# Identifying Costs and Benefits of Smart City Applications from End-users' Perspective

*Mario Jadrić*
*Faculty of Economics, Business and Tourism, University of Split, Croatia*
*Tea Mijač*
*Faculty of Economics, Business and Tourism, University of Split, Croatia*
*Maja Ćukušić*
*Faculty of Economics, Business and Tourism, University of Split, Croatia*

## Abstract

The widespread availability and adoption of various smart city solutions have benefited their users by providing new services and information generated in real-time. These solutions use different types of sensors and GPS to collect, process and display data within the web and/or mobile applications. Focusing on the determinants of the intentions to use an application or its success, a large number of researchers developed and validated models such as TAM, UTAUT, IS Success Model and similar ones. This paper presents an exploratory approach that is based on the cost-benefit analysis with end-users who were invited to express their perceptions of different smart city solutions. Qualitative data were collected to devise a research instrument in subsequent phases based on the feedback from second-year business students. For each of the selected four smart city applications (smart parking, water quality monitoring, air quality monitoring, and real-time traffic monitoring), respondents were asked to work in groups and create a list of benefits and costs from their perspective. The analysis resulted with the list of 98 different cost and benefit statements (16 costs common for four smart city applications, 12 benefits common for four smart city applications, 10 distinctive costs and 60 specific benefits).

**Keywords:** Smart city applications, Smart parking, Water quality monitoring, Air quality monitoring, Real-time public transit information, Integrated smart solutions, End-users perceptions, Cost-benefit analysis
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# Introduction and conceptual grounding

The increasing number of people living in cities and ubiquity of urban technologies contributed to the growing popularity of the smart city concept. It is often associated with citizen-oriented, i.e. user-oriented approaches that are turning out to be particularly important for the development of smart city applications (Singh & Singh, 2018). Even though the new ICT tools enable numerous opportunities to provide more efficient digital services in the public sector, there is still a lot of criticism regarding the underdeveloped user-(citizen-) orientation (Albino et al., 2015; Tan et al., 2013; Tomitsch, 2018; Verdegem & Verleye, 2009). Users' needs have to be taken into consideration; otherwise, applications will not be accepted nor used (Tomitsch, 2018). In that regard, behavioural intention (intention to use) and the use itself represent key elements of digital services' provision in the public sector.

There are several models that focus on the evaluation of acceptance and success of different technology solutions in particular. One of the more pertinent ones is Technology Acceptance Model (TAM) developed back in 1989 to measure the technology use (Davis, 1989), that quickly became the dominant model for investigating factors for user acceptance (Marangunić & Granić, 2015). TAM defined two variables addressing the use: perceived usefulness and perceived ease of use. Further to that, and as an extension of TAM, Unified Theory of Acceptance and Use of Technology (UTAUT model, had four core determinants of intention and usage (performance expectancy, effort expectancy, social influence and facilitating conditions), and up to four moderators of key relationships (Venkatesh et al., 2003). The review of standard models such as TAM and UTAUT is often complemented by DeLone–Mclean's model, representing an established and well-known information system (IS) model for assessing IS success. Based on the model, system quality, information quality, service quality, use/intention to use, user satisfaction, and net benefit are distinct, but related dimensions of IS success (DeLone & McLean, 2003).

Literature review confirms that many papers focusing on smart city-related topics, in particular, address the concepts of use and intention to use, i.e. explore the factors that can predict that kind of behaviour. In that regard, and in that context, it has been confirmed that that (perceived) ease of use and perceived usefulness affect the intention to use (Althunibat et al., 2014; Van Compernolle et al., 2018; Liao et al., 2007; Mensah, 2018; Susanto et al., 2017). Additionally, while exploring the factors affecting the behavioural intention to use smart city services, many authors confirmed that performance expectancy and effort expectancy positively affect behavioural intention (Gunawan, 2018; Habib et al., 2019; Zuiderwijk et al., 2016). Research that focused on the intention to use digital coupons among university students, showed, however, that perceived economic benefit has the greatest impact on intention to use (Guo et al., 2019). Further, results show that potential users may be willing to use a digital service when they expect it will give them an obvious advantage or benefit over the alternative approach to those services (Sepasgozar et al., 2019; Tomitsch, 2018).

