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Does Mobility Experience Matter? Insights from a Model-Oriented Practice in Zaragoza, Spain

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ABSTRACT
This study evaluates the role of model-oriented decision support systems in the understanding of complex variables related to urban mobility challenges. To this end, the MobilityExperience platform has been developed as a planning support system (PSSs) to contribute to better informed decision-making in citizens' commitment to climate neutrality and self-sufficient energy city policies. The results show that the three proposed visualization modes lead to an increase in understanding urban mobility; emphasize the importance of an interactive approach to reinforce the role of an increasing number of agents; and enable a deeper level of collaboration in a data ecosystem framework.

KEYWORDS
planning support system (PSS); smart planning; technology; urban science; urban mobility

Introduction

Many of the current problems and challenges in public policy and spatial planning are or may be addressed with the ideas and methods of complexity science. Urban mobility is one of these complex systems: millions of people live and interact from moment to moment and there are many kinds of interactions, such as bus journeys, car crashes, chats between neighbors, and business transactions (Ladyman and Wiesner, 2020). Although the incredible complexity of a city is becoming more related to people's behavior, and activities are becoming more person-based than place-based (Geertman, 2017), the fact is that simple predictable social behavior does sometimes arise. For instance, Bettencourt et al. (2007) found that pedestrians' walking speed is a function of population size.

To analyze complex behavior and simulate urban mobility, it is necessary to collate all the data to map the flow of vehicles, people, and information components in a city. The interactions between the components provide insights into complex urban mobility systems that help to understand, for instance, where the most congested areas are located (Kazak et al., 2018), or how the cities change in terms of shared mobility. Indeed, this understanding is decisive to evaluate if the outlined actions to improve

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the mobility of cities contribute to the achievement of the goals of climate neutrality and the energy self-sufficiency of cities (Kazak et al., 2019).

Daniel Sperling (2018) states that there is sufficient evidence that a triple revolution is taking place around mobility policies in cities to reach these goals. This triple revolution indicates that the trend is towards electrification, vehicle automation, and vehicle sharing, with the support of digitalization and new technological developments. Some of these actions include prioritizing the use of automated vehicles that provide transport services through mobility companies, as well as their management through intelligent devices, the existence of integrated mobility centers where other light modes of travel are available, or the reduction of the cost of travel, in terms of time, consumption, and emissions, for example. It is a revolution based on technology, but it requires the design of active policies to reach social involvement and acceptability.

To understand urban mobility it is necessary for urban planners to operate not only at a technical level but also at a citizen and user level. The need for urban planners to have adequate information to make decisions is no longer the problem; it is now necessary for those of us who live in a city to be aware of the consequences of our small daily decisions, as well as the advantages, in terms of cost and benefit, of each mode of transport. If we want to acquire a real commitment from society for an attractive and integrated mobility system, it is essential to assess comprehensively the complex network of environmental, energy, and accessibility costs associated with mobility. In addition, the challenge lies not only in converting data into knowledge, but also in knowing how to transfer it to contribute to better informed decision-making.

The *MobilityExperience* platform is a tool that helps people understand the implications of their actions. It also contributes to an evaluation of their commitment to climate neutrality by choosing the urban mobility option that works best for their lifestyle. The main impact of the platform is to provide insights into complex urban mobility systems by allowing us to test whether three different visualization modes can lead to an increased understanding of urban mobility.

The remainder of this article is organized as follows. The next two sections present an analysis of the main challenges faced by current planning support tools and provide the necessary context that justifies the design and conception of the platform, whose design and display modes try to respond to these challenges. The section after that provides the results obtained after testing the different approaches about PSS performance in an experimental study, to validate its user friendliness, usefulness, and functionality, and to measure to what extent the three different visualization modes from *MobilityExperience* lead to an increase in understanding urban mobility. Then the results are discussed and the limitations and implications of this study are outlined. Finally, the article ends with concluding remarks and ideas for future work.

Current Challenges Faced by Planning Support Systems

Digital technologies are increasingly being used to develop new decision-making tools for planning in order to contribute to making cities smart and the environment equitable and liveable (te Brömmelstroet, 2013; Goodspeed and Hackel, 2019; Pettit et al., 2018; Staffans et al., 2020). Visualization, digital dashboards, big data, and machine learning represent important approaches to foster the adoption of digital technologies into urban planning, especially with regard to analyzing and visualizing the complex and dynamic variables related to urban mobility processes (Young et al., 2021). Several planning support systems (PSSs) are being developed to provide practitioners, citizens, and other stakeholders with new planning tools (te Brömmelstroet and Bertolini, 2008; Grignard et al., 2018).

However, evidence suggests that there are multiple challenges in the use and adoption of PSSs (Arciniegas et al., 2013; te Brömmelstroet et al., 2016; Geertman, 2017; Pelzer et al., 2014; Vonk et al., 2005, 2007). In order to face these challenges, several practices have been developed (Punt et al., 2020) and their achievement has been evaluated in terms of user-friendliness, usefulness (te Brömmelstroet, 2017; Champlin et al., 2019), and functionality (Russo et al., 2018). According to these authors, a user-friendliness indicator relates to the ease of use for planning practitioners as the end users, a usefulness indicator evaluates whether a system allows people to achieve their desired goals easily and with satisfaction (Nielsen, 1993), and a functionality indicator refers to whether the system can do what is needed by users. Some of these practices focus on the linkage between the characteristics of user-friendliness and the potential added value of the interactive PSS, concluding that user-friendliness indicators have a positive effect on achieving planning and policy goals (te Brömmelstroet, 2017).

Visualization methods and interactive dashboards, in combination with various (real-time) data sources, provide a direct data communication with different stakeholders that was most apparent in the beginning of the last decade (Devisch et al., 2016; Smith and Martín, 2021; Valdez Young, 2015). Although there is an increasing interest in the development of big data systems for monitoring and sharing detailed information on trends and city achievements through user-friendly data visualizations, appropriate new toolkits are needed to help in the understanding of complex urban systems and attainable strategic goals and policies (Kourtit and Nijkamp, 2018). In terms of urban mobility and the triple revolution (Sperling, 2018), it is necessary to know the real commitment and demand from society towards an attractive and integrated mobility system. If a visualization mode provides information on the alternatives of urban mobility, and a comparative perspective on how these patterns have changed in recent years, then, it may provide knowledge to society on how their own urban mobility habits can contribute to achieving the abovementioned environmental planning and policy goals.

MobilityExperience Platform

The *MobilityExperience* platform is developed as a PSS based on the analysis and visualization of current urban mobility scenarios in the city of Zaragoza, Spain. This platform builds initial links between three visualization modes by comparing the current situation of vehicle flows and alternatives to urban mobility from a multidimensional perspective. The visualization modes are referred to as "Vehicle Flows," the "20 Min City," and "Transportation Cost."

