Benefits of Usability and User Experience in Automated Driving

Mikko Rajanen
INTERACT Research Unit
University of Oulu
Oulu, Finland
mikko.rajanen@oulu.fi

***Abstract*—This paper proposes a list of potential benefits of better usability and user experience adapted to automated driving and autonomous mobility. These benefits could be useful for understanding and communicating the importance of usability and user experience for the success of automated driving to be accepted by the non-technical public and becoming mainstream and successful. In this paper, the focus is on identifying usability and user experience benefits of human-machine interaction (HMI) in automated driving context. The goal of the paper is to legitimize the usability and the user experience activities in the eyes of the management of automated driving application and HMI development organizations. The user-centered design process focuses on users, their needs and requirements. This paper shows that the benefits of better usability and user experience through user-centered design can be identified in use context as well as application development context through competitive advantage, reduced risks, and reduced development costs.**

Keywords— Usability, user experience, benefits, automated driving HMI

I. INTRODUCTION

Usability is defined as one of the main quality attributes for applications, software products, information systems and online services in many international quality standards, which have been developed to offer different focus on usability processes and stakeholders [1]. Good usability can be achieved through adopting user-centered design process, performing usability activities (e.g., usability testing, expert evaluation, prototyping), and by having an overall focus on usability issues through the entire development process [2]. The importance of good usability has been highlighted also in the context of driver-car interaction, where easy to learn, fast to operate and error-free human-machine interaction (HMI) has been identified as an important requirement for safety, satisfaction and acceptance of new technologies in automotive context (see e.g. [3], [4], [5], [6], [7]).

Research on human-machine interaction showed that the evaluation of the user satisfaction with a certain product, system, or service had to be expanded with more subjective aspect of personal emotions and experiences. Since the turn of the millennia, the concept of user experience (UX) has been introduced to take into account the emotions and attitudes of user about using a particular product, system or service [1], [2]. While usability is crucial in order the users to take advantage of the product's functionality, good UX is needed in addition of good usability to guarantee a product's success with customers and in the market [8].

Usability and UX have been recognized as important aspects of autonomous mobility acceptability before the first use as well as the acceptance after the first use (see [3], [9]). Therefore, it is important that the usability and UX activities are brought also into the automated driving HMI design and development life cycle. However, bringing usability and UX activities into the software development life cycle in general have been a challenge since the beginning of the usability activities over fifty years ago as often the focus is on developing technological solutions rather than on the people that will actually use these technologies [10]. Furthermore, there is still a lot of diversity on the usability and UX professionals' practices, as well as how they conceptualize usability and user experience and motivate it for their management [2], [11]. Nevertheless, there has been a lot of progress making usability improvement activities a recognized and integral part of the development process.

Nowadays many of the development companies acknowledge the strategic importance of usability and UX, and see them as potential competitive factors for their success [11]. However, even in these cases, the usability and UX activities are often amongst the first to be sacrificed whenever there is a rush to deliver the product to the market. Furthermore, the development company management may still see the usability and UX improvement activities as just "nice to have" optional task in projects. In the eyes of these managers, such an 'extra' task is always a potential risk for project deadlines and therefore is often among the first to be cut from the project planning. Often these managers try to justify not investing to better usability through user-centered design with the argument that the users can be trained and that sooner or later, these users will learn to overcome the usability problems in the system and adapt their work flow to the intricacies of the software, system or service. However, it is also possible that the users simply refuse to learn to use the system with poor usability, or to accept and adopt a new technology, and that the technology that has been developed and the functionality that has been implemented in the system with so much cost and effort is never used [11].

Even today there are quite few product development organizations reportedly having incorporated usability activities fully in their product development process [2]. One reason for these difficulties is that the benefits of better usability are not easily identified or assessed [10]. Usability activities have been competing for resources against other stakeholders in the software development projects that do have objective and convincing cost-benefit data available for management decision making when the resources are allocated. Justifying the costs and identifying the benefits of the usability and UX improvement activities have been seen as key goals for successfully integrating usability activities into development projects in ICT development [11]. Furthermore, explicit introduction and justification of user centered design and usability work by managers is important in the development context, because developers cling to status quo and seek to preserve it, by claiming that they

follow the principles of user centred design and evaluation while in practice they do not, even if they genuinely desire to develop for high usability [12].

