

A Design Proposal of Integrated Smart Mobility Application for Travel Behavior Change towards Sustainable Mobility

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Abstract The private car dependency is prevalent due to its comfort, privacy, and convenience. However, it is challenging for the cities in environmental and economic aspects. The widespread car use arises from the urban network and land use pattern besides peoples' personal preferences. The study's concern is reducing car dependency. The study questions "how to empower behavior change with the use of smart mobility applications for sustainable mobility." The study aims to promote travel behavior change by leveraging technology through an integrated smart system design proposal, which is entitled Sustainability Aware Travel Service (SATS). SATS offers a smart mobile application for the citizens and a connected data platform for the decision-makers. The SATS platform bridges these different actors: the app aggregates the user travel data, and the data platform monitors user data to support mobility-related decisions. The paper presents a conceptual framework of this system. This paper aims to contribute to existing smart mobility applications by promoting active mobility modes, cycling, and walking.

Keywords Sustainable Mobility, Travel Behavior Change, Smart Mobility Applications, Urban Data Platform

1. Introduction

The mobility preferences of people mainly depend on driving in the cities. Private car use is preferable due to its comfort, privacy, and convenience. Apart from personal preferences, the condition of transportation infrastructure and mobility services are influential in private car use. The private car use has overgrown considerably during the last decades. According to the World Business Council for Sustainable Development (WBCSD) report, cars have 69% of all km traveled in Europe [1]. Private car use increased by 20% in the past 20 years [1]. Increasing car use poses a threat to sustainability. According to the International Energy Agency, the transportation system is responsible for 30% of total energy-related carbon dioxide emissions [2]. The agency predicts that the percentage can rise to 50% by 2030 and 80% by 2050 unless taking precautions [3].

The car use causes pollution, high costs of travel, loss of time in traffic, and lack of user experience of an urban environment. Based on these outcomes, the study describes private car use as a vital problem for the cities. These facts underline the significance of sustainable mobility modes. Sustainable mobility enables the movement with minimal environmental and territorial impact while satisfying travel needs. Benevolo and other colleagues [4] point out that smart technologies play a

significant role in the travelers' attitude towards mobility choices. The research aims to explore the ways of encouraging people to other sustainable mobility modes, instead of car use. The study questions "how to support users' behavior change and policymakers' strategy to promote users' QoL in mobility with the use of smart mobility applications." This research seeks to contribute both to user's travel behavior change and policymakers' mobility strategies.

A considerable amount of literature is available on smart mobility. Based on the literature review, there is a gap in intelligent services that serve both citizens' demands. This gap creates a need for an integrated application that provides communication between the stakeholders, planners, and citizens on the same platform. This paper presents a conceptual design of a smart mobility service, entitled as SATS, which stands for Sustainability Aware Travel Services. The SATS combines an application and platform in an integrated service. The SATS adopts a user-centric approach to the decision-making process of urban design. The motivation of the SATS is to improve citizens' quality of life by changing travel behavior and support decision-makers' decisions.

According to the study, travel behavior change is the driver, and quality of life is the outcome for sustainable mobility. People have to change travel behavior to perform sustainable mobility, and sustainable mobility improves the quality of life of individuals. Smart initiatives have the potential to raise user awareness on travel attitude. Therefore, the literature review urges upon these following questions:

- How to achieve behavior change;
- What are the parameters of QoL related to mobility;
- How to improve QoL with behavior change;
- What is the state of the art in smart mobility;
- How the relevant studies foster the design of SATS?

1.1. Behavior Change Towards Sustainable Mobility for QoL

Regarding the sustainable mobility strategies [5], the research concentrates on shifting the demand towards sustainable travel modes with the use of smart technologies. Banister [5] points out that its applicability depends on the understanding and acceptance of individuals. This section investigates the points to achieve behavior change with smart applications.

Cinderby and other colleagues [6] state that the bottom-up approach with personalized social marketing empowers the individual to make an informed choice. As a result, users reduce car use and increase cycling for travel [6]. Besides the bottom-up approach, continuous support for personal travel planning activities is essential for long-term behavior change [7]. Congratulating the users with updated changes, and challenging them to pursue travel behavior with the prize system can be the actions for

ongoing support.

Another factor in sustaining behavior change is positive behavioral support. The quality of life is a shared value that provides this behavioral support [8]. The quality of life (QoL) is 'the people's perceptions of life quality concerning their culture and value systems [9]. The modern lifestyle decays individuals' QoL due to inactive behavior dominance. The focus of this study is the mobility and health related QoL parameters, listed below:

- Environmental quality (average exposure to air pollution and land use factors);
- Personal health status (illness rate and life expectancy);
- The work-life balance (the duration of commuting);
- Mobility (travel mode and ticket price).

This study utilizes ICT to raise awareness aiming to shift travel behavior towards sustainable mobility modes. The use of ICT has a vital impact on managing travel activities and peoples' mobility behavior [11]. The ICT supported smart mobility services contribute to a reduction in congestion, accidents, within vehicle-dependent air pollution and noise. Among smart mobility systems, MaaS stands for mobility as a service. MaaS offers tailored mobility packages and additional services such as real-time planning, reservations, and payments for different transport modes [12]. MaaS aims to provide 'door-to-door mobility' for users' [12].