This approach exemplifies an attempt to reflect on suitable strategies that represent the current dynamic flows of the city, and it is based on the multiplicity of data interactions (Ascott, 2007; Blasco Cubas, 2017; Hoelzl and Marie, 2016; Wattenberg and Viegas, 2008).

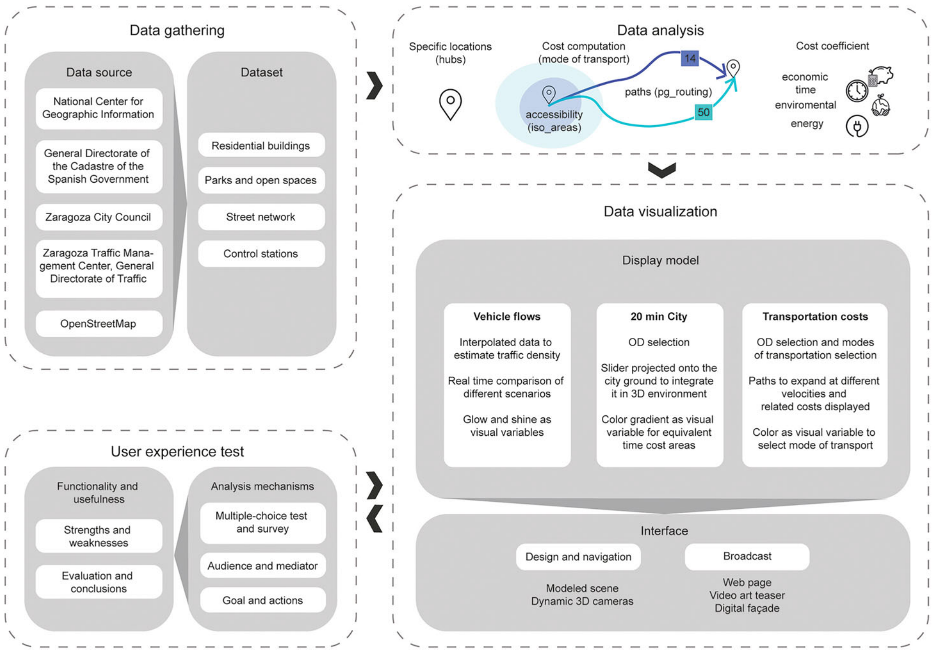

Figure 1: Conceptual model of workflow process
Source: Authors

The data-driven support function of the platform comprises data gathering, storage and retrieval of information, and communication and visualization of complex variables (See Figure 1).

Data Gathering, Storage, and Retrieval of Information

The variables that characterize the three display models are defined considering the city as a closed system. By predefining specific locations (hubs), computational cost is reduced, and it builds up a more dynamic and interactive user application. In this first prototype, 24 hubs homogeneously cover the city, and each of them represents the most relevant places from the point of view of urban mobility. Figure 2 shows the location of the 24 hubs.

As for the data sources, a vector cartographic base for defining the city geometry is provided by the National Center for Geographic Information and the General Directorate of Cadastre of the Spanish Government. Vector geodata for defining the street network have been retrieved from OpenStreetMap. Data obtained from the traffic flow sensors are provided by the Zaragoza City Council and the Zaragoza Traffic Management Center, General Directorate of Traffic, Spain. Spatial data sets cover the last 25 years, from 1995 to 2020.

Communication and Visualization of Complex Variables

The platform has been designed as a serious game intended for Entertainment-Education related to topics like traffic flow or environmental impact of different means

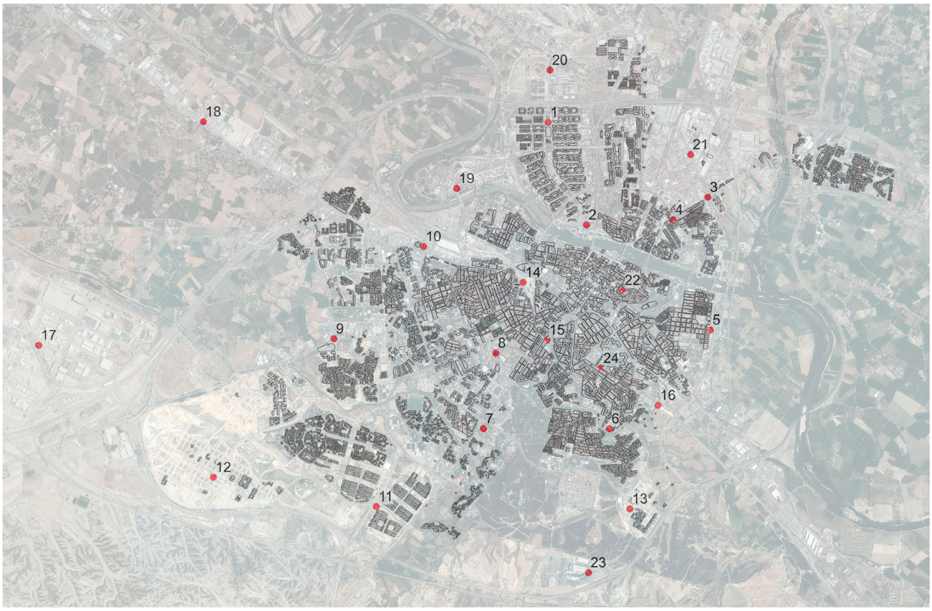

Figure 2: Location of hubs
Source: Authors

of transportation. In this regard, the PSS tool developed is useful for advanced users interested in, for example, comparing different situations, dates, event impacts, costs, or areas reachable within limited time frames. Nevertheless, it must prove attractive to the general public at learning environments and events, such as museums or expositions.

The selection of the three integrated graphic depictions of mobility in Zaragoza was motivated by previous research with the objective to analyze complex urban mobility variables and provide accurate information to different stakeholders of how daily decisions are aligned with the achievement of the goals of climate neutrality and energy self-sufficient cities (Ruiz-Varona, 2022).

A first visualization mode (Vehicle Flows) focuses on the current situation of vehicle flows in the city, where the more congested areas are located, or how vehicle flows change considering singular events or rush hours. By exploring this visualization mode, users learn if their mobility habits match with the most congested areas, or they can evaluate other routes more in line with their interests. A second visualization mode (20 Min City) assesses the perception of distance that the users may have from their city. As some authors have proved (Bettencourt et al., 2007), the perception of distance is determined by different parameters, such as the size of the population, so it is essential to represent a real situation of the city studied, including landmarks that are part of familiar routes for the user. A third visualization mode (Transportation Costs) compares the selection made of origin destination routes, which are made by the users, and provides information not only on distance but on a quadruple cost approach of those routes as well, considering the time, expenses, energy, and environmental cost of that route. This study explains how people can learn to choose wisely by learning where more sustainable mobility actions are available.