Based on the growing interest and the focus on the benefits of using new services, the research study presented here aimed at providing a complementary and alternative view on the intention to use smart city services. In general, the authors agree that smarty city applications are still missing a more universal approach to measure factors affecting intention to use (Rana et al., 2017). Like most other solutions, smart city services have to maximise benefits and minimise adoption barriers for citizens (Prybutok et al., 2008). In assessing the benefits of a new solution, it is customary to involve users that can critically evaluate the positives and negatives of using that solution (Weerakkody et al., 2017). For a systematic approach to evaluating benefits (positives) and cost (negatives) of several smart city applications, the authors of the paper opted for Cost-benefit analysis (CBA) (Drèze & Stern, 1987). CBA is a method of general applicability that can provide criteria for a more comprehensive assessment (Masera et al., 2018). Smart city applications that were explored were selected based on the results from a previous study (Ćukušić et al., 2019): Smart parking, Water quality, Air quality and Public time tracking. Specifically, the four applications are amongst the top-rated applications having the highest priority in a local context, each of them providing information generated in real-time. The overall aim of the study was to solicit and identify relevant costs and benefits of the selected smart city applications with end-users. It is the first step towards exploring and evaluating factors predicting end-users' intentions to use the applications in the future. End-users were thus invited to express their perceptions of the aforementioned applications. Accordingly, the study attempts to address the following questions: *(1) what are perceived costs and benefits for each of the selected smart city applications from end-users' perspective, and (2) are there common costs and benefits identified for all selected smart city applications?* Participants were asked based on the CBA method to generate and identify costs and benefits for each of the applications. It yielded a huge list of benefits and costs, and the results will then be used to devise a research instrument for the subsequent phases.

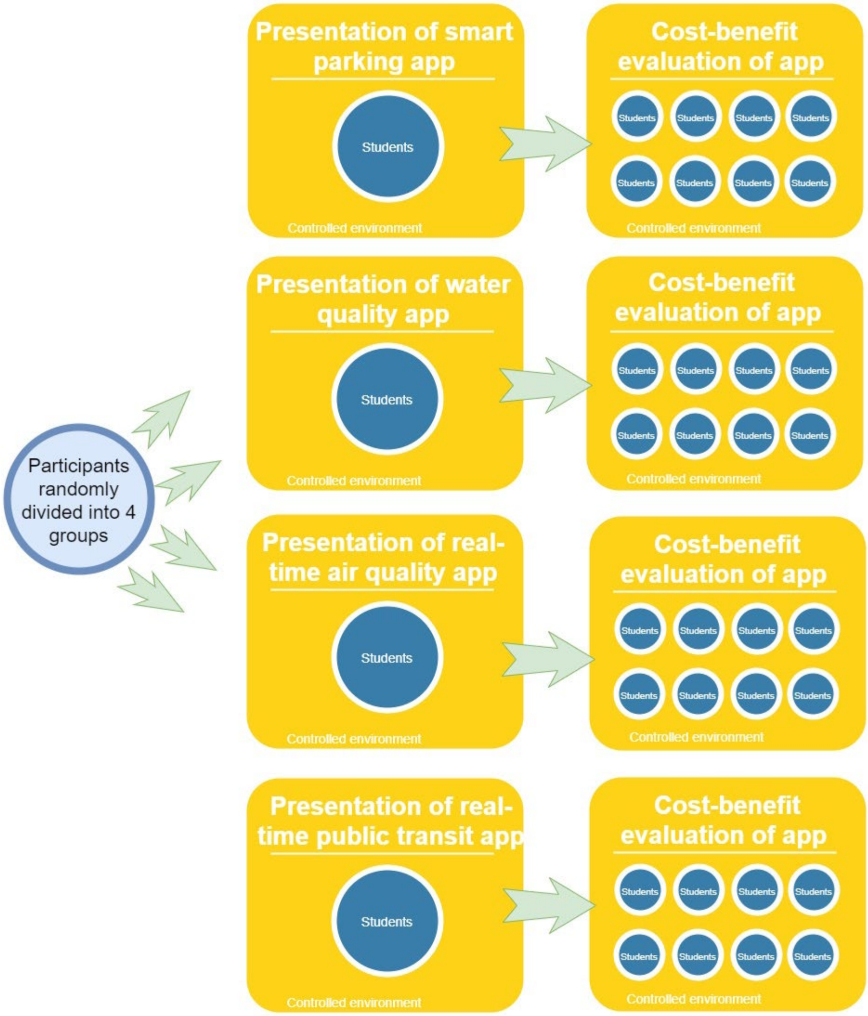
The paper is organised as follows: Section 2 describes the procedure in more detail, and Section 3 presents the results. Finally, the discussion with the theoretical and practical contribution of the paper, and conclusions with future research directions are given in Section 4 and 5, respectively.