This research analyses several MaaS applications. This analysis reveals that the existing MaaS applications are district and disconnected systems. For instance, the user utilizes different MaaS applications for different services, such as pricing and timetable information, payment, and journey planning. They lack presenting extensive customization options. The user has to utilize different applications to exploit mobility services.

Regarding the drawbacks of existing MaaS programs, SATS seeks to combine the services in one application program. Thus, the user can access many options in one application instead of using different services. The study suggests that integrating a MaaS application with an urban data platform would be useful for both users and policymakers. This integrated application makes a bridge between users and planners in sustainable mobility.

Urban data platforms engage citizens with stakeholders. The data platforms utilize many datasets from multiple sources to provide a holistic view of the city's functioning [13]. They perform as data aggregators by gathering multiple datasets under a single roof [14]. Tuncer and You [14] denote that these platforms create an interface as a strategic step for smart governance. They allow developing data-driven methodologies for informed urban management. Reference [13] categorize the levels of insights provided by platforms:

- Critical insight for recommendations;
- Analytical insight for patterns;

- Strategic insight for decisions.
- Operational insight for urban characteristics.

1.2. State of Art in Smart Mobility

Thus far, this paper explains the scope and goals of the data platforms. This section reviews the existing data platforms. The study limits the examples with Km4City and Informed Design Platform focusing on user-data. Tuncer and You [14] develop a data platform named 'Informed Design Platform (IDP)' as a part of the Livable Places project. The IDP platform adopts a data-driven approach to provide insight into livable public spaces [14]. The platform utilizes the usage pattern and perceptions of the crowd. It includes multi-sourced data concerning place, time, and people concepts, categorized in utilization, activity, opinion, and sensing parameters [14]. As another example, the researchers from Distributed Systems and Internet Technologies Laboratory (2015) develop a knowledge model for the city (Km4City) [15]. Nesi and others [15] state that Km4City brings a new approach to smart city APIs. The platform combines open data from the administration, private data coming from users and transportation system managers, and manage static and dynamic data. The objective of the Km4City platform is to support decisions about city infrastructure management. The platform measures and monitors the citizens' movement flow in parking and transportation hubs [15].

The existing data platforms mainly concentrate on processing statistical data. The studies that consider people's tendencies and routines about travel behavior are rare. Km4City takes the user data as input; however, it lacks displaying the trends of the crowds. The study distinguishes with its user-intrinsic data coming from the use of the app. The study deals with the social aspects of sustainable mobility by monitoring users' travel behavior patterns.

The researchers conduct a literature review to respond to the questions indicated in the previous section. The points for long-term impact are implementing personalized social marketing strategies, providing ongoing support with updated services, and positive behavior support. The enhancement of the quality of life is the outcome of the study. The study uses smart mobility services as a tool to alter users' travel behavior. For positive behavior support, the SATS application can involve a recommendation system. The system recommends according to the users' preferences. The user can get information about their financial savings, personal health benefits, and environmental benefits when they change travel behavior. The SATS application's objective is twofold: First, the SATS encourages people to change their travel behavior considering sustainability to improve their life quality through the smart app. Second, the app's connection with a data platform supports policymakers' mobility decisions in long-term.

2. Materials and Methods

The SATS is a model for the combination of an application and an urban data platform. Therefore, the methodology of the SATS system follows in two separate branches; the conceptual design of the SATS application and the SATS urban platform. Figure 1 is a workflow diagram that displays the general framework for two branches of the system. As shown in the workflow diagram, the SATS system's output becomes an input for the platform. Both two parts consist of data collection, analysis, user interaction, and representation stages. SATS seeks to target both the citizens and policymakers by improving the QoL of individuals and supporting policymakers' decision-making in mobility. Regarding two different target groups, the system will have three types of interaction, which are user-application, user-platform, and policymaker-platform interaction.

This study will be conducted in Istanbul. Istanbul suffers from traffic congestion. The INRIX publishes Global Traffic Scorecard report that represents the mobility trends and traffic congestion in the major cities of the world. Based on the results of INRIX [16] report, Istanbul is ranked as the 4th worst city in terms of traffic congestion, with a 6% increase. People spent approximately 157 in traffic in 2019. Other reason of why Istanbul is selected derives from the low well-being performance indicator, and unsatisfactory conditions in quality of life survey research conducted by OECD [17]. A series of researches has been conducted about mobility pattern analysis in the case of Istanbul. The research studies are intended for assess the relationship between user travel time and trip number, traveled with motorized vehicles [18]; between residential status and travel behavior [19]; travel demand indicators and urban form by comparing different cities [20]. There are also a series of reports about mobility strategies in Istanbul, which are organized by institutions or non-profit organizations (NGOs). For example, Smart Mobility Public Transport Report [21] presents the roadmap of Istanbul for smart mobility; while Sustainable Urban Mobility Report [22] examines the mobility condition in Istanbul considering other demographic, geographic, economic and legal parameters. The SATS proposal seeks to contribute the strategies of *supporting sustainable and healthy choices* and *promoting to use active mobility mode*, as indicated in [21]. It also aims to support the quantitative evaluation of users' mobility pattern by monitoring it in its platform.