The analysis of the *MobilityExperience* platform would give evidence on how user friendliness is incorporated in the design process of the three visualization modes to reinforce the usefulness and functionality of the planning tool. The three visualizations require an interactive and functional graphic design (Kirk, 2019). Moreover, as it is an interactive product, the application must be easy to use, and the navigation system must be friendly, simple, and intuitive. User friendliness of the platform is based on technological development and smart media display interaction (Han et al., 2019; Pelzer et al., 2015; Wilson and Chakraborty, 2019), and it aims to provide immersive experiences among different stakeholders to contribute to the understanding of complex urban mobility in the city.

Draft considerations for the design include the fact that the user should be able to navigate freely through the modelled scene of the city, either by creating a view of the city as a whole or by setting a point of view as the real observation point of the space that the user can perceive while passing through. This requires simplification of urban reality. The built environment represents residential spaces and singular elements at the neighborhood level, together with the most recognizable open spaces at the city level. The Ebro River is considered the reference item to orient other spaces in Zaragoza city. Considering that the volume of detailed information affects design navigation and user experience, the spatial base has been defined in dark color, so that the represented items become the reference base to orient oneself on the visualized space at any time (Allanwood and Beare, 2019). On this spatial base, the three display models are activated. Common design criteria and cartographic code have been defined for each of these three visualizations, guaranteeing coherence and continuity of content. The visual variable is color and its definition and combination is based on the theory of opponent colors (Webster, 1996), which also reinforces the meaning of the different elements of the interface. Descriptive text labels and icons are located at key points in the interactive space and have been designed to make the user experience easily interpretable.

The navigation system allows the activation of, and easy interaction with each of the three display models and is a modular and intuitive way to experience all functionalities of the platform. In this sense, the information structure and visual design of the platform have focused on understanding how users respond to experiences and how they act (Norman, 1998), thus making the platform a didactic tool on the experience of urban mobility in the city.

The interface design is focused on simple interactions that allow for maximum functionality. The inclusion of three different visualization models, dynamic 3D cameras, and interactive modifiers and selectors enable users to select and display detailed information about mobility, accessibility, or traffic with just a few clicks or touches. The main input devices considered include tactile screens, mice, and any kind of pointing interface. The complexity and details of data analysis, calculations, and estimations are hidden behind a friendly interface that transforms data research into a playful experience. Virtual reality interaction has been similarly designed using controllers as pointer input devices and allowing the user to "fly" around. Augmented reality could work in the same way as long as devices support pointing interaction seamlessly.

Furthermore, application design provides different platforms for the dissemination of the tool (Champlin et al., 2019). The informational and accessible nature of the Internet transforms it into a broadcast channel to reach this aim, and this first prototype is easily

Figure 3: Launch of *MobilityExperience* platform at the European Mobility Week in Zaragoza
Source: Authors

accessible on a single web page, from where it can be run on an interactive table or laptop by the user (Pettit et al., 2017). Additionally, three video art teasers have been designed to be projected on a 600 sqm digital media façade (See Figure 3). The media façade is a communication medium that uses the facades of buildings through integration of electronic technology to disseminate graphic discourses capable of being integrated into the urban landscape (Haeusler et al., 2013).

Each of these three visualization models can be accessed independently, and the variables that characterize them are calculated by applying heuristic algorithms. The methodology is based on street networks analysis tools provided by QGIS software (Boeing, 2017). Data processing and real-time rendering according to the criterion definition and selection of variables are accomplished through the Unity game engine and C# as the main programming language. Unity mainly operates to interact, render, and draw on the screen, while C# scripts are the cornerstone of data management, including loading, saving, and calculation.

Although multiple state-of-the-art open-source game engines are available with useful tools and capabilities that could be used to develop the PSS under consideration, Unity has been chosen for quality, performance, and productivity reasons, together with the possibility to port the application to multiple platforms.

Using a professional game engine as the main development tool improves the workflow in the different stages of the process as game engines are designed to support hundreds of entities while running at 30–60 frames per second. Game engines not only improve performance, but also offer tools that help optimize applications, assisting in the search for bottlenecks that could destroy the fluency and smoothness of any interactive experience. Regarding the study's urban context and Zaragoza city renderings (buildings, roads, and paths), optimization and game development techniques are implemented to provide users with a real-time and fluent experience, which helps to orient the visualization to the physical references.

Moreover, the implemented tools are designed to support the construction of complex and portable interfaces in the easiest possible practice, so as to attain suitable usability and functionality (Nielsen, 1993). This cutting-edge technology also enables developers to export a visualization to different platforms, such as *Windows*, *Mac*, *HTML5*, and *HTC Vive* virtual reality.

Vehicle Flows

This study aims to provide insights into the effects of mobility on cities, where the most congested areas are located, or how the cities change in terms of shared mobility. Different visualization modes allow for establishing links between traffic flows and recent historical events in the city (Verendel and Yeh, 2019). In particular, detailed information of vehicle flows during the lockdown in Zaragoza due to the COVID-19 pandemic is included for comparison purposes.

Data sets including data regarding the number of vehicles per minute in certain locations of the city were obtained from the Urban Mobility Service of Zaragoza City Council. This information was processed to obtain the number of vehicles per hour. A total of 732 traffic sensors (temporal and permanent) have been collecting data for the last 25 years. The two types of traffic sensors differ in terms of the coverage period and location: permanent traffic sensors cover fixed locations for long durations, whereas temporal ones are installed to collect data in certain locations for a period of 24 hours. For simplicity, this first prototype only considers data provided by permanent traffic sensors.

Vehicle flow data retrieved from permanent sensors is interpolated to include road lanes, estimate traffic density, and distribute vehicles evenly. Road lanes glow and shine according to the number of vehicles and vehicle density, respectively, at a specified date and time. The ability to compare the two different scenarios in real time is outlined by defining the same city area frameworks separately, so that the differences between the two events become clear when compared side by side (See Figure 4).

20 Min City

This model depicts the travel time to reach different urban hubs in Zaragoza depending on the mode of transport. The aim is to reflect and compare the areas accessible to pedestrians and those using other modes in 20 minutes (Cruise et al., 2017; Ellis et al., 2016; Handy and Niemeier, 1997; Tang et al., 2020). Network analysis is applied to calculate accessibility areas. The different modes of transport include walking, cycling, public transit, and private vehicle. For calculation purposes, walking and cycling speeds correspond to 4 and 12 kilometers per hour, respectively. Public transit includes urban bus service (average speed of 14 kilometers per hour) and single tram line (Ayuntamiento de Zaragoza, 2017). The maximum speed of urban roads is considered for calculations of private vehicles. Although the maximum speed is not always reached, the difference in speed compensates for the stopping time at intersections, traffic lights, and crosswalks,

Figure 4: Vehicle flow display model example
Source: Authors

which was not considered in the initial calculation. Results are compared in real-time, and a correction coefficient was applied.

