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ISSN (Print: 2537-0154, online: 2537-0162)
International Journal on:
The Academic Research Community Publication
DOI: 10.21625/archive.v5i1.814

Design of Sustainable Smart Bus Station; Case Study of Bilecik, Turkey

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Abstract

The urbanization rate has increased with the emerging fact of rural-to-urban immigration after the industrial revolution, thus causing various urban problems based on rapid population growth. Today, transportation and traffic problems in cities are becoming more prominent, growing with each passing day. Along with the rapid population growth in cities, as leading to an increase in the number of vehicles, preference of east-to-implement & shallow measures, instead of drastic and radical solutions in the infrastructure, operation, administration and controlling of the unplanned urbanization. Public transportation vehicles play a critical role in the lives of many, living in cities. The city-dwellers generally use public transportation vehicles as they leave their homes in order to get to the workplaces or schools. Facing with certain problems in transportation due to the buses being delayed while waiting at the bus stops, they may be late for where they are expected to arrive due to the delay of buses. In other words, it is a critical fact that people know where the bus they take is and how long it will take until they arrive at the bus stop.

Keywords

Urban aesthetic; smart stop; sustainable design; urban furniture design

1. Introduction

Providing a more comfortable living space to users in urban areas is important for the development of the urban furniture industry which is not yet sufficient in our country. Bulut et al. (2008) The reinforcement elements define the properties and objects that facilitate the life of the person in the urban fabric and provide the communication between the users, give the space a certain meaning in terms of functionality and aesthetics, having different qualities and quantities, defining and completing the space. For this reason, in addition to functionality, urban reinforcement elements are of great importance in terms of their revitalizing effects that make the urban landscape dynamic (Akyol 2006; Aksu 2013).

In addition to urban reinforcement elements, “as bus stops seating elements, billboards, etc.” many factors such as artificial environment, architecture, lifestyle, and culture of the city are effective in giving cities an identity. The concept of urban identity expresses different characteristics of cities rather than similar ones and reveals the original and different aspects of cities (Lynch, 1960). Urban reinforcement elements come to the fore in the presentation of the original publication of the cities. Instead of standardizing urban reinforcement elements, it is important to make original designs that consider the features and functions of each space (Bayazıt and Kısakürek, 2020). Unsustainable

mobility is introduced as a major challenge in cities. Urban designers can offer certain solutions for the mitigation of the environmental issues introduced by the increased vehicle circulation and urban sprawl such as creating urban forms encouraging walking and increasing the use of public transportation (Stojanovski, 2020). Public transport stops are commonly considered merely as the functional elements of the transport system. The design thereof is based on technical parameters and standardization. However, public transports can find themselves an important spot in the urban environment. Moreover, they are in concurrence with the generation and enhancement of the public spaces. Nevertheless, the idea of transportation infrastructures as urban spaces is primarily referred to as major railway, subway, or intermodal stations in all respects (Brovarone, 2020).

The urbanization rate has increased with the emerging fact of rural-to-urban immigration after the industrial revolution, thus causing various urban problems based on rapid population growth. Today, transportation and traffic problems in cities are becoming more prominent, growing with each passing day. Along with the rapid population growth in cities, as leading to an increase in the number of vehicles, preference of east-to-implement & shallow measures, instead of drastic and radical solutions in the infrastructure, operation, administration and controlling of the unplanned urbanization. Public transportation vehicles play a critical role in the lives of many, living in cities. Thanks to developing technology, urban furniture situated in transportation transfer centers can be designed with smart systems and performed and designed with functions aim to inform, interaction and recreation. (Najafidashtape, 2018). Bus stops are areas where one or more bus loading areas take place, depending on the number of buses that will simultaneously use the stop. Optimal positioning of bus stops for passengers and operators, which constitute an important part of public transport arrangements;

Determining the location, number and intervals of stops in this direction has a significant effect on the performance of public transportation services and the demand for public transportation. It is important to provide safe direct access to bus stops for passengers coming from all directions, minimize vehicle waiting times, create waiting areas that are comfortable, safe and do not interfere with traffic, eliminate the obstacles in the stops, bus landing and boarding for the disabled, and to make the stops that are easy to identify (Url 1, 2018). Technology, the course of time, has advanced with quite a high pace and therefore, the lifestyle of the population, as well as the services available in cities ranging from competitiveness to the quality of life of the urbanites, have been modernized accordingly. Smart cities (Kummitha et al, 2017), considered as the new urban space, integrate the vision of development by means of using the information regarding every aspect of the city and the technologies and trends arisen such as automation, machine learning and the Internet of Things (IoT) for the purpose of managing every asset of the city is highly intelligent and innovative means (Tostado, 2017).

