Towards Requirements related to Future CCAM Services for Road Usage Optimization

Florian Hofbauer[1], Manuel Walch[1], Wolfgang Schildorfer[1], Matthias Neubauer [1]

[1] Logistikum – Department of Logistics at the University of Applied Sciences Upper Austria, Wehrgrabengasse 1-3, 4400 Steyr
{florian.hofbauer, manuel.walch, wolfgang.schildorfer, matthias.neubauer,}@fh-steyr.at

Abstract. Road damage on highways and freeways lead to numerous construction sites and maintenance activities every year, causing congestion, increased environmental pollution and costs. In addition, road damage exposes road users to an increased risk of accidents. The EU project ESRIUM aims to help reducing both the number of road works and the associated problems by using new digital services for intelligent road infrastructure use and predictive maintenance. The aim of this study is the presentation of four use cases and the elaboration of non-technological requirements of the offered digital services, which should lead to a deep understanding of the requirements of all stakeholders in the early phase of the project.

Keywords: Autonomous Driving · CCAM · Predictive Maintenance · EGNSS · User Acceptance · Technology Acceptance

1 Introduction

Congestion, air pollution, increased travel times and costs are the main problems caused by road damage and affect many travellers every day. In addition to these challenges, road damage also poses a significant safety risk, and can lead to vehicle damage as well as road accidents. The EU project ESRIUM [1] addresses these problems and aims at increasing the safety and resource efficiency of mobility on the road. The key innovation will be formed by a homogeneous, accurate and recent digital map of road surface damage and road wear. Road wear data in combination with machine learning algorithms will be used for predictive maintenance purposes to anticipate potential road damages and initiate appropriate countermeasures. In addition, services such as providing road users with EGNSS (European Global Navigation Satellite System) correction data via C-ITS (Cooperative Intelligent Transport Systems) messages aim at adjusting the driving path (in lane and between lanes), resulting in lower degradation of the road surface and therefore fewer construction sites. The provision of such services as well as the interconnection of vehicles with infrastructure serves as another building block for CCAM (Cooperative, Connected and Automated Mobility) [2, 3].

This study presents selected results of the first project phase of ESRIUM, which includes both, detailing various use cases for different stakeholders for the illustration of potential ESRIUM services as well as the definition of non-technical requirements

for the realization of their respective functionalities. The aim of this phase is to understand the requirements of the stakeholders and to map them with the aid of a requirements list. The requirements are then to be taken into account in the development of the ESRIUM services in order to optimize the interaction between humans and the system and thus increase user and technology acceptance. However, as different stakeholders need to be considered when formulating use cases and functional requirements, e.g. end users, original equipment manufacturers (OEMs) and road operators, the requirements for the ESRIUM system require a methodical approach to formulate requirements taking into account diverse stakeholder needs.

2 Methodology

Use Case und Service Definition
Due to the Covid-19 pandemic situation, the formulation and validation of the ESRIUM use cases was primarily conducted in online meetings. In general, a stepwise approach was implemented:

(1) First of all, we performed a use case analysis in order to develop a detailed description of the services that can be offered by ESRIUM. Within this analysis, four application scenarios of ESRIUM services including their potential target groups and application requirements, as well as the respective challenges were defined and developed.

(2) This project internal view has been validated during a bilateral workshop with the key customer (road operator) of the ESRIUM services

(3) Following this bilateral workshop and the integration of related feedback in an advanced version of the use cases, another internal validation process with all project partners started to develop consensus within the diverse and multidisciplinary team of the ESRIUM project.

(4) Finally, an external validation of the use cases with ASECAP (European Association of Operators of Toll Road Infrastructures) members and the integration of related feedback into a final version of the use cases is in progress.