This model visually presents real distances according to the selected mode of transport and a specific time slot. A color gradient is used to help identify equivalent zones and time costs. The final image can be cropped live using a slider and is projected onto the city ground to integrate the information with the 3D city map (See Figure 5).

Transportation Costs

This model provides information on the cost of traveling from one hub to another in Zaragoza depending on the selected mode of transport. The main objective of the visualization is to monitor and measure the cost of different variables related to urban mobility. Specifically, the platform distinguishes four types of travel costs: energy cost,

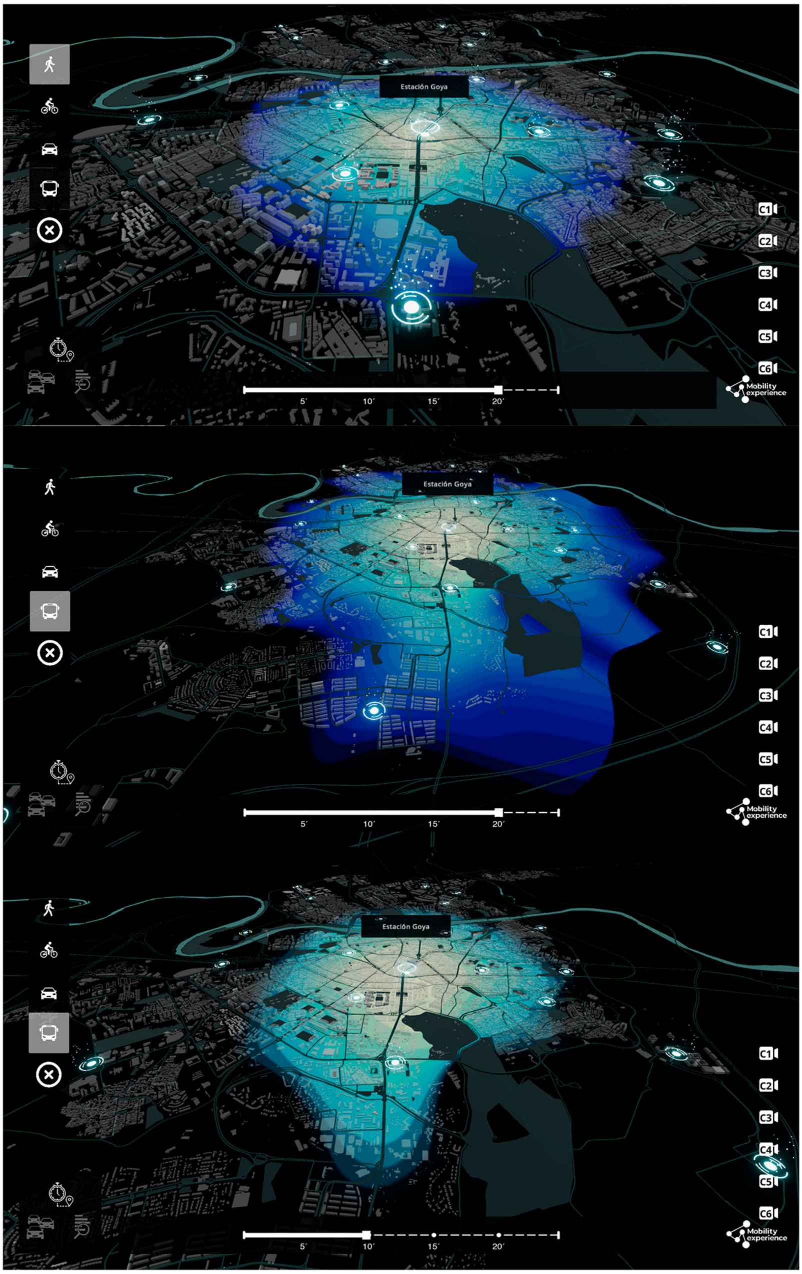

Figure 5: Accessibility display model example
Source: Authors

environmental or pollutant emissions cost, time cost, and economic cost. For this calculation, the distances between each of the nodes were considered, as well as the different coefficients per kilometer associated with each type of cost. The distances were calculated in real time by defining the point of origin and destination, as well as the selected mode of transport. Two hubs were selected and the colored paths between them provide information about different modes of transport. In addition, the paths were expanded at different speeds to provide additional information on which route was the fastest and which the slowest (See Figure 6).

In the upper right corner, the cost related to each mode of transport is shown, including time, energy, emissions, and economic cost. The cost is calculated by multiplying the real distance corresponding to the distance travelled on the virtual map and the related cost coefficient (See Table 1).

The energy cost is related to the energy consumption required for transportation. A purposeful literature review on approaches to assess consumption ratios for walking and cycling was carried out (Marshall et al., 2009; Rojas-Rueda et al., 2011, 2016; Sasaki et al., 2015; Shcherbina et al., 2017; WHO, 2017). The consumption values for private vehicle take into account the age of the vehicle fleet from the last available census (Ministerio del Interior, 2020). Vehicle consumption values were retrieved from the manufacturer technical documentation, and comparative studies developed by main agencies at the national (IDAE, 2020a, 2020b) and European level (European