Smart transportation systems (STS) are simply referred to as the advanced applications that aim to offer innovative services with respect to various transportation modes and traffic management without externalizing the intelligence and enabling the users to be further informed and render safer, more coordinated and “smarter” use of the networks of the transportation (Nathanail et al, 2016).

Public transportation vehicles are, without doubt, one of the most critical constituents of our lives. The majority of the society generally prefers using their personal vehicles for going to work, school, etc. instead of public transportation vehicles. With the globally increasing population, this leads not only to traffic jam but also to the increase in the emission of harmful gases to nature with the increasing number of vehicles. Therefore, it can be clearly said that encouraging people to use public transportation vehicles plays a critical role in the reduction of carbon emissions. In today’s World, we face various problems concerning the public transportation systems. The time spent while waiting at the bus stops, including the insufficient and misinformation, uncomfortable waiting areas, as the most significant problems, lead the public transportation vehicles not to be preferred. Within the scope of this research, a sustainable smart-stop design sample has been developed, by generating solutions in terms of the effective usage of public transportation vehicles (American Public Transportation Association, 2012). Stop spacing adverts to the distance between the stops along a certain route and thus, serves as a trade-off between the accessibility of transit (convenience of access to frequent stops) and the efficiency of operation. Briefly, thanks to the additional stops along a certain route, the route becomes more accessible by the walk-up riders, on the other hand, the routes operate more

slowly for the riders already in the vehicle. Thus, this impairs the efficiency of the transit service and the cost-effectiveness and therefore, makes it less attractive for the riders (Septa, 2013).

2. Background of Contextual Framework

General Design Principles

In addition to making bus stops accessible to everyone, safety should always be a primary concern. The guidelines provide methods to increase the safety of people, whether they are boarding, alighting, waiting for, or riding the bus. Whenever possible, far-side stops (after the intersection) are preferred since this encourages pedestrians to cross behind the bus and not in front of it. Additional general principles include: (Rosenfeld, 2020). Bus Stops Should be Located in Convenient and Comfortable Locations: First and foremost, bus stops should be located in places that are convenient to where people are traveling to and from, including concentrations of residences or jobs and major destinations such as social services or shopping destinations. Ideally, stops should also provide shelter-either through the installation of a bus shelter or through the use of existing buildings or awnings.

Bus Stops Must be Positioned in Safe Locations: In addition, passengers must be placed in locations that will be able to feel comfortable, which is a location with enough people/activity/lights to not feel isolated. In addition, the location of the stop itself should be well lit, and the stop should provide adequate space for waiting riders to sit or stand, away from other pedestrian flow and Street traffic.

Bus Stops Should be Visible and Easily Identifiable: Bus stops should be located in easily identifiable places, so they can be found without difficulty, and where bus drivers can clearly see whether there are waiting passengers. Stops should be identified by the MATA brand so that they are a recognizable component of the transit infrastructure. Even if the facilities at the stops differ from each other, the elements at the public transport stop must be suitable for the users.

Bus Stops Should Provide Information About Services Provided: All transit customers need basic information about the service, such as: can I get to where I want to go from this stop, is the route running at this time of day, and when will it arrive? This type of information is available to passengers using a cell phone (real-time) or by contacting MATA's Call Center. Higher volume stops should have schedule and route information at the stop.

Bus Stops Should Have Good Pedestrian and Bicycle Access: Bus stops should be located at sites that provide safe, ADA-accessible pedestrian access to the surrounding area, especially to the other side of the street. This should include well-defined and contiguous pathways to and from the stop, as well as crosswalks. This is currently a major challenge in parts of the Greater Memphis Region. As pedestrian and bicycle infrastructure develops, the responsible agencies will need to encourage pedestrian pathways, especially pathways to/from high volume bus stops.

Bus Stops Should be Well Integrated with their Surroundings: To the extent possible, bus stops should be integrated with their surroundings. When new developments are constructed, the stops should be designed as part of the overall project, rather than placed as an afterthought. Similarly, when roads and/or sidewalks are reconstructed, bus stops should be developed as part of the overall design.

Bus Stops Should Provide Users with Comfortable Facilities during the Waiting Period: Providing amenities, comfortable. For many reasons, including cost, it is not an easy process to provide all facilities at each stop. Generally, more extensive facilities are provided in the places where the station is used most intensively.