Within the development of the use cases, the project team specified potential application areas for ESRIUM services and relevant system components. The planned functionalities and development steps identified in the process can be listed as follows:

- Road sensing and damage mapping system development
- Road damage map / road wear map creation
- C-ITS based RTK (Real Time Kinematic) correction message standard development for EGNSS
- An intra- and in-lane position recommendation system concept and prototype demonstration utilizing the Road Wear Map information
- Development of ADAS/AD (Advanced Driver Assistance Systems and Autonomous Driving) functions that are capable to utilize the routing and position recommendations
- Integration of Galileo OS NMA (Open Service – Navigation Message Authentication) based position authentication

The above-mentioned features to be implemented in the course of the project were subsequently used as a basis for identifying potential target groups. In doing so, three key target groups were identified, namely (1) road operators, (2) B2B customers like OEMs, wear map providers and navigation service providers and (3) end users (e.g., truck drivers, logistics service providers, automated vehicle owners, etc.). As a result, both the planned functionalities as well as the identified target groups were used to formulate appropriate application scenarios, with a total of four use cases being formed. All four use cases have been described in detail with the following structure:

Table 1: Structure of use case description

Use case Description	
Use case #	<Defined use case ID>
Name	<Title of the respective use case>
Preliminary pain points	<Pain points addressed by the ESRIUM service>
Short description	<Textual description of the use case>
Preliminary target group	<Target group of the respective ESRIUM service>
Demo-site	<Site for use case demonstration>
Key assumption	<Key assumptions necessary for service realization>
Involved stakeholder roles	<Stakeholders contributing to the service realization>
Involved project partners	<Project partners contributing to the service realization>
Realization prerequisites	<Prerequisites regarding physical and digital infrastructure as well as data availability>
Challenges / Barriers / Open issues	<Potential obstacles of points still to be clarified>
Target / Evaluation metric	<Methods for measuring the results of the use cases>
Preliminary USP	<Unique Selling Point created by the use case>

Non-technical Requirements

The methodological approach for the elaboration of the non-technical requirements (NTR) was also carried out in a stepwise approach (Figure 1).

(1) Items and constructs from the technology acceptance models UTAUT [4] and TAM3 [5] were examined and a preliminary list of non-technology requirements for ESRIUM services was derived. The final list will serve as a basis for future measurements of user acceptance of ESRIUM services and shall help to optimize human-system interaction and thus increase user and technology acceptance.

(2) In addition, the non-technical requirements were associated with
    a. The use cases defined
    b. Relevant Stakeholders (e.g. road operator, truck driver, logistics operator, OEM in the roles as customer or supplier of the respective services)

c. ESRIUM-related subcategories considered in the project proposal (user acceptance, convenience, traffic safety, traffic efficiency, environment, organization from data gathering to service provision, legal issues including privacy).

(3) The preliminary NTR list was then revised in an internal validation process during a workshop with numerous project partners (e.g. road operators, technical experts) to ensure a multidisciplinary view from different perspectives.

(4) Finally, an external validation of the NTR list will be performed by ASECAP members and the feedback received will be incorporated into a final version.

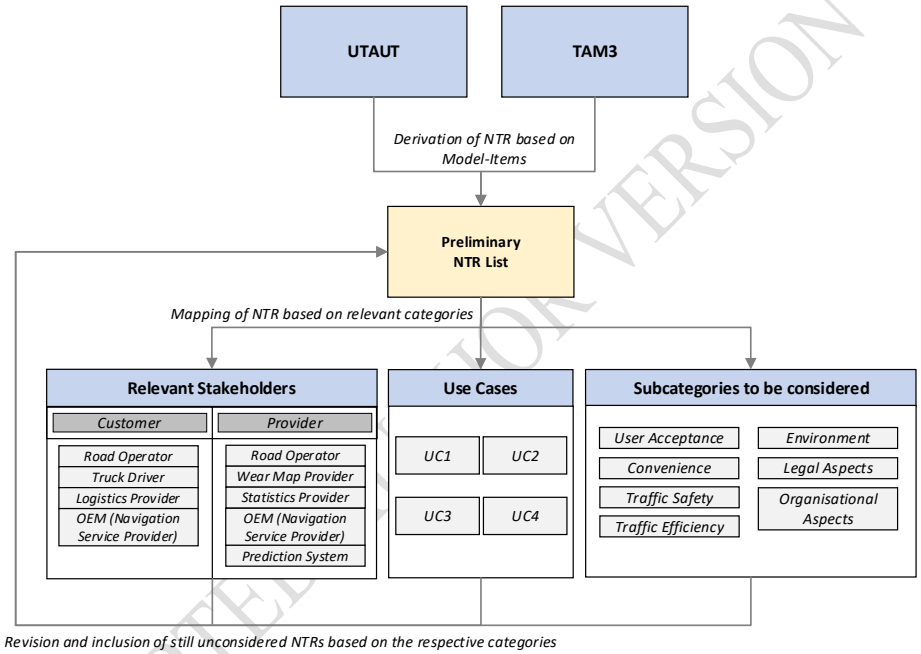

Figure 1: Process for the definition of non-technical requirements

Based on the methodology described above, non-technical requirements were developed, which can be described as follows:

Table 2: Evaluation categories of non-technical requirements

Category	Required information
ID	Defined non-technical requirement ID
Title	Title of the respective non-technical requirement
Description	Textual description of the non-technical requirement
Topic focus	Assignment of the non-technical requirements to the following main topics: user acceptance, convenience, traffic safety, traffic efficiency, environment, organization from data gathering to service provision, legal issues including privacy
Customer	Stakeholders who are in the role of the customer for the respective non-technical requirement
Provider	Stakeholders who are in the role of the provider for the respective non-technical requirement
Use case	Relevant use cases for the respective non-technical requirement

3 Results and Discussion

Based on the methodological approach for the development and validation of various potential application scenarios of the ESRIUM services, the following use cases were developed.

- UC1: AI-based road damage prediction to support enhanced road maintenance planning
- UC2: Routing Recommendations based on the road wear map, provided via C-ITS messages (Manoeuvres within lane and between lanes)
- UC 3: C-ITS Message 'GNSS-correction data' provision
- UC 4: Wear map content provision

UC1 describes an AI-based road damage prediction system based on current road wear data. Based on the predicted onset of road damages road operators can set-up a derived predictive road maintenance and action plan to proactively reduce more severe road damages, which leads to overall maintenance reduction, reduction of CO_2 emissions due to avoidance of construction zones and financial benefits due to enhanced road maintenance planning.

Based on early damage prediction, road operators can derive an enhanced action plan to proactively avoid severe road damages. As an example, UC2 describes routing recommendations such as lane changes or in-lane offset recommendations for drivers. UC2 therefore serves towards the avoidance of severe road damages and critical safety-related situations (e.g. vehicle side damage avoidance) as well as a contribution for the equal utilization of the road to prevent unequal road surface wear.

The implementation of routing recommendations, especially in-lane offsets, can only be realized on the basis of precise position data of the respective vehicles. As a result, EGNSS-based correction data for enhancing the positioning accuracy of vehicles is

needed. The precise positioning allows following the lane change or in-lane offset recommendations accurately and therefore avoid road wear. Providing the EGNSS correction data via C-ITS also acts as an additional source of correction information and adds redundancy for requirements of functional safety for automated mobility.

UC4 describes the provision of the road wear detected via a road wear map, and is intended to be available to stakeholders such as navigation service providers, OEMs and road operators. It allows new routing possibilities such as the selection of the most convenient route, resulting in enhanced driver convenience and traffic safety by proactively avoiding road wear geolocated in the road wear map.

As described above, the individual use cases are not independent of each other, but are partly based on the results of other use cases. Similarly, the use of individual use cases is not the same for all stakeholders. As an example, road operators use road damage prediction and maintenance planning services to make routing recommendations based on GNSS-corrected vehicle positions. Both the routing recommendations and the GNSS correction data are thereby sent to end users via C-ITS messages. At the same time, by providing the road wear map based on UC1 and UC4, end-users can make general routing decisions such as choosing the most convenient route to drive on. A visual representation of the individual use cases and their interrelation and connection to the relevant stakeholders can be seen in the figure below.

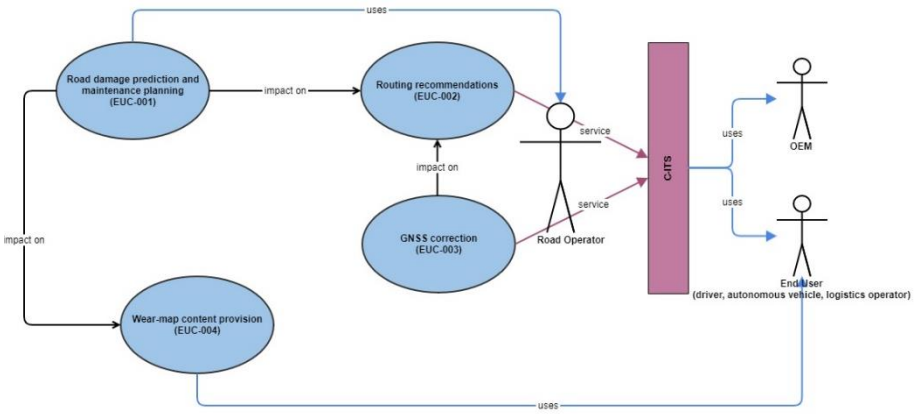

Figure 2: ESRIUM use cases interrelations and result usage

Non-technical requirements:

Within the internal validation process, 24 non-technical requirements related to the planned ESRIUM services were defined. The subcategories user acceptance and convenience were addressed in five non-technical requirements each, followed by traffic safety, organization form data gathering to service provision and legal issues including privacy with four non-technical requirements each. The subcategory environment is addressed in two non-technical requirements. Due to the length and current status (under external revision) of the entire list, we have refrained from presenting the complete list and present selected examples in the following table.

Table 3: Preliminary list of non-technical requirements (examples)

	ID	ENR-001	ENR-002
	Title	Reduction of construction sites	Clear lane change recommendations
	Description	I would like to know how many construction sites per year I can save by using the forecast model	Lane change recommendations for manual maneuvers must be clearly understandable and easy to learn
Subcategories	User acceptance		X
	Convenience		
	Traffic Safety		
	Traffic Efficiency	X	
	Environment		
	Organization from data gathering to service provision		
	Legal issues including privacy		
Customer	End user (truck driver)		X
	End user (logistics provider)		
	Road operator	X	
	Navigation service provider/OEM		
Provider	Wear map provider		
	Prediction system		
	Road operator	X	
	Navigation service provider /OEM		X
	Statistics provider	X	
Use case	UC1	X	
	UC2		X
	UC3		
	UC4		X

Example ENR-001 illustrates the requirements of the road operator for the prediction model to reduce construction sites and thus increase traffic efficiency. ENR-002 refers to end-user acceptance of lane change or in-lane offset recommendations and specifically addresses ease of use and comprehensibility as relevant aspects of technology acceptance (cf. TAM3 [5], UTAUT [4]).

4 Conclusion and Further Research

The EU project ESRIUM aims to contribute to reducing both the number of road works and the associated problems on motorways by using new digital services for the intelligent use of road infrastructure and predictive maintenance. For the purpose of realising these very goals, different use cases were developed within the project, which were validated both internally and externally with selected stakeholders. The use case descriptions serve as a foundation for the future development, as well as testing and assessment of tasks within the project. Moreover, the described use cases serve as a basis

for the formulation of both technical and non-technical requirements as well as system interface design aspects for ESRIUM services.

A preliminary list of 24 non-technological requirements for ESRIUM services was formulated taking into account state-of-the-art acceptance models (TAM3, UTAUT). After external validation, this list will serve as a basis for the creation of adapted technology acceptance models and items to measure the user and technology acceptance of the different stakeholders. The stakeholder survey will be conducted as part of initial field tests on test routes. The results of the survey shall help to optimize the human-system interaction of ESRIUM services and subsequently improve user and technology acceptance.

Acknowledgement

ESRIUM has received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004181.

Disclaimer

The content of this paper reflects only the author's view. Neither the European Commission nor the European GSA is responsible for any use that may be made of the information it contains.

References

1. (2021) ESRIUM: EGNSS-enabled Smart Road Infrastructure Usage and Maintenance for increased energy efficiency and safety on European road networks. https://esrium.eu/. Accessed 14 Jun 2021
2. European Commission (2020) Cooperative, connected and automated mobility (CCAM). https://ec.europa.eu/transport/themes/its/c-its_en. Accessed 14 Jun 2021
3. AustriaTech (2016) C-ROADS - The platform of harmonised C-ITS deployment in Europe. https://www.c-roads.eu/platform.html. Accessed 14 Jun 2021
4. Venkatesh V, Morris MG, Davis GB et al. (2003) User acceptance of information technology: Toward a unified view. MIS Quarterly Vol.27:425–478
5. Venkatesh V, Bala H (2008) Technology Acceptance Model 3 and a Research Agenda on Interventions. Decision sciences 39:273–315. https://doi.org/10.1111/j.1540-5915.2008.00192.x