# Research methodology

## *Procedure and participants*

The study began with the random separation of the participants into four groups in a dedicated workshop organised for the second-year students of the University in Split, Faculty of Economics, Business and Tourism. To each group, one of four selected smart city applications was presented in person and writing, after which they had time to look for further information using the computers. Participants were then asked to generate a list of costs and benefits for a particular application. For this task, they were asked to organise into teams (of 2-3 participants per team). Thus, each of the four groups was divided into eight teams, resulting in 32 teams in total. The time limit was set to 90 minutes, and the analysis following the CBA rules was performed in a controlled environment. All qualitative assessments were collected separately for each application, and afterwards, the statements were analysed to detect redundant and unique ones. The participants are from a relatively homogeneous group, coming from the same age group, and sharing a similar educational and economic background. With regards to gender, almost 70% of the participants are female, but this is consistent with the institutional enrolment data where female students prevail. The procedure is graphically presented in Figure 1.

*Figure 1*
Research design illustration




*Source:* Authors' illustration

## *Research material for the workshop*

In preparation of a dedicated smart city workshop, a half-page description for each of the four selected smart city applications was formulated. The descriptions were based on the information provided by solution vendors, industry reports, and personal experiences. A brief outline is presented in Table 1. All four applications were earlier identified as smart city priorities for the City of Split (Ćukušić et al., 2019), where the study took place. The applications were first presented in person by the authors of the paper, while the full description and the CBA form were provided in written form. During the process of drafting the CBA, the teams were allowed to look-up further information about the applications, and CBA as the workshop took place in computer labs.

*Table 1*
A brief outline of smart city applications' description used in the workshop

| Smart city application | Brief description of the application |
|---|---|
| **Smart parking** | Smart parking application detects via sensors whether a public parking space is vacant or occupied and visually presents the actual status for each parking space in a convenient map. Users can check the occupancy status using their mobile devices and see the number of vacant parking places, including accessible parking spaces. The application displays the real-time situation in the form of pins on the map, containing numeric information on the availability. Users can then use the application to navigate to the nearest available or selected parking space, both for street and off-street parking. The application thus contributes to reducing traffic, lowering exhaust gas levels, and reducing anxiety among drivers. It can also affect the demand-side through variable pricing. |
| **Water quality monitoring** | The application for water quality monitoring uses data from different types of sensors: water level sensor, temperature sensor, piezometer, anemometer, and others. As the data is collected, it is converted to a compatible format and imported into the database, with the entire process being fully automated. It can then be displayed using a graphical interface and organised and presented according to user requirements. It is possible to create real-time views, charts, alarms, APIs, and much more. The application can thus send notifications to the general public through different channels (mobile applications, emails, text messages, and websites). It can ensure a prompt response from the city and municipal governments in alarming cases. |
| **Real-time air quality information** | Air pollution is one of the most important indicators of life quality, and it has a significant impact on the health and economy of society. Due to technological improvements in sensor technology, sensors for measuring air quality became proportionally inexpensive and small devices. Users have the option to track related information about the quality online and adjust their behaviour accordingly. The sensors detect and monitor air pollution (outside or inside), collect real-time data, and send it for further processing, depending on users' needs. |
| **Real-time public transit information** | The application contains real-time information about the arrival and departure times for public means of transportation. The system provides passengers with estimated arrival times for all means of public transport and across all platforms. Location-based systems are used to source the data, for example, GPS tracking devices on vehicles, which are increasingly used by bus carriers. Information can be delivered in a variety of forms such as through information screens at bus stops, carrier websites, text message notifications, or third-party applications. The information enables users to quickly adapt their behaviour on-the-go in response to newly received data. |