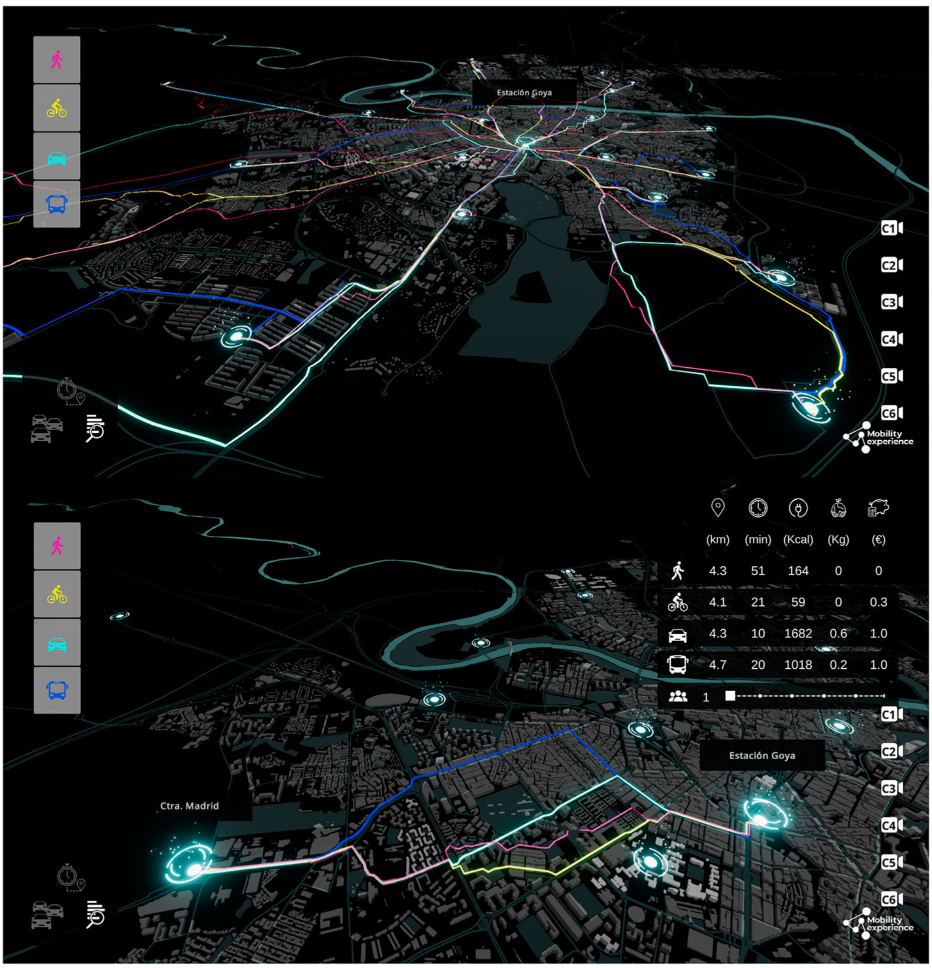

Figure 6: Transportation costs display model example
Source: Authors

Table 1: Cost coefficient for each mode of transport

Mean of transport	Cost per user ratio (Km)		
	Energy (Kcal)	Environmental (Kg)	Economic (€)
Walking	38,20	0,00	0,00
Bike	14,30	0,00	0,07
Car	393,98	0,13	0,23
Transit	217,40	0,05	0,22

Source: Authors

Environment Agency, 2019a). Since the coefficient was calculated per user or passenger, the average values are divided by the average occupancy of private vehicles (Ayuntamiento de Zaragoza, 2017, 2018). Extant studies (European Commission, 2017; Graurs et al., 2015; Kammuang-lue and Boonjun, 2019; National Research Council, 2011) and technical specifications of vehicles providing services in Zaragoza city (Ortego-Bielsa et al., 2015) report the energy consumption of public transport, including both buses and trams.

To calculate the environmental (or pollutant emissions) cost coefficient, it was necessary to consider two types of emissions: those that affect global warming (CO_2) and those that affect human health (NOX, CO, unburned HC, lead compounds, sulfur dioxide, and PM). The former are related to the greenhouse effect, whereas the latter are more harmful at the city level. Only emissions affecting global warming (CO_2) were taken into account in this study. The environmental cost was considered zero for walking and cycling (WHO, 2017). To calculate the emission values for public transit and private vehicles, the emission value per passenger provided by the Institute for Energy Diversification and Saving (IDAE, 2020a, 2020b) and the European Environment Agency (2019b), respectively, was taken as reference.

The economic cost coefficient was calculated per user, considering not only fixed costs but also variable costs, which depend on the estimated number of kilometers travelled per year. Considering the private vehicle, the fixed costs correspond to the purchase or rental price, the amortization period, vehicle insurance, and the parking cost (an average from private parking, rental, and parking ordinances). Variable costs include fuel and car repairs. The same calculation method was applied to bicycles, except for the cost of parking as it is not regulated in these economic terms. As for public transport, the price of a regular user's ticket has been considered, without taking into account the subsidy from the city council, which currently covers part of the costs of public transport. This methodology was contrasted with studies carried out at the local, national, and European level (IDAE, 2019; Vera-Ovejas, 2016; WHO, 2017).

Results

By measuring the user-friendliness, usefulness, and functionality of the *MobilityExperience* platform in a user experience test, we evaluated the performance of the PSS and aimed to validate this platform as a suitable tool for interacting with complex urban mobility variables. Furthermore, by organizing an immersive exhibition workshop to test the *MobilityExperience* platform, we provided insights on whether the three visualization modes led to an increased understanding of urban mobility.

User Test Experience

User experience has become one of the major topics related to interactive applications (Cybulski and Horbiński, 2020; Filippi and Motyl, 2020), and it has been employed to evaluate and measure the user-friendliness, usefulness, and functionality of platforms (Marcus, 2011; Pelzer, 2017). For this purpose, the user experience methodology considered three definition phases in the test.

The target audience is the first phase, as it is important to take into account how people acquire, internalize, process, or externalize information based on sensations, perceptions, and interactions to achieve greater productivity, accuracy, and satisfaction. The second refers to objectives and metrics. The definition of questions and actions to be performed by the users focus on the goals and require an indicator to evaluate success and failure (quantitative approach), and behavior and emotional experience (qualitative data). Finally, the third one includes a journaled session and a mediator to moderate and observe the test while analyzing the users' behavior. The mediator explains the objectives to be achieved through the test.

The twelve-question multiple-choice test was conducted through *Kahoot*, a real-time gamification-based application (See Table 2, Q1–Q12).

In this interactive test, users are asked to perform a series of tasks to interact with the *MobilityExperience* interface, in order to discover specific issues such as how to navigate, how to perform specific actions, what are the positive perceptions of the platform, or what functionalities are missing. These perceptions allow the team to improve the application to ensure adequate user experience. The test results provide details such as the reason for correct answers, the average time taken by the user to perform a task, and the number of users who successfully complete the task (See Table 3).

In addition, a five-question survey has been designed using Microsoft Forms to be completed individually after testing the platform (See Table 2, Q13–Q17). It has been defined to provide qualitative data about the platform and assesses users' considerations of the usefulness, strengths, and weaknesses of the platform (See Table 3).

Table 2: Multiple-choice test and survey questions

Multiple-Choice Test				Survey	
Q1	How many display options does the platform offer?	Q7	Which icon indicates the energy costs per user required to move?	Q13	Do you think the application is easy to use?
Q2	To activate the display of scrolling times, which icon should I press?	Q8	What is the energy cost per user required to make the movement indicated in the image on foot?	Q14	What did you like most about the application?
Q3	From which hub do all the routes represented in the image start?	Q9	Select the means of transport that generates the most emissions, per user	Q15	What did you like least about the application?
Q4	You have 15 minutes to go from hub22 to hub10. According to the image, are you on time?	Q10	To activate the visualization of vehicle flows, which icon should be pressed?	Q16	What did you think of graphic design?
Q5	To activate the display of travel costs, which icon should I press?	Q11	The image represents the flow of vehicles on the day hub10 was inaugurated, at what time?	Q17	Do you think you would use this application again?
Q6	According to the image, how long does it take to walk from hub22 to hub15?	Q12	According to the image, which day was there the greatest flow of vehicles in the city?		