Usability and UX work will be integrated in the development context when a strategic decision is made by the decision makers to incorporate it into the business and development processes of the organization [13]. Usability has many different forms of potential benefits also for the development organization. These benefits include increased productivity due to less user errors and less time spent on work tasks. In addition to the traditional software development context, the emergence of online commerce has shifted the emphasis from the advantages of better usability to the penalties of the online commerce site not having good usability. Usability cost-benefit analysis has been identified as a potential method for arguing for strategic usability (see e.g. [14], [15], [10], [11]).

II. Usability cost-benefit analysis

Cost-benefit analysis is a method for assessing the projects from the investment point of view [16]. This method involves making an investment decision by comparing the estimated costs and benefits of the planned actions. This comparison is based on collected and analyzed data regarding technological and financial aspects of the project. As a result, the management concentrates the available resources in the most useful way on such planned activities that have low costs and potentially high benefits, as well as finding new strategic openings for their business [10]. The usability cost-benefit analysis is in practice conducted in the planning phase of a development project [17].

While there are many different cost-benefit analysis models for different contexts, there are still relatively few published models for analysing the costs and benefits of usability work in general, and they focus on the company software development context [11]. While cost-benefit analysis has been used in the automated driving context, the focus has been on analyzing the autonomous mobility services and not on the human-machine interaction, usability or UX (see e.g. [18]).

Generally, the five traditional models of usability cost-benefit analysis differ by the focus and perspective they adopt. Mayhew et al. [19] focuses on the benefits that are of most interest to the audience of the analysis. Ehrlich et al. [20] focuses on the benefits of usability from the viewpoint of the vendor company, corporate customer, and end user. Karat [16] analyses the usability benefits through cost-benefit calculation of human factors work. Donahue [21] divides the focus between the costs for the development organization and the benefits for the customer organization. Bevan [22] analyses the benefits of usability to the development organization during different phases: development, sales, use, and support.

There are also other approaches, such as cost-justification of usability and UX activities through fear-setting, where the focus is on potential losses of inaction if the technology is not adopted or market is lost due to inferior usability and UX of the product, system or service (see e.g. [23]).

There is still a need for research studies where usability cost-benefit analysis perspective has been employed in and adapted to specific contexts such as automated driving HMI, or where the results of using usability cost-benefit analysis in a case study would have been contrasted with the literature on usability cost-justification or usability cost-benefit analysis to validate especially the benefits identified in the literature [11]. Furthermore, special care should be taken when using usability cost-benefit analysis as motivational factor for usability activities, as management can focus on the costs of usability instead of its benefits and get discouraged, even though the costs such as interface development would be realized in any case [24]. Therefore, it is better to focus on usability and UX benefits instead of the complete cost-benefit analysis of usability and UX activities [11].

III. Benefits of usability and UX in automated driving

This paper proposes the following preliminary usability benefits for automated driving applications in organizational context and use context. This paper addresses autonomous driving applications and HMIs on all SAE driving automation classification levels from basic warnings and cruise control to no direct human intervention needed during driving and covers different use cases such as privately owned vehicles, communally shared vehicles, mobility on demand, public transportation, and autonomous delivery vehicle. These preliminary benefits can then be further refined, validated through empirical and experimental testing, and further refined for example to the context of completely autonomous mobility solutions. These proposed usability benefits are based on the existing general usability cost-benefit literature (see e.g. [14], [15], [10], [11]), as well as on a continuous longitudinal literature review on the usability and UX benefits that the author has studied for over 20 years from different perspectives and in different contexts (see e.g. [10], [11], [15], [24], [25]). Furthermore, the proposed benefits are also based on the literature of adapting usability and UX benefits into different contexts, such as open source software development [24], games and gamification [25], and on the literature on HMI in driving, automated driving and autonomous mobility contexts.

A. Usability benefits in automated driving context

1) Organizational context (development and sales)

Increased sales

As a result of usability and UX methods and processes, the business objectives of the automated driving and its HMI are well defined, understood, and embedded in the design, especially through user-centered design. The better usability will result in increased user acceptability and acceptance of novel technology and therefore increased level of adoption of new technology. This may result increased sales and strategic competitive advantage when compared to competitors with worse HMI usability (see e.g. [11]).

Reduced development costs

The user-centered design makes the whole design and development process of automated driving HMI iterative and incremental, therefore making sure that the critical issues, concerns and functionalities are well designed and tested with real users before implementation, thus resulting in less need for later costly changes. Furthermore, this speeds up the development of the new technology and time to enter the market (see e.g. [20], [4], [3]).