2.1. Conceptual Design of SATS Application and Platform

The motivation for designing the SATS application comes from people's increasing tendency to use social media and carry smartphones. The key concerns in smart mobility applications are making people aware of their mobility behavior by displaying the impact of their actions

on the environment, their financial budget, or time spent traveling. What differs SATS from relevant applications is that it gives more information about QoL and other motivation factors to stimulate sustainable mobility. It gathers user data in the platform's database with user permission for long-term behavior support. Table 1 displays the expected features of the SATS application.

We identify the guidelines for data collection, data flow and process, and user interface to draw a conceptual framework. For data collection, we determine what type of data is collected by the developer, and what kind of data obtained from the application used as input. Regarding the dimensions of QoL, the required input data is described based on the travel modes. We gather the primary data from relevant institutions, while the secondary data through the APIS and crowdsourcing. The data flow stage describes how to transform input data to output via the application and transmit it to the stakeholders, as shown in Figure 1. The system will perform the following tasks to process information; travel planning, different travel options based on travel modes and traffic, and journey evaluation, assisting in generating a mobility database based on user travel patterns and preferences. In user interface design, we determine the criterion expected to meet, as following:

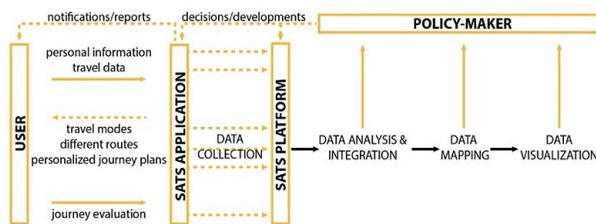


Figure 1. Conceptual Design of the SATS System (drawn by authors).

- Clear for simple user interaction;
- Consistent and well-structure to ease the use;
- Flexible for interoperability with other smart devices;
- The convenient interface design for user-friendliness;
- The use of color palette that evokes the sustainability.

While the existing data platforms focus on evaluating the physical and spatial quality of the urban environment, the SATS platform will monitor users' travel prefer. Instead of the time and cost-intensive surveying methods for data collection in travel behavior, the platform aims to collect data through the application automatically. The SATS platform acts as a bridge between decision-makers and users: it aggregates the user data from the mobile app. It visualizes to support decision-makers in terms of sustainable mobility. The study's contribution is to exploit smart technology to understand the citizens' travel behavior aiming for long-term behavior change. The study

hypothesizes that the platform might have a long-term impact on changing individuals' travel behavior towards sustainable mobility by creating awareness on users and assisting policymakers for user-centric informed decisions.

The SATS platform's motivation is implementing a data-driven approach to understand and analyze user behavior in terms of sustainable mobility.

The study hypothesizes that the platform might have a long-term impact on changing individuals' travel behavior towards sustainable mobility by creating awareness on users and assisting policymakers for user-centric informed decisions. The SATS platform is developed, aiming to:

- Find out what factors are more influential for behavior change;
- Monitor to what extent the user changes the travel behavior and how long to observe the behavior change;
- Understand how the application influences individuals' behavior and how it contributes to sustainability.

The SATS platform consists of three main elements; (i) an information model that integrates multiple data types (ii) an interface with control panel, dashboard for information visualizations (as diagram and graphics), and (iii) an interactive map that shows spatial information. SATS platform will be an online, interactive, open-sourced, and web-based mapping platform. Additionally, the platform would be user-centric, flexible, and open. Openness means being accessible through public APIs and having open-source content open to development. Flexibility means leveraging from different programming languages such as Python, R, and SQL to develop the platform.

2.2. Data Collection

For data collection, we integrate different input data types derived from both user and developer; therefore, we categorize the input datasets as user input datasets and developer input datasets. The first dataset consists of the user travel mode preference, commuting travel patterns, user travel data (kcal, produced CO), GPS traces, the rates, and comments within images. We plan to obtain the user data via the SATS smart mobile application. These data types are unstructured data and mainly based on qualitative data. The second dataset consists of the road network, infrastructure, station and charging stations, the timetable, traffic density, existing air quality. These data types are structured and mainly based on quantitative data. The database is categorized according to the dimensions of QoL indicators, as stated in the OECD [9] framework. Regarding the aspects of QoL, Table 2 describes how the system functions in terms of data management

Table 1. The Features of the SATS Application (drawn by authors)

