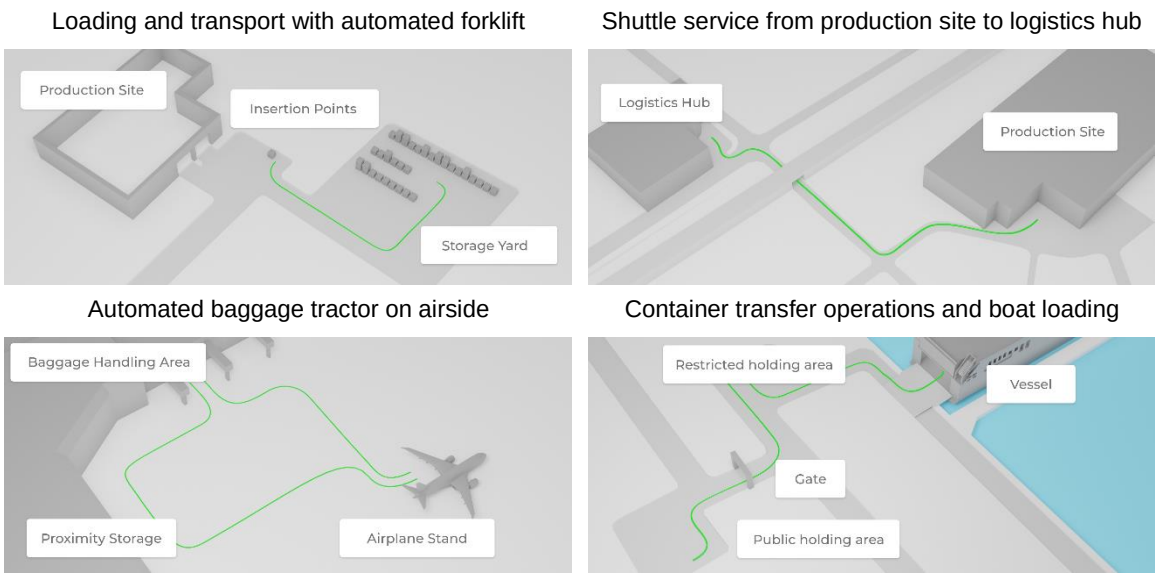


Figure 2: Key four use cases for automated road transport logistics discussed in AWARD

5 THE ACCEPTANCE PERSPECTIVE

Several technology acceptance models have been developed, adapted and extended in recent decades to improve understanding of the processes underlying technology acceptance and to clarify the factors and antecedents that clearly influence the acceptance of different types of technologies. Most prominent among these models are the Technology Acceptance Model TAM, developed by Davis [3], that established “Perceived

Usefulness" (U), "Perceived Ease of Use" (E) and "Behavioral Intention to Use" (BI) as core factors indicating actual system use. This model was extended to TAM2 [12] and TAM3 [11], which include "Social/Subjective Norms", "Experience" and "Voluntariness" as further factors impacting BI, as well as a growing list of antecedents to U and E. The Unified Theory of Acceptance and Use of Technology Model UTAUT [13] was an attempt to improve the TAM by integrating it with a number of existing related models, therefore increasing the explanatory powers and simplifying model choice for researchers.

These models serve as a base to assess user acceptance and understand the importance of a variety of factors in shaping acceptance. They have been applied in a wide range of contexts including automotive technologies, most prominently the C-TAM [10], which builds on the U-TAUT and extends it to include several trust-related factors (towards the technology and oneself). Neubauer and Schauer [9] took a closer look at core acceptance factors for automated road transport logistics through the development of scenarios and stakeholder interviews. They identified "Perceived Usefulness", "Job Relevancy" (as in clear definition of new job profiles & related training), "Social Dimension" (as in acceptance by different stakeholder groups), and "Perceived Safety" as factors central to the acceptance of automated road transport logistics. The authors further emphasized the importance of clear communication in order to align expectations and technology performance, as well as careful consideration of appropriateness of automation.

Based on these insights, we have developed an automated road transport logistics acceptance model (ARTLAM) which includes the four dimensions emphasized by Neubauer & Schauer and the traditional ease of use factor that we expect to be a sensitive and relevant acceptance component in this context. We have further extended both safety and job relevancy into the broader concepts of trustworthiness and facilitating conditions, therefore incorporating some of the spirit of the C-TAM, as well as learnings from behavioral models that point to the high impact of situations constraints on adopting behaviors [7]. The developed model, on which serves as the base for the data capturing activities and the derivation of requirements insights is depicted in Figure 3.

