Quality of Experience of Future ICT-based Logistics and Transport Systems

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Abstract

Quality of experience (QoE) is a multidimensional concept that has been in the focus of the research community for quite some time, especially after the rapid development of information and communication technology (ICT). It has been examined in many contexts (web, telecommunications, economy, medicine, etc.), for different media types (text, audio, video, augmented/virtual reality, etc.) and systems in various domains. Given that logistics and transport is a potent ICT-based domain for research activity in the future, in order to ease and improve the investigation of QoE in the contexts of logistics and transport, we aim to sum the recommendations and lessons learned for the investigation of QoE on the basis of our existing research. These suggestions cover how to treat the concept of QoE and relate it to other fields, techniques and environments to examine and treat QoE, as well as future technologies that need to be included. We provide insight into how these challenges can affect examination of QoE in logistics and transport and discuss ways to overcome them.

Keywords: *Examination, Future, ICT, Logistics, Quality of experience, Transport*

1 Introduction

Logistics and transport systems are critical components of prosperous economy allowing the movement of people, services, and goods as efficiently as possible. To improve the efficiency and provide better, personalized delivery of services while maintaining certain quality, there is an ever-increasing use of information and communication technology (ICT) in this context. Application of ICTs in logistics and transport systems has been studied so far in terms of automated identification technologies and data collection (e.g., radio frequency identification (RFID), global positioning systems (GPS), near field communication (NFC), quick response (QR)), data exchange technologies (e.g., Bluetooth low energy (BLE), wireless sensor networks (WSN), wireless fidelity (Wi-Fi)), and internet of things (IoT) and cloud computing environment [1]. These and emerging technologies have a great potential to improve the user experience (UX). Therefore, the use of interoperable ICTs should be encouraged further as a matter of priority. When fully utilized, it is expected that these technologies hold the key to a personalized, memorable, and convenient user experience. As logistics and transport domain tends to become more user oriented, it is necessary to understand the impact the user experience and its quality have in this context. In this paper, ICT-based logistics and transport systems refer to systems that apply modern ICTs and solutions.

The user experience and quality of experience (QoE) domains overlap because they have almost same goal, i.e., to understand and improve the user perception and overall satisfaction with the service [2][3]. Improving the user experience and its quality is the driving strategy in logistic and transport ICT-based systems which have been previously investigated to some extent. Therefore, the aim of this paper is to summarize lessons learned from previous research and provide recommendations for future research of QoE in ICT-based logistics and transport systems.

The rest of the paper is organized as follows. Section 2 introduces the concept of QoE, whereas

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section 3 provides an insight into the techniques and testing environments used for QoE examination. Relationship between QoE and other fields (e.g., cyber security, quality of life (QoL)) and future technologies (i.e., 5G, 6G, augmented reality (AR)/virtual reality (VR), web of things (WoT)) are described in section 4 and section 5, respectively. Finally, section 6 summarizes the paper.

2 Quality of Experience Concept

This section tends to give high-level foundation recommendations related to the concept of QoE that can be implemented in the context of ICT-based logistics and transport systems. These four suggestions are based on the results of our QoE research done so far in domain of web, video, united communications, etc., i.e., media that can be used in ICT-based logistics and transport systems [2]-[26].

Item 1: Multidimensional concept

Regardless of the context (i.e., domain, system, media, etc.) in which is examined, QoE of ICT-based logistics and transport systems should be considered as a multidimensional concept that can be decomposed into multiple perceptual QoE dimensions which are impacted by various QoE factors. Having a multidimensional approach to QoE may improve its better modelling, monitoring, assessment, optimization, control, and management.

Item 2: QoE management framework

QoE management framework for ICT-based logistics and transport systems should comprise of three main phases: (i) modelling, (ii) monitoring and measurement, and (iii) optimization and control. The selection of the key factors and dimensions specific for logistics and transport systems context is the most important issue in modelling QoE. The main challenges related to QoE monitoring and measurement are: what, where, when, and how to collect data. Similarly, the what, where, when, and how to improve QoE summarize the challenges of the QoE optimization and control phase. These last two phases have to be tailored to the context of these systems as well.

Item 3: QoE dimensions and factors

For ICT-based logistics and transport systems, the various specific and important perceptual QoE dimensions, i.e., perceivable, recognizable, and nameable characteristics of the individual's experience of a service which contributes to its quality, and wide spectrum of specific QoE factors, i.e., any characteristic of a user, system, service, application or context whose actual state or setting may have influence on the QoE, should be considered.