Reduced training and support costs

The automated driving HMI is tailored and adapted to the drivers and not vice versa, by understanding, knowing and modelling the expectations and behaviors of drivers. Better usability makes the automated driving application easier to learn, therefore reducing the need for providing training and support (see [22]). Easier learning can also be used as competitive factor [11].

Easier and faster acceptance and adoption of automated driving

Automated driving is a complete paradigm shift for car users, and all kinds of problems, issues, mistakes and problems with the new technology and its HMI will hinder the acceptance and adoption of automated driving [26]. Better usability will make it easier and faster for the former active car drivers to accept the automated driving and to adopt it, by allowing the users to see the benefits of the new technology instead of concentrating on everyday problems and issues emerging from it [26]. Therefore, good, intuitive and error-free HMI allows previously active car drivers to be confidently adopt more and more passive role in automated driving and still feel that they are in control. Furthermore, it can be argued that the acceptance and adoption of different levels of automated driving is a crucial step for further development and acceptability of autonomous mobility solutions.

Reduced risk of legal liability

User errors and mistakes when using automated driving HMI may potentially cause accidents, which would carry a risk of legal liabilities for the developer of the HMI. The ethical and legal responsibilities emerging from the HMI design have been highlighted in the literature (see e.g. [27]). Better usability reduces the risk of user errors and unintentional mistakes made by users, and therefore reduces the liability risks of the developer. Furthermore, this could further reduce the costs associated with injuries and damages, as well as legal services and insurances (see e.g. [18]).

Conforming to regulations and ethical principles

Automated driving has huge impacts on national and international legislations, regulations, and ethical principles. Better usability of automated driving HMIs through user-centered design will ensure that important regulative and ethical aspects such as accessibility, inclusive design, and user empowerment are explicitly taken into account in the design of automated driving HMI, as the users and other important stakeholders can actively participate in the design process from the beginning. By proactively conforming to the regulations, as well as to the ethical and inclusive principles, the automated driving HMI manufacturers could show that automated driving HMIs do not have to be heavily regulated by the legislators (see e.g. [28]).

2) Use context

Reduced errors

Automated driving application is designed according to usability requirements for ease of use, effectiveness, and efficiency, as well as UX requirements of subjective experience with respect to the target user groups and the business objectives. User errors and mistakes especially during the everyday use will decrease user satisfaction and the level of trust to the new technology, therefore generally decreasing the willingness to accept and adopt the automated driving (see e.g. [29]). Furthermore, errors in automated driving HMI may have dangerous unintended consequences and endanger both lives and property.

Reduced learning effort

The automated driving application is designed for easy of learning, therefore requiring less learning effort and reducing the potential barrier of acceptance and adoption. Ease of learning further increases user satisfaction and willingness to adopt new technology (see e.g. [30]).

Increased user satisfaction

The potential end-users are accepting and adopting the automated driving application, accepting and adopting the automated driving as a concept, and provide positive feedback about them through different means and channels. Positive user satisfaction will have an impact on general acceptability of the new technology, as well as to the sales.

Increased safety

Automated driving and autonomous mobility can potentially increase the safety of the driving in addition to increasing efficiency in driving time and costs. (see e.g. [7]). Therefore, better usability of automated driving HMI may help to prevent accidents and other dangers to both life and property. Furthermore, increased safety may make automated driving and autonomous mobility more appealing to consumers as well as to businesses.

B. UX benefits in automated driving context

1) Organizational context (development and sales)

Increased brand appeal

In addition to fast, efficient and error-free HMI achieved through usability methods, the HMI can be further improved from UX perspective by making it more visually appealing and integrating it as part of the organizational brand. The customers are more willing to spend money on expensive products, systems, or services if they consider the brand more appealing. (see e.g. [31]). One example of this approach is Apple, which has been focusing in their strategy on UX and visual design as important parts of their brand appeal [31]. Increased brand appeal through better HMI from UX perspective would help automated driving HMI manufacturer to gain further competitive advantage over competitors with less visually appealing and brand-connected HMI.

2) Use context

Increased perceived value

While good usability in automated driving HMI is the prerequisite for its acceptability and acceptance from the user perspective, an automated driving HMI and its related brand can further be made more attractive for the customers through better UX design. Users attach perceived value on good UX design. Therefore, good design from UX perspective makes the user feel like they have good value for their money, which further increases user satisfaction and the value of the brand in the eyes of the customers (see e.g. [31], [7]).