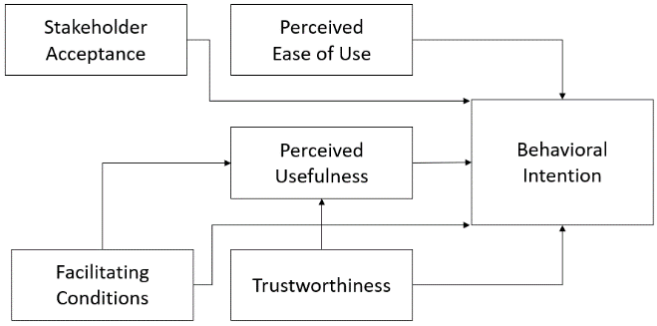


Figure 3: The Automated road transport logistics Acceptance Model (ARTLAM) developed for the Requirements Analysis

6 CAPTURING REQUIREMENTS FROM MULTIPLE PERSPECTIVES

In order to address the challenges for requirements analysis of automated road transport logistics (cf. section 2), an empirical requirements elicitation method has been designed that incorporates the stakeholder, operations and expectations perspectives. To capture the data necessary for gaining insights related to the ARTLAM factors, a mixed-methods approach is used that shall enable for quantitative modelling of expectations factors across different stakeholder groups, as well as for deep insights into the workplace requirements of

future automated logistics. Contextual inquiry studies are conducted with the direct process participants within the current work context at the selected use case test sites introduced in section 0, in combination with contextual interviews structured along the ARTLAM factors. In order to complement this in-depth research with a broader coverage across regions and a larger number of representatives of all stakeholder categories, an electronic survey was developed. In order to take the perspectives of different stakeholders and their operational expertise into account, respondents select the stakeholder category and the use case and are then asked specific questions related to the ARTLAM factors. In order to discuss needs and requirements on an expert consultation basis, workshops are being conducted among representatives of the stakeholder groups.

7 CONCLUSIONS

Acceptance of all involved stakeholders is considered a main success factor for the introduction of automated transport in logistics. This paper introduces a new requirements elicitation framework that builds on a comprehensive stakeholder taxonomy, integrates the operations perspective and enables qualitative and quantitative capturing of expectations, both for directly affected human operators in their actual usage context and on a broader regional and societal level. The proposed mixed-methods approach is expected to provide a robust means for coping with constraints on-site investigation possibilities in the context of the COVID-19 outbreak, and it invites for the development of novel cross-media approaches for gathering contextual insights at virtual site visits. The analysis of the currently gathered data will feed into the validation of the proposed ARTLAM framework and will be elaborated for wider refinement.

ACKNOWLEDGMENTS

This work was performed within the European R&D project AWARD. The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006817. The content of this paper reflects only the author's view. Neither the European Commission nor CINEA is responsible for any use that may be made of the information it contains.

REFERENCES

[1] Andrea Bottalico. 2021. The Logistics Labor Market in the Context of Digitalization: Trends, Issues and Perspectives. In Digital Supply Chains and the Human Factor (pp. 111-124). Springer, Cham.

[2] Chiara Cimini, Alexandra Lagorio, David Romero, Sergio Cavalieri, and Johan Stahre. 2020. Smart Logistics and The Logistics Operator 4.0. IFAC-PapersOnLine 53, 2 (2020), 10615–10620. https://doi.org/10.1016/j.ifacol.2020.12.2818 21th IFAC World Congress

[3] Fred D. Davis. 1989. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly 13, 3: 319–340.

[4] Matthias Baldauf, Peter Fröhlich, Sadan Sadeghian, Philippe Palanque, Virpi Roto, Wendy Ju, Lynne Baillie and Manfred Tscheligi. 2021. Automation Experience at the Workplace..CHI Extended Abstracts, 2021.

[5] Peter Fröhlich, Matthias Baldauf, Thomas Meneweger, Manfred Tscheligi, Boris de Ruyter, and Fabio Paternó. 2020. Everyday Automation Experience: a Research Agenda. Personal and Ubiquitous Computing, 24(6), 725-734.

[6] Peter Fröhlich, Klemens Schwieger, Philippe Nitsche, Martin Reinthaler, Manfred Gruber, Manfred Tscheligi, Michael Nöst, Matthias Neubauer, Andreas Pell: Defining HMI and UX Test Environments for Automated Logistics"; Proc. Mobile HCI 2017 Workshop: Mobile Interaction With and In Autonomous Vehicles

[7] Christian A. Klöckner and Anke Blöbaum. 2010. A comprehensive action determination model: Toward a broader understanding of ecological behaviour using the example of travel mode choice. Journal of Environmental Psychology 30, 4: 574–586.

[8] Bram van Meldert and Liesje de Boeck, L. 2016. Introducing autonomous vehicles in logistics: a review from a broad perspective. FEB Research Report KBI_1618.

[9] Matthias Neubauer and Ollver Schauer. 2017. Human factors in the design of automated transport logistics. In International Conference on Applied Human Factors and Ergonomics (pp. 1145-1156). Springer,

[10] Sebastian Osswald, Daniela Wurhofer, Sandra Trösterer, Elke Beck, and Manfred Tscheligi. 2012. Predicting information technology usage in the car: towards a car technology acceptance model. Proc. Automotive'UI 2012.

[11] Viswanath Venkatesh and Hillol Bala. 2008. Technology Acceptance Model 3 and a Research Agenda on Interventions. Decision Sciences 39, 2: 273–315.

[12] Viswanath Venkatesh and Fred D. Davis. 2000. A theoretical extension of the technology acceptance model: Four longitudinal field studies. Management science 46, 2: 186–204.

[13] Viswanath Venkatesh, Michael G. Morris, Gordon B. Davis, and Fred D. Davis. 2003. User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly 27, 3: 425–478.