Application	SATS - Sustainability Aware Travel Services
Scheme (Area) and Status (Year)	Istanbul / Development phase (2019 - ...)
Transport modes related services	Public transport (including local transport modes) Walking paths Bike-sharing Car sharing, including e-cars Parking places Charging stations
Platform & Tariff option	Application and website Pay-per-use
Available functionalities	Real-time information / Trip planning / Booking (and cancellations if needed) Ticketing / Payment /Service alerts Informing about quality of life as an individual/ Database for policymakers Virtual budget / Physical activity diary
Type of actors involved Service aggregator User of technologies	Public and private actors Third-party GPS / e-Pay
Personalization	Input personal address, preferable transport modes Store regular and preferred (favorite) routes / Store tickets Saved (often visited) locations Optimized travel plan based on user's daily agenda (through agenda synchronization) and most environmentally friendly
Customizations	Enable route accessibility for people with special needs Enable mode filtering based on cost, CO ₂ footprint and the calories burned Identify the benefits of improving your QoL

Table 2. The input datasets and output information for the data platform

CATEGORIES	INPUT		DATA TYPE & MAPPING INTO	OUTPUT	
	BY DEVELOPERS	BY USERS		FOR POLICYMAKERS (THROUGH THE PLATFORM)	FOR USERS (THROUGH THE APPLICATION)
1. Mobility					
1.1. Passive Mobility					
public transportation	public transportation services network (GIS & OPM) locations of the stops and timetables of public transportation the travel expenses of public transportation services traffic condition (Google Maps/ Yandex traffic services)	choice of public transportation selecting journey type (single/daily commute) ranking public transportation quality demands such as public transportation services for time table, location of stops review and comments	Map the GPS traces and find the location based clusters	map of the public transportation preferences and the most used network show the ranks/ reviews and demands for public transportation services decision support for improvement and satisfaction of the road conditions	travel planning based on traffic and public transportation conditions cost & time estimation for transit travel mode Shows the quality of public transportation according to specific parameters comparison between the public transportation and other travel modes in terms of cost, health and air quality
Car - sharing system & electric car	road network (GIS&OPM) traffic condition (Google Maps traffic services) locations of car-sharing points & gas/fuel stations locations of electric stations and parking lots cost of the use of car-sharing system fuel/ gas per km cost of the electric per km	-Choice of car-sharing system -Ranking car-sharing services according to specific parameters -Demand for locations of new car-sharing points -Ranking electric car services according to specific parameters -Demand for locations of new electric stations and parking lots	Map the GPS routes, reviews Categorize based on rankings in grading scale	-Map the most used car-sharing and electric car network and ranking its quality -Map the car-sharing demand within the routes and rankings -Map demand for locations of new electric stations and parking lots -Display the reviews -Decision support for improvement of the electric car services -Decision support for improvement of the car-sharing system	-Travel planning for car-sharing system based on traffic condition and rankings -Cost calculation based on the fuel/gas per km & electric use per km -Shows the car-sharing quality and electric car quality based on the rankings -Comparison between the electric car use, car-sharing systems and motor vehicles in terms of cost, health and air quality
1.2. Active Mobility					
Cycling/ electric bike Bike sharing system	cycling road network (GIS) locations of bike parking lots locations of bike-sharing points cost of the bike-sharing per hour cost of the bike-sharing per hour locations of electric stations cost of the electric per km	-Choice of cycling/ bike sharing and electric bike -Ranking the cycling experience according to specific parameters -Ranking bike sharing and cycling quality (with images and reviews) -Demand the locations of new bike parking lots/ new bike-sharing stops and electric charge stations	Map the GPS routes, reviews Categorize based on rankings in grading scale	-Map the most used cycling route and most visited bike parking lots -Show the demand for locations of new bike parking lots and routes, bike-sharing parkings and routes -Display the reviews -Decision support for improving the physical infrastructure and promoting the use of bicycle within the bike-sharing systems	-Travel planning for cycling based on the rankings -Show the cycling quality and bike-sharing system performance according to specific parameters -Comparison between cycling and other travel modes in terms of cost, health and air quality
Walking	street network (GIS) street views (Google Earth)	choice of walking Ranking the walking experience according to specific parameters (with images and reviews)	Map the GPS routes, reviews Categorize based on rankings in grading scale	-Map the most used cycling route and most visited bike parking lots -Show the inadequacies and demands in physical infrastructure and physical elements -Display the reviews -Decision support for improving the physical infrastructure and urban environment for walkability	Suggestions of different routes Travel planning for walking Shows the walking quality according to specific parameters Comparison between walking and other travel modes in terms of cost, health and air quality
2. Work-life Balance					
Duration of commute	road network within land use (GIS)	tagging the home and working place (GPS tracing and travel time) ranking of the commuting time between home-work	Map the GPS routes, reviews Categorize based on rankings in grading scale	Display the most used commuting time between home-work Decision support for new employment area considering commuting time	Show the commuting time between home-work Display the most preferred commuting network for each area
3. Health Status					
Lung disease related	effect of air pollution on diseases air quality map road network	user health condition (related with lung disease) (optional)	Map the GPS routes, reviews Categorize based on rankings in grading scale	-Map the lung disease distribution for each area -Map the most active zones based on user preferences -Decision support for population health issues	-Calculation the amount of effect on diseases according to different travel modes -Calculation the consumed calori in whole travel (based on walking and cycling distance) -The amount of decreased risk of obesity in case of walking and cycling -Personal physical activity diary -Comparative analysis between different travel modes in terms of physical activity
Personal health data / obesity risk related	consumed cal per m according to the type activity	Height Weight Fat Percentage (optional)			
4. Environmental quality					
Air quality	quantity of air pollution produced by fossil powered motor vehicles the air quality map	users' travel mode choice	Map the GPS routes, reviews Categorize based on rankings in grading scale	Map the air pollution change Decision support for decreasing air pollution	Calculation of produced air pollution by users' preferences for each travel Comparative analysis between different travel modes in terms of air pollution