Source: Authors

Table 3: Platform analysis mechanism, goals, indicators, and metrics

Analysis mechanism	Goal	Actions	Questions	Indicator	Metrics
Multiple-choice test	To explore the strengths and weaknesses (SW) of the user interface (UI) application to guarantee a proper conceptual understanding	Ability to differentiate three display models	Q1	Number of correct answers	Quantitative
		Ability to understand features from the different display models	Q4	Number of correct answers and time to answer	
			Q6, Q8–Q9, Q12	Number of correct answers	
		Ability to understand the display organization and placement of features	Q11	Number of correct answers and time to answer	
	To explore features to improve in terms of the technical and design quality	Ability to formally recognize the map	Q3	Number of correct answers	
		Ability to recognize meaning of icons	Q2, Q5, Q7, Q10		
		Ability to identify the meaning of the color palette	Q4, Q12	Number of correct answers and time to answer	
	To identify those functionalities and tasks more difficult to perform or understand	Ability to differentiate three display models	Q1		
		Ability to perform a multicriteria selection according to different parameters	Q8, Q9		
		Ability to execute a task	Q1–Q12	Number of users who complete the task successfully and number of correct answers per test	
Survey	To explore the usefulness and functionality		Q13, Q17	Measuring the topics subjected to study	Qualitative
	To explore the SW of the platform		Q14–Q16		

Source: Authors

This evaluation based on the test and survey as analysis mechanisms allows for greater user participation in decision making, thus contributing to the effectiveness of the platform interaction (Damodaran, 1996). The data obtained on user experience provide improvements in the graphical user interface for communication based on progress and improvements in interaction once the results have been analyzed (Molina et al., 2012; Norman and Nielsen, 2010).

As the data-driven *MobilityExperience* platform was launched in September 2020—at one of the events organized in Zaragoza on the occasion of the European Mobility Week 2020 (See Figure 6)—a pilot study was conducted to evaluate the platform. Citizens and planning practitioners tested this platform in different workshops and webinars organized during the fall semester to evaluate its usefulness and functionality. The sample of participants (n = 92) was self-selected to take part in the pilot study during a webinar organized by USJSénior, an adult education university extension. Once the mediator introduced the platform and demonstrated its functionality, the user experience test was conducted (See Figures 7 and 8).

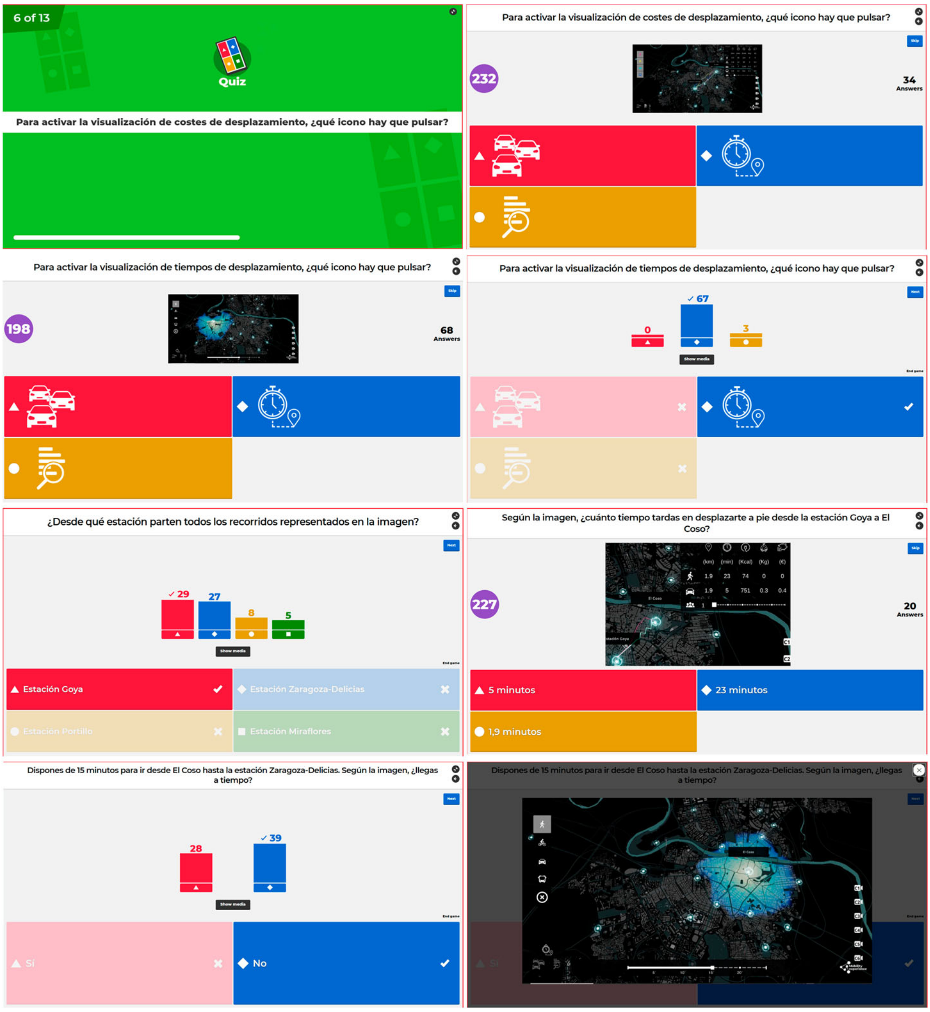

Figure 7: Screenshots of the users experience test, conducted on December 17, 2020
Source: Authors

The test results indicate that correct answers represent 59.45 percent of the total number of answers and that the mean and median of the number of correct answers per test were 8.3 and 9, respectively (See Figure 9). Taking into account the different nature of the questions (See Table 3), some findings can be drawn by analyzing the percentage of correct answers and the average time taken by the user to perform a task (See Figure 10).

Most of the questions to evaluate user-friendliness, usefulness, and functionality of the platform were answered satisfactorily. Prior to the test, participants were informed about the different display models of the *MobilityExperience* platform; however, they found it difficult to navigate between the models when interacting with the platform. Interestingly, the results reveal that the time taken to answer Q1, compared to the questions that were also answered incorrectly, was higher than the others. This demonstrates that the ability to differentiate the three display models is obtained from understanding the platform, not from previous knowledge. This also reveals that a home display would

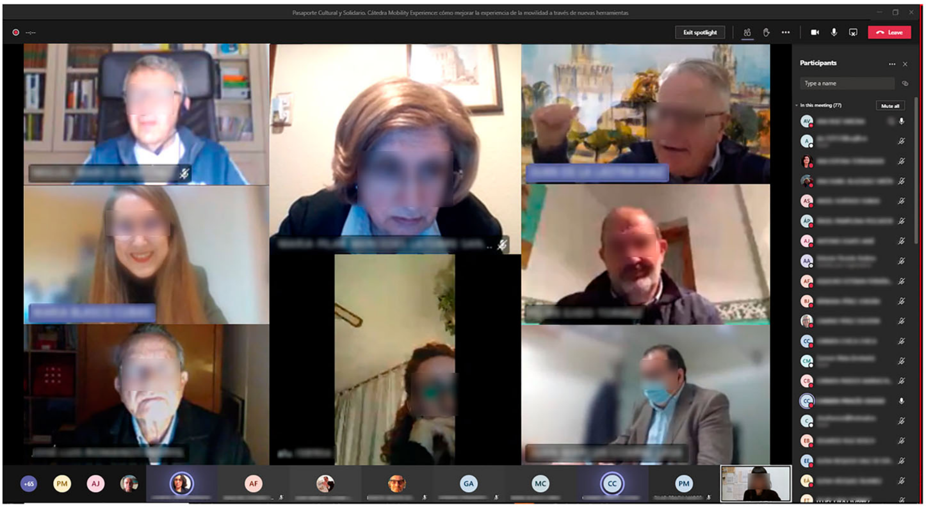

Figure 8: Participants and mediator interacting in the webinar, conducted on December 17, 2020
Source: Authors