Source: Authors' work

## Results of the study

As presented already, the study aimed to collect data on perceived and potential costs and benefits for end-users per each presented smart city application. Eight student teams analysed the application allocated to them (32 teams in total). They generated a list of qualitative statements concerning the costs and benefits of the specific application, but from the perspective of a user. All distinctive statements will be included and used in the subsequent phases of the research. In case there were repetitive, i.e. redundant statements, the ones that were formulated in the best way were left-in. As a follow-up, the filtering of the statements, costs and benefits that are common to all four applications (smart parking, water quality monitoring, real-time air quality information, and real-time public transit information) were identified. The intention was to explore the scenario where all four applications could be offered as a part of one integrated smart city solution. For illustrative purposes, several of the statements that could be viewed as common for all four applications have been shown (also with frequencies) in Table 2 (for smart city application costs) and Table 3 (for smart city application benefits).

In the tables, it is listed how many times has a cost or a benefit that could apply to all four applications been identified. Specifically, it is listed how many out of the eight evaluation teams identified a cost (Table 2) or a benefit (Table 3) per application. The column labelled as Total refers to a total number of teams that identified a cost or a benefit that could be common for all four. For example, the cost "*Mobile data consumption…*" has been identified by seven evaluation teams for Smart parking and Water quality monitoring, while all eight teams identified it for Real-time public transit information and Real-time air quality information, with the total frequency of 30 teams out of the 32. On the other hand, not all common costs and benefits were identified by all teams. The total number of identified costs that could be considered as common for all smart city applications is 16 (with the most identified by the teams focusing on the water quality monitoring, a total of 13 out of 16 statements). Fewer common benefits for the selected smart city applications from end-users' perspective were identified (a total of 12 statements), the most frequent one being the "*Updated and transparent information is always available…*"

Apart from the common costs and benefits, several distinctive ones were stemming from the main purpose of the application. Numbers of distinctive costs and benefits specific to a smart city application are presented in Table 4. Benefits surpass the costs for end-users in this regard, understandably so, since each application meets specific users' needs. This qualitative analysis resulted with the list of 98 different cost and benefit statements (16 costs common for four smart city applications, 12 benefits common for four smart city applications, 10 distinctive costs and 60 specific benefits).

*Table 2*
Excerpt from the list of identified common costs for selected smart city applications

| Identified common costs | f Smart parking | f Water quality monitoring | f Real-time public transit information | f Real-time air quality information | Total |
|---|---|---|---|---|---|
| Mobile data consumption… | 7 | 7 | 8 | 8 | 30 |
| Cost of battery charging… | 3 | 5 | 6 | 5 | 19 |
| Reduced memory space… | 3 | 4 | 6 | 2 | 15 |
| … | … | … | … | … | … |
| Total common statements | 10 | 13 | 11 | 11 | 16 |

Source: Authors' work

*Table 3*
Excerpt from the list of identified common benefits for selected smart city applications

| Identified common benefits | f Smart parking | f Water quality monitoring | f Real-time public transit information | f Real-time air quality information | Total |
|---|---|---|---|---|---|
| Updated and transparent information is always available… | 0 | 2 | 7 | 4 | 13 |
| It helps in organising our time and behaviour. | 0 | 0 | 5 | 0 | 5 |
| The available information reduces our stress. | 0 | 0 | 3 | 0 | 3 |
| … | … | … | … | … | … |
| Total common statements | 0 | 3 | 5 | 6 | 12 |