2.3. Data Analysis

We implement data mining techniques to obtain useful information from different data sources. Data mining is the synthesis of statistics, machine learning, information theory, and computing to generate evidence-based insight into decision making [22]. The data mining process consists of three main stages; (1) data preparation, (2) data analysis, (3) evaluation of patterns, and interpretation as knowledge [23]. Data mining stages are inserting, classifying, clustering, and associating to reveal the hidden relations between datasets. In data preparation, we transform the multi-source unstructured data into structured numerical data frames. The semantic data-

derived from the comments- can be enumerated through the sentiment analysis. The ranking data can be evaluated with a graded system, using a grading scale of 1-5, with a ranking algorithm [24]. We analyze the metadata of photos to evaluate the popularity of routes. These different input data, which comes from the application, are connected with their geo-location. We organize datasets based on their spatio-temporal information (coordination, date & time) and create a database. Then, we will apply the clustering algorithm to classify datasets based on their interdependencies. K-means and DBSCAN are two of the most used clustering algorithms. DBSCAN stands for density-based spatial clustering of applications with noise. K-means is a distance-based clustering technique; while,

DBSCAN is density-based. These clustering analysis methods depend on distance between the points. The research will employ the K-means clustering analysis method, which basically divides n observations into k clusters to decrease the square error objective function where d is the distance between the data point and the mean of the cluster [25], as shown in Equation (1).

$$\sum_{j=1}^k \sum_{i=1}^n (d_j^i)^2 \quad (1)$$

We apply the K-means clustering method to find the clustered pattern in the neighborhoods. Further, we apply the gravity-based population-potential model on the clusters to explain the relations based on distance and population of the neighborhoods. Gravity models are the mathematical formulations to analyze and predict the spatial interaction models [26].

The types of gravity models are (1) origin-based, (2) destination-based and (3) network or potential models [19]. The potential models measure the network of relation between places, illustrated by potential surface maps. Ravenstein adapts the gravity model, based originally on Newton's gravity law, to social sciences first to measure the migration patterns [26]. Equation 2 both describes the gravity model and gravity potential model. In the gravity model, where ij is the interaction between places i and j , k is a constant, P_i and P_j are measures of the size of places i and j (e.g., populations), d_{ij} is the distance between places i and j , and b is the friction of distance. In the gravity potential model, where V_i is the population potential of place i , M_j is the population of j , and d_{ij} is the distance that separates place i and j [26]. Here, we take the most used GPS traces as input for distance and the active user number for population of the location.

$$G_{ij} = G M_i M_j / d_{ij}^2 \quad V_i = \sum M_j / d_{ij} \quad (2)$$

We plan to use Python and R programming tools for data analysis and visualization. Weka and RapidMiner are the other effective programs for data mining.

2.4. Data Mapping and Visualization

The study employs a Web-GIS environment for data mapping. It is an advanced form of Geospatial Information System available on the web platform and allows users to manage all their geographic data. GIS environment works commonly with vector data (geometrical data) in shape-file format raw data in structured CSV file format. By structuring the metadata into CSV file format with its geo-coordinates, other types of data (text, image) can be used in a GIS environment to provide spatial information. We will process the relational databases in a programming environment (such as Java code or R) for data visualization. In further steps, the study seeks to benefit from the existing GIS-based maps. The SATS platform interface includes the following components:

- A control panel (on the top) that allows selecting the analysis measures,
- The analysis results of the parameters (on the left),
- Interactive map (in the middle),
- A dashboard for the information panel (on the right) displays the selected zone's statistical data as visual information (Figure 2). 2.5 SATS System Interactions

This paper examines the general framework for the interaction between the target groups and the SATS system under three categories: user-application, user-platform, and policymaker-platform.

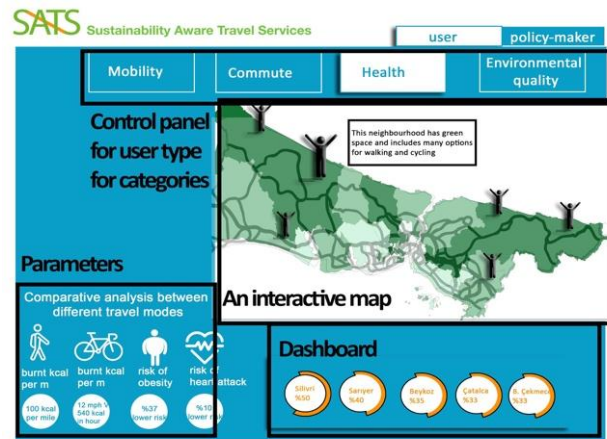


Figure 2. The interface of the SATS platform (drawn by authors).