Increased automated driving appeal

The pace of automated driving adoption beyond early adopters depends on automated driving having not only positive image among potential users, but also having an appeal. Potentially automated driving can increase the levels of user comfort, safety and traffic efficiency (see e.g. [32], [33]). Automated driving HMIs with good UX would make automated driving more desirable than conventional forms of driving and move the automated driving adoption from innovators and early adopters to more mainstream (see e.g. [6], [7]).

IV. CONCLUSIONS

This paper is the first step on filling one of the gaps in the literature of usability in automated driving context by highlighting the strategic role of usability and user-centered design in the development of automated driving HMIs. This paper contributes to the literature by proposing a list of dedicated usability benefits for automated driving context. Furthermore, this paper contributes to the theory by exploring, contrasting and adapting the usability benefits identified in productivity software development context to create usability benefits perspectives fitting the automated driving HMI context. The preliminary results from this paper indicate that it is possible to fit the usability benefits into the automated driving context and to identify the benefits from better usability and UX through user-centered design in automated driving application in both development context and in use context.

The results of this paper can be utilized by the practitioners (e.g., managers, usability specialists, and HMI developers) in the automated driving context to motivate and justify the usability and UX activities, and the resources needed for them. Furthermore, researchers interested in usability and UX benefits can use the identified usability and UX benefits as systematic criteria to further develop better usability and UX cost-benefit analysis models in general as well as developing further specific usability cost-benefit models tailored to the contexts of automated driving and autonomous mobility HMIs.

With regard to future areas of research, one future area of study is to evaluate and validate empirically the proposed usability and UX benefits in automated driving HMI context. This kind of empirical study could be done in development companies or educational settings. This evaluation could be carried out as an exploratory case study in a car manufacturing company, automated driving research organization, automated driving HMI development company, or as a survey among these companies, as well as among end-users, decision-makers and other stakeholders. Furthermore, another future area of research is to expand the proposed usability and UX benefits to explicitly take into account different aspects of usability and UX such as effectiveness, efficiency, satisfaction, safety, safety, processes, methods, as well as to integrate these benefits into service design perspective as well as autonomous mobility service perspective.

REFERENCES

[1] D. Marghescu, D. "Usability evaluation of information systems: A review of five international standards," In Information Systems Development, Springer, Boston, MA, 2009, pp. 131-142.

[2] D. Rajanen, T. Clemmensen, N. Iivari, Y. Inal, K. Rızvanoğlu, A. Sivaji and A. Roche, UX professionals' definitions of usability and UX–A comparison between Turkey, Finland, Denmark, France and Malaysia. In IFIP Conference on Human-Computer Interaction, Springer, Cham, 2017, pp. 218-239.

[3] M. Körber, and K. Bengler, Measurement of momentary user experience in an automotive context. In Proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 2013, pp. 194-201.

[4] M. J. Pitts, L. Skrypchuk, A. Attridge and M. A. Williams, "Comparing the user experience of touchscreen technologies in an automotive application," In Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 2014, pp. 1-8.

[5] J. Orlovska, C. Wickman, and R. Söderberg, "Big data analysis as a new approach for usability attributes evaluation of user interfaces: an automotive industry context," In DS 92: Proceedings of the DESIGN 2018 15th International Design Conference, 2018, pp. 1651-1662.

[6] H. Cornet, S. Stadler, P. Kong, G. Marinkovic, F. Frenkler and P. M. Sathikh, "User-centred design of autonomous mobility for public transportation in Singapore," Transportation Research Procedia, 41, 2019, pp. 191-203.

[7] O. Hagman and J. Lindh, "How autonomous cars can affect the car industry - Implications for user experience and competition," Master's thesis, 2019.

[8] K. Battarbee and I. Koskinen, "Co-experience: user experience as interaction," CoDesign, 1(1), 2005, pp. 5-18.

[9] V. Distler, C. Lallemand, and T. Bellet, "Acceptability and acceptance of autonomous mobility on demand: The impact of an immersive experience," In Proceedings of the 2018 CHI conference on human factors in computing systems, 2018, pp. 1-10.

[10] M. Rajanen, "Applying Usability Cost-Benefit Analysis - Explorations in Commercial and Open Source Software Development Contexts," PhD Dissertation. Acta Universitatis Ouluensis Series A 587. University of Oulu, 2011.

[11] M. Rajanen, "Usability Cost-Benefit Analysis for Information Technology Applications and Decision Making," In E. Idemudia (ed.), Information Technology Applications for Strategic Competitive Advantage and Decision Making, 2020, DOI: 10.4018/978-1-7998-3351-2.ch008

[12] A. Wale-Kolade and P. A. Nielsen, "Apathy towards the integration of usability work: a case of system justification," Interacting with Computers, 28(4), 2016, pp. 437-450.