Source: Authors' work

*Table 4*
Number of distinctive costs and benefits specific to each of the smart city applications

| Smart city application | Distinctive costs | Distinctive benefits |
|---|---|---|
| Smart parking | 6 | 20 |
| Water quality monitoring | 2 | 16 |
| Real-time public transit information | 2 | 12 |
| Real-time air quality information | 0 | 12 |
| Total | 10 | 60 |

Source: Authors' work

## Discussion

The study, among other objectives, aimed to identify perceived costs and benefits for end-users of several smart city applications. The orientation to end-users' perspective was selected in response to research questions set in the first part of the paper, specifically intending to address the criticism and disregard of end-users in the stated context of developing information systems for citizens. For that purpose, a specific group of (future) users of smart city applications, was asked to generate all the costs and benefits they could make out, from their perspective. After careful analysis of the compiled list, a good number (98) of different costs and benefits was identified providing suitable insight into perceived costs and benefits for each of the selected smart city applications from end-users' perspective (addressing research question 1, in particular). Out of the 98 items, it was easy to demarcate the costs and benefits common for all four selected smart city applications (in response to research question 2). It is important to indicate that the respondents identified more common costs (16) than common benefits (12). It is the other way around for the costs and benefits characteristic for the smart city applications where the number of distinctive benefits (60) significantly outweighs the number of distinctive costs (10). From end-users' perspective, the result is reasonable since the costs of using only one application are usually same or at least similar to using many, whereas the benefits of using different applications vary greatly depending on their main purpose. In understanding the end-users' point of view, it is important to note that they perceive a lot fewer costs than benefits.

Smart parking application yielded the biggest number of benefits. The reason for a high awareness of the smart parking category and the perceived importance of the application could be the fact that in Split-Croatia (were most participants come from) there is popular and well-promoted smart parking application. The second biggest number of benefits is identified for water quality monitoring. The importance of prompt alerts and reaction in cases of contamination, raising awareness on water pollution and reducing undesirable effects on individuals' health, among other benefits, are all well-recognised by the group. Again, this is something of relevance to the group of respondents considering the isolated water-related incidents in the wider Split area (Rogulj, 2017).

The results contribute to considerable research on the topic of evaluating the information systems from end-users' perspectives. To date, the analysis of costs and benefits conducted from the perspective of (future) users of smart city applications has been underresearched, however. This study confirms that costs have to be adequately considered, not only from the perspective of a provider but also from the perspective of the user. In that, if prioritised and developed properly and based on the needs of the users, the costs of an integrated smart city application could be minimised for users, considering a great number of costs is common regardless of the function. At the same time, the benefits could be maximised as different functions could be bundled together and branded as part of an integrated smart city solution. Governing smart cities is becoming more complex – apart from resolving challenges arising from the evolution from the vertical to the horizontal integration of innovative smart city solutions (Frascella et al., 2018), the expectations for engaging various groups of stakeholders are growing as well. The vertical integration approach focuses on solving specific city problems leading to better resource management (e.g. improving energy efficiency, reducing water leakage) while the horizontal, transversal or holistic approach looks at the city as a system of systems and aims to integrate data from different sectors to manage the city better. In that regard, the conclusion of this study can contribute greatly, in the specific context of Split –

Croatia in particular. The approach can be applied in other settings as well, depending on the priorities of a city. Nevertheless, the costs would be expected to be comparable to the ones identified here even though the benefits might vary depending on the prioritised services. Benefits of an application containing information on water quality are closely related to users' (citizens') health – and as recent research stated, health and well-being agenda has the potential to shift the focus of smart cities to centre on social aims (Trencher & Karvonen, 2017). Undoubtedly, a widespread emergence of open data platforms containing health parameters that could be used within the smart city context would serve as a means to improve the lives of citizens. Complementing water quality monitoring, air quality is also an important factor to be considered in planning services for citizens (Forkan et al., 2019).