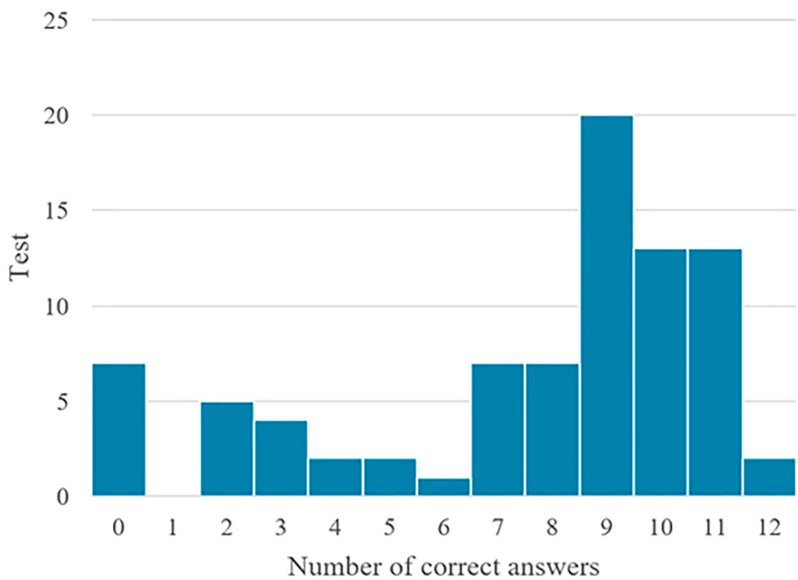

Figure 9: Number of correct answers per test
Source: Authors

be helpful to easily identify the three display modes, without the need to include additional information.

In addition, the information provided by the platform was easily handled and the features were understood using the different display models (Q6, Q8–Q9, Q12). Some specific features were difficult to understand considering their location, and more time was needed to answer Q11. Although the time taken to answer Q11 (28 seconds) was

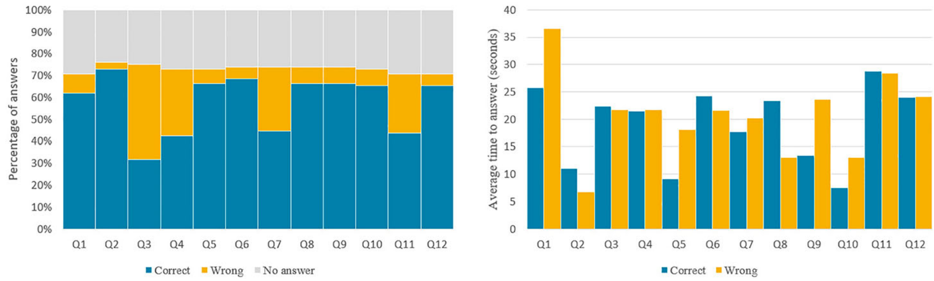

Figure 10: Percentage of correct answers and average time taken by the participants, 2020
Source: Authors

relatively longer than that required for others, the time span is considered reasonable, as average time taken to answer was 20 seconds per question.

Interestingly, there were significant differences in the answers to the questions that evaluated the user-friendliness of the platform. The lowest number of correct answers was obtained in Q3 (32 percent), which tried to evaluate the understanding of the map to analyze mobility. The identification of the different hubs was not easy if relying exclusively on the interpretation of the map by the participants. Q4 also obtained a lower-than-average correct response rate (42 percent); it is possible that one of the difficulties encountered in interpreting this assumption was related to the fact that the hubs mentioned in the question did not have identifiers labeled on the image. This necessitated the inclusion of (●)a permanent text identification of the hubs, instead of the provisional one that currently appears.

The rest of the questions aimed at assessing user-friendliness have an above-average response rate, and the time taken to answer the questions—both correctly and incorrectly answered—is one of the lowest of all the questions provided.

Furthermore, users demonstrated knowledge of the platform's functionality and easily identified the access icons in response to questions 2, 5, 7, and 10. Based on both the percentage of correct answers (73 percent) and the response time (11 and 7 seconds for questions answered correctly and incorrectly, respectively), the most easily recognizable icon corresponds to "20 Min City," which is represented by a clock (Q2). However, it is worth noting that one of the most difficult icons to identify relates to energy and environmental costs, with a response rate of 29 percent. This reflects a lack of awareness of the related costs when considering mobility.

Comprehension functionalities were measured by assessing the ability to differentiate between visualization models, to make a multi-criteria selection based on different parameters, and to execute a task. The questions related to the three capabilities obtained an adequate rate of correct answers, with those related to the first two having an above-average rate of correct answers.

A comparative analysis of the results of Q8 and Q9 reveals that the percentage of correct answers was the same (66 percent), whereas the time taken to respond varied considerably. The average time taken to answer Q8 (23 seconds) was relatively longer than the one taken to answer Q9 (13 seconds). To answer both questions, it was necessary for the user to interpret the dynamic cost table provided with the display model. The time taken to answer both questions included the time required to understand how the information was provided and how to answer the queries. Since the procedure was the same for both questions, the time required to answer decreased considerably from Q8 to Q9, almost by half. In addition, although the percentage of incorrect answers is low (8 percent), the response time increased from Q8 to Q9, potentially due to confusion in the interpretation of the pivot table, since Q8 is a closed question and Q10 required comparing values for different means of transport.

Immersive Exhibition Workshop

Although this test gives evidence for the validation of the *MobilityExperience* platform, it is necessary to assess whether the three visualization modes from the platform led to a greater understanding of urban mobility. The previous test addressed a specific question related to learning and understanding complex urban mobility systems. To add value to this research question, a second test was developed under different usage conditions. The role of the three visualization modes in helping to achieve a better understanding of complex urban mobility systems was evaluated by designing an immersive experience in an exhibition workshop. This exhibition was installed and opened to the public in September 2021, on the occasion of European Mobility Week 2021, and was available until March 2022.