[13] G. Venturi, J. Troost and T. Jokela, "People, organizations, and processes: An inquiry into the adoption of user-centred design in industry," International Journal of Human-Computer Interaction, 21(2), 2006, pp. 219-238.

[14] R. G. Bias, and D. J. Mayhew, (Eds.) "Cost-justifying usability: An update for the Internet age," Elsevier, 2005.

[15] M. Rajanen, "Usability Cost-Benefit Models - Different Approaches to Usability Benefit Analysis," In proceedings of 26th Information Systems Research Seminar in Scandinavia (IRIS26), Haikko, Finland, 2003.

[16] C-M. Karat, "A Business Case Approach to Usability Cost Justification," In Bias, R., Mayhew, D. (eds.): Cost-Justifying Usability. Academic Press, 1994, pp. 45-70.

[17] M. Maguire, "Methods to support human-centred design," International journal of human-computer studies,55(4), 2001, pp. 587-634.

[18] P. M. Bösch, F. Becker, H. Becker and K. W. Axhausen, "Cost-based analysis of autonomous mobility services," Transport Policy, 64, 2018, pp. 76-91.

[19] D. Mayhew and M. Mantei, "A Basic Framework for Cost-Justifying Usability Engineering," In Bias, R., Mayhew, D. (eds.): Cost-Justifying Usability. Academic Press, 1994, pp. 9-43.

[20] K. Ehrlich and J. Rohn, "Cost Justification of Usability Engineering: A Vendor's Perspective," In: Bias, R., Mayhew, D. (eds.): Cost-Justifying Usability. Academic Press, 1994, pp. 73-110.

[21] G. Donahue, "Usability and the Bottom Line," IEEE Software, Vol. 18(1), 2001, pp. 31-37.

[22] N. Bevan, J. Carter and S. Harker, "ISO 9241-11 revised: What have we learnt about usability since 1998?," In International Conference on

Human-Computer Interaction, Springer International Publishing, 2015, pp. 143-151.

[23] M. Aly and C. Sturm, "Hacks for Cost-Justifying Usability: Fear-Setting vs. Goal-Setting," In Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services, ACM, 2019.

[24] M. Rajanen and N. Iivari, "Usability Cost-Benefit Analysis: How Usability Became a Curse Word?," In Proceedings of the INTERACT 2007. Rio de Janeiro, Brasil, 2007, DOI: 10.1007/978-3-540-74800-7_47.

[25] M. Rajanen and D. Rajanen, "Usability Benefits in Gamification," Proceedings of the 1st GamiFIN Conference, Pori, Finland, 2017.

[26] M. König and L. Neumayr, "Users' resistance towards radical innovations: The case of the self-driving car," Transportation research part F: traffic psychology and behaviour, 44, 2017, pp. 42-52.

[27] T. Bellet, M. Cunneen, M. Mullins, F. Murphy, F. Pütz, F. Spickermann and M. Baumann, "From semi to fully autonomous vehicles: New emerging risks and ethico-legal challenges for human-machine interactions," Transportation research part F: traffic psychology and behaviour, 63, 2019, pp. 153-164.

[28] W. Ribbens, "Understanding automotive electronics: an engineering perspective," Butterworth-Heinemann, 2017.

[29] H. M. Sitorus, R. Govindaraju, I. I. Wiratmadja and I. Sudirman, "Interaction perspective in mobile banking adoption: The role of usability and compatibility," In 2017 International Conference on Data and Software Engineering (ICoDSE), IEEE, 2017, pp. 1-6.

[30] G. Nayanajith, K. A. Damunupola and R. J. M. Ventayen, "Website Usability, Perceived Usefulness and Adoption of Internet Banking Services in the Context of Sri Lankan Financial Sector," Asian Journal of Business and Technology Studies, 2(1), 2019, pp. 28-38.

[31] R. R. Gehani, "Corporate brand value shifting from identity to innovation capability: from Coca-Cola to Apple," Journal of technology management & innovation, 11(3), 2016, pp. 11-20.

[32] A. Nunes, B. Reimer and J. F. Coughlin, "People must retain control of autonomous vehicles," *Nature 556*, 2018

[33] G. H. Walker and N. A. Stanton, "Human factors in automotive engineering and technology," CRC Press, 2017.