As a general note, the results from this study can be used in developing/improving future smart city projects to make sure that planned applications provide (at least) commonly perceived benefits. The devised and followed approach in determining the costs and benefits gives end-users' the opportunity to review and present an integrative view, where costs and benefits can be compared (Masera et al., 2018). In summation, the study contributed to elucidating the often neglected users' perspective and brought to the forefront a possible direction (area) to which city managers have to actively contribute.

# Conclusion

The whole smart city concept is considered complex, with a large number of stakeholders (Lee, 2010). The primary objective of the study was to examine the end-users' approach for identifying the costs and benefits of smart city applications. Besides a long list of perceived costs and benefits, results from this research solicited a huge number of specific benefits, which could be difficult to identify without the insights from end-users'. This qualitative approach provided a better insight into the end-user perspective.

It should be noted that the study has several limitations that impair broader generalisation of the findings. First, study was conducted with a younger generation of (future) users, the students. Even though it can be argued that students are at the same time in the role of citizens, it is evident that the student population shares common opinions, which can vary significantly from respondents in other age groups.

For getting a more objective insight into what users perceive as the most important costs and benefits, future research will include the quantitative analysis. Precisely, quantitative survey, will be used used to estimate the importance of both costs and benefits and the behaviour intention for each application. Factor analysis and linear regression model are planned to be used in order to inspect and predict the intention to use an integrated smart city solution comprising of the four selected applications the services. Furthermore, the geographical focus and limitation should also be addressed in future research, in particular, because some other studies confirm the effect of local factors on technology acceptance (Sepasgozar et al., 2019). It would be interesting to conduct a similar study in another city in Croatia and outside of Croatia to compare the results and enable the generalisation of the results.

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## About the authors

Mario Jadrić, Ph.D. is an Associate Professor at the Faculty of Economics, Business, and Tourism (FEBT), University of Split, Department of Business Informatics. Holds a PhD from the University of Zagreb, Faculty of Organization and Informatics. (Co)-author of more than 60 scientific papers on the topic of e-learning, technological innovations, business processes improvement and user perception of new technologies. He teaches E-learning in Business Environments, Business Process Simulation and Business Information Systems at undergraduate and graduate level and Computer Simulation at the PhD level. He is a member of the research team of MIS4SC project financed by Croatian Science Foundation and has participated in several international and national projects. The author can be contacted at **jadric@efst.hr.**

Tea Mijač is a teaching and research assistant at the University of Split, Faculty of Economics, Business and Tourism, Department of Business Informatics. Member of the research team of MIS4SC - User-oriented process (re)design and information systems modelling – a case of smart city services (project funded by Croatian Science Foundation). At the moment, she is enrolled in a PhD programme at the home institution. Up till now, she has been a co-author on more than ten published papers. Her research interests are the smart city, smart campus, data-driven development, information systems, digital services and user-oriented paradigm. Her previous working experience includes being Project Manager at Faculty of Science (EU project; Croatian Qualification Framework) and as Web Administrator (IPA project; LMS for visually impaired). The author can be contacted at **tea.mijac@efst.hr.**

Maja Ćukušić, PhD is an Associate Professor at FEBT, University of Split, Department of Business Informatics. Before joining academia, she worked for three years in a Dutch company in the design and implementation of complex ICT solutions for global markets. Currently, she is the manager and the principal investigator of the project financed by the Croatian Science Foundation on the topic of smart cities, leading the group of three PhD students and five international researchers. She is also a key expert for e-learning in the SEA-EU European University Alliance. In her teaching activities (courses OLAP systems, ERP systems, E-business, E-learning), she uses examples and studies on the use of business intelligence technologies, visualization tools (open data), smart devices and similar. The author can be contacted at **mcukusic@efst.hr.**