It is reasonable that not all perceptual QoE dimensions and QoE factors important for ICT-based logistics and transport systems can be identified and considered, but the key ones should be identified and examined. Perceptual QoE dimensions should be contextualized for system usage, while QoE factors should stem from human, system, and context groups.

Item 4: Quantification of QoE relations and interplays

In order to gain deeper understanding of QoE for ICT-based logistics and transport systems, the relationships and interplays of wide spectrum of identified QoE factors, various perceptual QoE dimensions, and QoE should be quantified. Based on those models one can further have better predictions, monitoring and measurement, and consequently optimize QoE in a more effective manner.

3 Quality of Experience Examination

This section continues with discussion related to the examination of QoE for ICT-based logistics and transport systems. The addressed three learned-lessons points are also based on the activities in our QoE research done so far in domain of web, video, united communications, etc. and tend to ease the decision making process while investigating QoE [2]-[26].

Item 5: QoE data collection

After key QoE factors and perceptual QoE dimensions are identified in the modelling process of QoE for ICT-based logistics and transport systems, one must take care of granularity and degrees up to which the factors are manipulated. It is recommended to have more degrees of factor manipulation, i.e., greater granularity, which contributes finally to more accurate prediction models, since the more input levels of variable we have, the model will be able to better capture the variation. The same approach should be applied to data collection in monitoring and measurement process. Data collection in general largely depends on the selected QoE impact factors in logistics and transport systems context.

In addition, one can differentiate between objective and subjective methods for data collection. Objective ones collect data solely from objective quality measurement or indices, while subjective data collection processes must have specified the methodology to be used, identification of the dependent and independent variables to be considered, user test participants, testing scenarios, testing environment, and rating scales.

Also, important thing is the selection of data collection scales (Likert scales, mean opinion score (MOS), etc.) or development of questionnaires (post-study system usability questionnaire (PSSUQ), etc.) which need to be in accordance with the selected perceptual QoE dimensions since they are included in order to capture the perceptions and QoE.

Item 6: QoE experiment environment

When conducting the studies dealing with QoE of ICT-based logistics and transport systems one has several options: lab, field, or crowdsourcing environment. As already discussed in the literature, each of the options has its own advantages and disadvantages. The choice usually should depend on the timing of the study. It is advisable to have both lab and real-world test in order to gain more quality results and conclusions that can be generalized. Of course, it is important to note that field and crowdsourcing tests can gather large amounts of data with less cost and time in comparison to laboratory-based ones, but controlling the experiment represents the challenge. Of course, it is of great importance to stress that each study should have as much as participants as possible in order to avoid drawing misleading or inaccurate conclusions often present in human related studies. In addition, the researchers should carefully design the testing scenarios which should capture the perceptions and QoE.

Item 7: QoE data processing

When processing data, one can use three different techniques: mathematics, statistics, and machine learning. Each of these methods have their own pros and cons in dependence of the required final outcome. Therefore, it is crucial to know what one wants as a result of data processing and choose a method. Using mathematics means one wants to present relationships between different variables, parameters, and defined limitations by using differential equations and algebraic and logical statements as auxiliary relations. Using statistics means using mathematical models and statistical assumptions in order to generate data patters and predictions related to the real world. This method helps researchers to approach to data in a strategic way and relate one or more independent variables to other dependent variables, but requires understanding the outcomes and results prior to its usage. Machine learning represents the ability of the algorithm to generalize based on the previously learned connections between the data. This method is looking for patterns hidden in data independently of all assumptions.

4 Quality of Experience and Other Fields

QoE is a broad concept related to humans and their perceptions since they are quality meters today and will remain in the future. That is why it cannot be considered in isolated fashion. This section gives several points when it comes to QoE research related to other fields, but the cases where QoE should be examined and domains to which it should be related are much wider and will be even more in the upcoming period [23][24][27]-[29].

Item 8: Multidisciplinary concept

Although QoE should be, as a concept, considered as multidimensional, it is important to stress that it is also needs multidisciplinary approach since it is human-oriented technology-related, and context-dependent. This means that researchers from all relevant disciplines should be included in QoE research depending on the context. For example, in ICT-based logistics and transport systems case, one should include the following disciplines: technology, engineering, psychology, design, security, and transport. Therefore, depending on the nature and the domain of the system being considered, QoE should be addressed in a multidisciplinary manner. Also, various other fields offering wide variety of factors should be included when addressing QoE. For example, in logistics and transport systems, energy efficiency or security also can be examined as influencing factors.