2.4.1. User-Application Interaction

The application interacts with the user in six stages. First, **creating a user profile** is to start to use the app. The users define user profile information, while other input data such as height, weight, and fat percentage are optional. There is an option to add friends from the existing users or inviting via a link. This feature of the application aims to promote the use and create a commune awareness in society. In terms of privacy settings, they could have public, private, or semi-public profiles. The public profile is open to every user, semi-profile is open to friends, and personal profile is closed to anyone. The options of creating a virtual budget and physical activity diary customize the use of applications according to users' activity and budget to provide personal spaces aiming to sustain the behavior change. The user can control their travel expenses with a virtual budget to observe daily & monthly costs and savings. In a physical activity diary, the users' physical activities can be tracked daily & monthly and saved automatically.

Second, **planning a journey** presents two types of travel: a single trip and a daily commute. For a single trip, origin and destination points are necessary. If they search for a daily commute, they need to save their home, work, or school locations. They can also define the time range for their daily commute.

Third, **selecting an option** presents users the sustainable mobility choices to promote behavior change. There will

be six different options, including different travel modes for the same journey. The six categories are determined as follows: i- user-friendly, ii- cost-friendly, iii-social friendly, iv- environment-friendly, v- time-friendly, and vi-health friendly according to users' priorities. There will be brief information about categories such as time, cost, emission level, and consumed energy. When one of the options is selected, brief information will be given (including time, travel expenses, emission level, and energy). The system generates different routes for each travel chosen mode. For instance, for a cost-friendly option, the user will get financial-weighted information, and the travel options will be generated based on cost, time, and energy. The priority of the information and parameters determining the routes shows variation according to the selected option. The ways differ based on travel mode. The system recognizes urban spatial quality for walking and cycling, the service capacity, the number of public transportation changes, and congestion and air quality for car use. For instance, in selecting private car use or car sharing, the user can be informed about the air pollution level in the zones by

choosing different routes.

The fourth step is to **rate the journey** after completed. The reason for the evaluation stage is gathering data for the platform and investigating the reasons behind the users' travel behavior. According to the travel modes' selection, the app displays different parameters to rank are physical and personal parameters:

- The quality of transportation infrastructure, the timetable of public transportation, the convenience for walkability and cyclability, land use pattern;
- Information quality of the service, Journey experience, safety, time, and cost-efficiency.

We rank the survey options according to selected travel modes: public transportation, car-sharing, electric car, bike-sharing, electric bike, cycling, and walkability. The system allows including comment or photo regarding the journey. These comments and images will be informative to evaluate the trip's experience and the quality of the urban platform.