The visual immersive experience was based on a motion sensor input device from which the user (player) interacted with the platform. The player was required to answer a series of questions related to the three visualization modes that the platform launched while presenting the experience. The platform alternated questions related to each of the three visualizations and each player had to answer the same number of questions for each of the visualizations. A sample question was sent for each of the three displays:

- *Vehicle Flows*: On November 30, 1995, Michael Jackson's concert was held in the city of Zaragoza. At what time of the day was there the greatest flow of vehicles at the most congested point in the city
- *20 Min City*: you have to travel from Hub 1 to Hub 2, and the travel time has to be 20 minutes. By which means of transport?
- *Transportation Cost*: you must travel from Hub 1 to Hub 2, with an environmental cost of 0.2 kilograms of CO_2 emissions per passenger. Which mode of transport do you use?

The type of questions were multiple choice, and the player not only demonstrated if he or she understood the information provided by the platform but also confirmed if he or she acquired the necessary knowledge to answer the question correctly (See Figure 11).

During the six months that the platform was active, guided tours for schools and families were conducted, as well as other activities focused on all citizens interested in data visualization and urban mobility. The number of experiences per day were 7.3 and the average number of correct answers per experience reached 69 percent. Several visits were organized, and a group discussion was held as a part of the immersive exhibition workshop. The results show that, prior to the immersive experience, players had little consideration for environmentally related transportation and energy costs. In

Figure 11: Immersive exhibition test
Source: Authors

fact, most participants evaluated their urban mobility habits from a more critical point of view, in terms of a greater commitment to climate neutrality goals.

Discussion

Based on extant research and empirical results from experimental case studies of different PSSs that have been developed in the last decade, this study focused on the complex urban mobility systems and hypothesized whether different visualization modes lead to an increase in understanding urban mobility.

As previous studies mentioned, PSS are not frequently used because they are not adequately adapted to users' needs, as they are considered difficult to use (Russo et al., 2018). In this sense, the group discussion towards the end of the event, together with the survey, provided some important insights, in line with similar experimental case studies.

In terms of functionality, some participants suggested making changes to the tool to provide better navigation support and a mobile responsive design. As the performance of the *MobilityExperience* platform was evaluated under different conditions, participants concluded that the usefulness of the application lied in informing their daily activities (Champlin, 2019). They recommended improving user interaction on mobile devices and including a home display model. In addition, the controllers were found to be more touch-sensitive than expected, making it difficult to navigate and adjust the visualization to the selected sector of the city. However, the dynamic 3D cameras provided sufficient views to support the functionality of the platform. In addition, interactive analysis of mobility patterns based on the three visualizations required comprehensive spatial references. Some users found it difficult to maintain their sense of location when visualization provided a changing camera view. Therefore, easy spatial reference

Table 4: Strengths and weaknesses of the tool

Strengths	Weaknesses
Multicriteria-based and dynamic mobility app	Only as interoperable as the data availability
More atractive and interactive than other real time applications	Not as flexible as other real time applications (GoogleMaps)
Responsiveness of tool attributes	Not a as responsive design as expected on mobile app
Easy operation of tools	Lack of home display to present functionality of tools
Focus on content with a clear data visualization	Lack of text identification at hubs
Easy navigation support and simplified built environment depiction	Using controllers are more touch sensitive than expected
Exchange of knowledge through an explorative user experience	Limited software support
Suitable for webinars, teaching and strategic scenario planning	

Source: Authors

was required to better understand the user's mental models (Russo et al., 2018). Some participants suggested making the platform more accessible and expanding it to include other cities, which is flattering as well as challenging.

In terms of usefulness and user-friendliness, the design and aesthetic of the platform was especially valued, as it favored the understanding of complex variables in a more intuitive and interactive way. In general terms, users positively valued the usefulness and usability of the support tool, particularly considering that the application offered integrated help documentation as part of the experience (Russo et al., 2018). In addition, the informative feature of the platform allowed the user to decide how important accessibility, sharing, proximity, or environmental, expenses, and energy costs are in their everyday mobility pattern. This point was widely discussed among participants as they considered the platform to be innovative compared to other existing applications designed to provide optimal route calculation based on distance, time, and economic cost criteria. Taking all the above mentioned into account, and contrary to Geertman (2017), this case study did reveal that the *MobilityExperience* platform can become a valuable tool in planning practice.

However, the immersive exhibition experience revealed that there is a lack of awareness about the environmental and energy cost of mobility among people. Although results revealed an increased understanding of urban mobility systems in the city, and provided participants with alternatives and information to contribute to better informed decision-making, the fact remains that there is still a gap between the increased understanding of complex and dynamic variables related to urban mobility processes and the actual contribution of PSS to real-world problems (Punt, 2020) and, more specifically, to society's commitment towards climate neutrality and energy self-sufficient cities. In this sense, participants' perceptions revealed their concern about the transferability of the application's knowledge to children and young people, not only because it raises awareness and provides information to make informed decisions about everyday mobility, but also because its friendly interface turns the understanding of the data into a playful experience (See Table 4).

Conclusion

The data driven *MobilityExperience* platform offers new approaches to understanding and exploring the impact of urban mobility on quality of life. Visualization as a guide to exploring the meaning of data is important, and this platform represents an example of how visualization can contribute to the effective implementation of a dynamic, interactive, and interoperable PSS in the smart planning process. *MobilityExperience* transforms data into knowledge and has an interactive geo-visual environment to transmit that knowledge and interact effectively with citizens.

The main advantages of this platform are twofold. First, it is a data-driven heuristic platform. It presents three models to visualize urban mobility and provides the user with parameter settings to understand the effect of different variables on planning and transportation. Second, it has an interactive framework that allows users to choose between the different parameters and understand the importance of accessibility, time, distance, and carbon footprint reduction in their daily mobility pattern.

The user experience test and the immersive exhibition workshop both verified the functionality and usability of the platform. They assessed whether the three visualization modes led to a better understanding of urban mobility and revealed that *MobilityExperience* is a remarkable reference as a PSS to be integrated into the planning and decision-making process.

To improve the functionality of the platform, it is important to enhance user interaction when accessing it from mobile devices and to include a home display model. In addition, given that people are less aware of the environmental and energy costs of mobility and its effect on travel routes, it is suggested that the platform be applied to existing applications that take into account distance, time, and economic cost criteria. Although this study concerns a specific case in a specific period, the results reveal insights related to the platform's effectiveness that are worth further investigation, and the methodology is directly transferable to other locations and data sets. A desirable step to improve the presented method would be to focus on real-time data and to reconcile the attention paid to environmental and energy cost with the calculation of travel routes. Although this experience reveals that these three modes trigger learning, further research is needed to better understand the role of different modes in visualizing complex urban mobility.

Finally, there is a continuous and increasingly satisfactory interaction between the content provided in the three visualization models, the PSS tool, and the mobility experience in the city. The results also reveal that understanding the data in a user-friendly environment is important, and that collaboration between universities, local governments, and citizens is necessary to achieve this purpose.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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