Item 9: QoE and life

Given that QoE is related to humans and their opinion on the technology, it ultimately should improve their QoL. QoL is very complex and it can be improved in many ways, but QoE channel is one of them. Nowadays our lives vastly depend on the technology which is rapidly developing thereby changing the way we live. The ultimate goal of the technology, including logistics and transport domain, should be the improvement of QoL, but in order to achieve that, one must have quality experience with it. Therefore, in order to have adequate ICT-based logistics and transport systems which will improve the lives of people in general (QoL), one must address the QoE when using them.

Item 10: QoE and cyber security

With the outburst of COVID-19 pandemic and rapid development and dominance of technology, threats and attacks against the digital infrastructure have exploded due to increased usage of cyber space and low cyber hygiene (awareness, behavior, and knowledge). Therefore, cyber security became a prominent notion in everyday human life and technology with no intention to pull back, but quite the opposite, i.e., to rise. This means that it cannot be ignored by future QoE studies related to any ICT-based system either as QoE influence factor of perceptual QoE dimension.

5 Quality of Experience and Future Technologies

This section provides an insight into the relationship between QoE and future technologies in the context logistics and transport.

Item 11: QoE and 5G

5G opens new opportunities to transform the logistics and transport. With the advent of 5G services (i.e., eMBB (enhanced Mobile Broadband), URLLC (Ultra Reliable Low Latency Communications), and mMTC (massive Machine Type Communications)), the new requirements in terms of methodology and set of parameters for QoE examination have appeared. The traditional QoE concept is appropriate for eMBB, but not for URLLC and mMTC because the end-user is a machine, not a human. This requires a machine QoE to be defined. The challenge of how to quantify QoE needs to be addressed. Thus, a new understanding of what constitutes QoE is needed which calls for a revised concept of QoE and new techniques for QoE examination [30].

Item 12: QoE and 6G

6G will provide extensions and combinations of 5G services (i.e., eMBB+, URLLC+, and mMTC+) while introducing two new usage scenarios, i.e., sensing and artificial intelligence (AI). This means that 6G will be intelligently combined with 5G allowing end-users to customize their own QoE. It is expected that data analytics and AI will improve the QoE and enable its personalization. 6G will keep on with the 5G trend of defining QoE over individual parameters [31]. This will be beneficial for ICT-based logistics and transport systems where the importance of user-centricity has been already recognized.

Item 13: QoE and XR

Providing QoE for extended reality (XR) applications, including AR, VR, and mixed reality (MR) is challenging. In such applications, QoE is critical as their usage can cause the sickness or nauseas. Moreover, these are multimedia applications which incorporate audio, video, interaction, and environments [32]. The QoE of such applications is affected by many influence factors whose relationship to QoE should be quantified. Since the logistics and transport sector is one of the first sectors to make use of XR, it is important to define the QoE requirements in terms of performance and methodology in this context.

Item 14: QoE and WoT

Using the WoT in ICT-based logistics and transport systems provides many benefits to QoE which can either neutralize or avoid all negative influence factors. Describing the relationship between different influence factors and QoE, it is possible to identify the importance of distinct influence factors, develop accurate prediction models of QoE, and find the relation between QoE and QoL in WoT context. All interested parties may use this knowledge to understand how their work affects others in WoT delivery chain or how others are affecting their processes. It is important to find how WoT will improve QoL, model the relationship between QoL and QoE, and extend the multidimensional QoE models in the WoT context for logistics and transport domain [27].

6 Conclusions

Ever-increasing usage of ICTs in logistics and transport systems provides opportunities to improve user experience and its quality. Being the potent domain for future research, this paper has summarized the recommendations and lessons learned for the examination of QoE based on our previous research activities. Thus, the contribution of this paper is three-fold. Firstly, we have given the high-level recommendations related to the concept of QoE of ICT-based logistics and transport systems based on our QoE research findings related to various media that can be used in this context (Section 2). Secondly, we have discussed the examination of QoE for ICT-based logistics and transport systems in terms of QoE data collection, QoE experiment environment, and QoE data processing (Section 3). Thirdly, we have considered multidisciplinary concept of QoE in relation to other fields (i.e., QoL and cyber security) and future technologies (i.e., 5G, 6G, XR, WoT) and steps (Sections 4 and 5), while providing insight how they can impact the QoE examination in logistics and transport domain.

Future research in the context of investigating the QoE for future ICT-based logistics and transport systems should identify the important services to be addressed. Those services should include future ICT technologies (e.g., 5G, 6G, XR, WoT). After the identification, one can consider our recommendations and discussed items when treating the QoE, i.e., address it as a multidimensional concept, manage (model, monitor, and optimize) QoE, and investigate QoE accordingly by using multidisciplinary approach and in new environments.

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