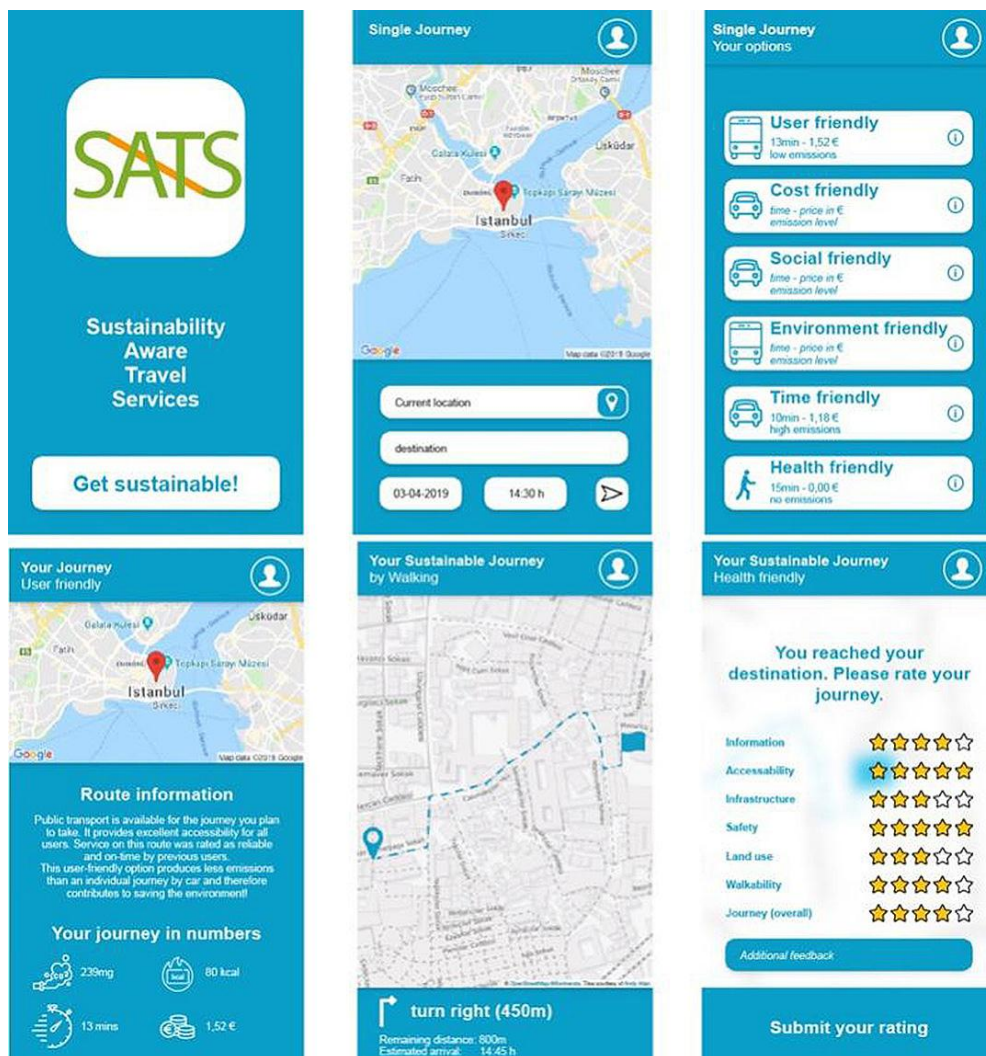


Figure 3. SATS Application Interface (drawn by authors).

The fifth feature is **receiving notifications** about the SATS platform. The users' travel preferences, marks, comments, and images will be input for the platform, and policymakers will develop their strategies according to these analyses. We plan to deliver general information about transportation, health conditions of the society, or annual reports about the air quality to the users via the notifications. We aim to show the users that their decisions and feedback could play an essential role in policymakers' decisions. The last feature is **checking the homepage**. The notifications and news edited by developers and decision-makers, the friends' actions, and all information will be available on the homepage. With those options, we aim to create social interaction between the SATS and users and increase public awareness in terms of sustainable mobility. Figure 3 displays the particular stages of interaction via the application interface.

2.4.2. User-Platform Interaction

The user can engage with the platform both via mobile application and web application. The platform gives information about urban mobility situations based on identified QoL parameters: mobility, commute, health, and environmental quality. In the **mobility parameter**, the user can get information about the public transportation network, timetable, and cost. The users can decide which transportation mode would be more efficient in terms of health, travel expense, and time by comparing transit modes. The platform displays the problematic or preferable road segments, based on the users' comments and rankings. For the active-mobility modes selection (cycling and walking), the platform shows the benefits of active mobility in terms of cost, health, time, and air quality with graphs and statistics in the dashboard. The users can monitor each neighborhood's ranking score; thus, their awareness level of mobility can increase. For the **commuting parameter**, each user can observe their commute time and work-life balance diagrams. The data can be compared with other users' outputs anonymously to see the effects of travel mode choices on their work-life balance. In the **health parameter**, the users can observe the ranking of road segments in terms of air quality and create their healthy route based on the rankings. They can also create a personal physical activity diary, which measures the decrease in risk of obesity via walking and cycling, and compare the impact of different travel modes on physical activity. In the **environmental quality parameter**, the map of air pollution of each zone from the interactive map will be available. Besides, this parameter would be useful for vulnerable groups who suffer from lung disease. In contrast, the other group of users can see

the percentage of the risk of lung-related diseases derived from air pollution. Figure 4 displays the user interface of the SATS platform.

2.4.3. Policymaker-Platform Interaction

The platform enables policymakers to implement a data-driven approach during the decision-making process in terms of mobility. The platform's output information mainly assists in developing transportation-related urban systems decisions based on the identified QoL parameters. In the **mobility parameter**, the policymaker can monitor the condition of the transportation system and services, and user travel patterns, within preferences. By observing the user travel pattern, we plan to identify the factors that affect behavior change to promote active mobility.

The factors can show differentiation according to the characteristics of the neighborhood. For instance, for the region with low income, the cost-effectiveness can be the primary driver for behavioral change. On the other hand, for a business district, time efficiency can be the primary driver; accordingly, the transportation strategy can be more time-efficiency oriented in these areas. These outcomes show the importance of customization of the neighborhoods. Moreover, we plan to monitor citizens' demands on physical infrastructure, stations, the condition, and quality of the public transportation system, the quality of the built environment via the platform. The user ranking can help to detect the road network and infrastructure elements that need to be improved. The high rated routes could be a role model for the improvements. With the help of the **commuting parameter**, the policymaker can track the commuting pattern of the citizens. We plan to identify the traffic congestion based on the user commuting routes. In the long term, this parameter can assist policymakers in making decisions in the new employment area. From the **health parameter**, the planners can gather information about the distribution of vulnerable groups in the city and direct transportation decisions considering this or concentrate clean mobility strategies, particularly in these regions. In the **environmental quality parameter**, policymakers can analyze the vehicle-related air pollution density. They can detect the risk area in terms of air pollution. They can prepare developers' annual reports in terms of mobility, and develop the long-term mobility strategies based on the annual report. Besides data monitoring and decision support, the platform allows policymakers to include the notifications about the new developments in transportation services and feedback on the comments and demands of citizens. This feature opens up opportunities in citizen-governance and participation.

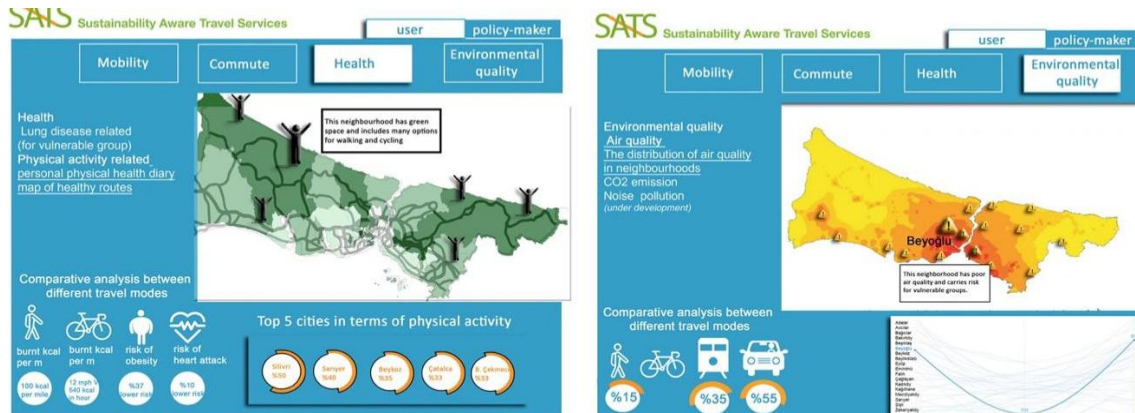


Figure 4. The User Interface in Health and Environmental Quality Parameters (drawn by authors).

3. The Expected Results

We elaborate on the project's expected results in three main aspects: behavioral change of the people towards more sustainable mobility, increase in quality of life, and decision support system for urban planning. It is expected that individuals' travel choices can change towards sustainable mobility with the SATS system. This system can promote ongoing support, which is vital to maintain the behavioral change for long-term benefit, with its notifications and customized application use. The expected results are a decrease in air pollution, noise pollution, and CO₂ emission in terms of environmental quality. In terms of health status, the expected results are an increase in people's daily physical activity level and a decrease in their fat percentage. An expected reduction in air pollution derived from carbon-based transportation will provide more fresh air, especially for people suffering from respiratory diseases, which are lung cancer, asthma, or bronchitis. In terms of work-life balance, we foresee a rise in productivity in the workplace due to less commuting time and more physical activity.

We also expect an increase in cost-time efficiency in daily commute journeys. In terms of mobility, one of the expectations is an increase in sustainable mobility modes. We expect users to shift travel demand to lower-carbon modes such as walking, cycling, and electric vehicles. Last but not least, we assume that the expansion of the MaaS with an integrated system has contribution decision systems in urban planning by including data-driven methodologies. Last but not least, we think that the expansion of the MaaS with an integrated system has a contribution to decision systems in urban planning by adding data-driven methodologies. We believe that this system encourages the citizens' motivation for participation in the urban planning decisions since it allows them to comment, rank and make recommendations on existing built environment conditions, and follow the results of this evaluation. We foresee clear communication between the users and policymakers via the SATS platform. The SATS might be a starting point for the cities to implement smart

governance in the city. The project can contribute to scientific knowledge in the field of evidence-based urban analysis and design. Overall, the most significant expected result is designing and planning more sustainable neighborhoods regarding mobility following these contributions.

4. Discussion and Conclusions

This paper concerns the conceptual framework of the SATS to present an innovative solution for travel behavior change. The literature review addresses the research questions of how to achieve behavioral change towards sustainable mobility with ICT for increasing QoL. The SATS system differs from the existing MaaS application with the integrity of the application and platform. The second difference of the SATS derives from being more user-friendly and open to customization. The other difference is the way of collecting information and diversity of information content. The system will gather user opinions via ranking evaluation, updated simultaneously, rather than surveying methods. It will benefit multiple data-sources for data collection ranging from images, rankings, to reviews. The advanced options to process various user data would be an innovative side of the project. The ways of data processing are quantifying comments and other user data, detecting clusters in different data types, and mapping it according to geo-location.

To conclude the research, the researchers discuss the limitations and present recommendations about the project for further studies. First of all, the prevalent use is crucial to maximizing the benefits of the system. The developers should be sure that people use the application because the use rate of many MaaS applications is low. The second point is the promotion and marketing strategies for the application. Another point is the inclusion of sociological and physiological reasons for people's travel behavior. Most people consider using a car as a prestige. Lastly, the researcher should drill down the details of computational

methods to provide the dynamic information flow between the application and platform. This study will follow a case study design in Istanbul. The reason is the insufficient level in QoL measures and the high level of car-dependency, compared to other European countries. The customization of the SATS system to the context brings both possibilities and limitations. For further stages, the system can be useful both for real estate and tourism. The more ranked places in the SATS can become the points of interest (POI). The ranking and comment option can be useful to detect attractive public spaces, for real estate and tourism development. The study recommends that integrating smart services with ambient intelligence through the sensors. The integration of RFID technologies with the SATS app improves the quality and accuracy of the data platform. The data platform can monitor the activity pattern of the crowds in real-time.

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