3. Material and Method

The study has been structured as a design proposal for the province of Bilecik, Turkey. Bilecik is located in the southeastern part of the Marmara Region and on the intersection point of the Regions of Marmara, Black Sea, Central Anatolia and Aegean. As for the coordinates, the province is located between 39°39' and 40°31' north latitudes and 29°43' and 30°40' east longitudes. The province is neighbored by the provinces of Bolu and Eskişehir to the east and Kütahya to the south, while Bursa lies to the west and Sakarya to the North. Bilecik, with its area of 4,302 km², is among the provinces with considerably smaller areas in Turkey. It is ranked 65th in terms of the area. The total population of the province is 204,116 and the population density of the province is (person/ km²) is recorded as 47.

The first settlement in the province of Bilecik province in history dates back to 3000 BC. The first name of the province was Belekoma. Bilecik hosted many civilizations and dominions in history, served as the foundation center of Ottoman State after the Kayı Tribe's arrival to Söğüt from Central Asia with 400 yurts. Bilecik, positioned at an average altitude of 600 m above the sea level, experiences the climate transitions due to its location at the intersection point of 4 geographical regions (Marmara, Black Sea, Central Anatolia and the Aegean Region) of the Asia Minor (Bursa Eskişehir Bilecik Development Agency, 2018; Ocak et al. 2017).

The reinforcement elements within the urban texture comprise a certain part of the urban constituents, and besides the fulfillment of the increased requirement of use, establish a bond between the urban life and societal life. It plays an important role in the realization of the safety, comfort, aesthetic value judgments of the users and ensuring the functionality of the space and the economy in practice. In this study, a project proposal has been drawn up for the province of Bilecik, in accordance with the smart station design, by considering ergonomic features, aesthetics and functionality offered to the users.

The main material of the work consists of the smart bus stops which are urban furniture designed by junior students of the department of industrial design. The aim of the process-based design approach is to ensure the development of the best part possible from the viewpoint of functionality, production, support and operation. The process-based design contains the six-step defined procedure.

- Develop the design goals for producibility,
- Develop a plan for product and process,
- Set off design components for MountAbility,
- Redesign the elements taking the ease of manufacturing in consideration,
- Apply optimization and adjust the design,

The team concentrated mainly on the development of a product and process plan for the design and improvement of a smart bus stop, and carried out activities stated below (Translink, 2007):

- To limit the material processes for the basic component
- Product architecture
- Assembly concept

Within the scope of this study, the design of smart bus stops will be studied and examined thoroughly from various aspects, taking the key stages in product development into consideration. These stages are as follows:

- A general research is done concerning the design and the product to be developed.
- The consumer needs are identified.
- Transforming the voice of consumer (VOC) into the needs of consumer,
- Developing metrics (product specifications) in order to discuss the consumer needs in terms of technological aspects,
- Developing the relationship between need & metric,
- Utilizing the Quality Function Deployment as a tool for building the quality room,
- Creating the concept,
- Choosing the concepts with the help of a concept scoring matrix,
- Process-based design,
- Product architecture,
- Design for manufacturing,

- Reflecting the result and the process.

A questionnaire study was carried out in the central area of Bilecik and Bilecik Şeyh Edebali University in order to identify the consumers needs. Additionally, the one-to-one interview methods were utilized for obtaining healthier data. The questions of the survey were answered by 100 individuals (Male: 58, Female: 42).

4. Finding of the Study

The designs of the bus stops located in the province of Bilecik have been evaluated in terms of functionality, aesthetics, and ergonomics within the scope of the study. Bus stops made of aluminum-PVC construction are located throughout the city. As the images presented the Figures A2 and A4 indicates, the bus stops are designed within the framework of the universal design criteria. Advertising billboards and information on the stops are also available. Atatürk Boulevard hosts Smart Bus Stops (A1). A covered area has been put into practice at the stops for the purpose of protecting the people from the external factors and providing a more comfortable waiting area for the local people during the hot/cold weather conditions. However, in consideration of the design criteria and aesthetics, it has been identified that the stops offer insufficient features, and it is noteworthy to point out that they are highly dependent on the infrastructure and there is a lack of technology features.

A1- Smart Bus Stop | A2-Bus stop with aluminum-PVC construction | A3- Bus stop with aluminum-PVC construction | A4- Bus stop with aluminum-PVC construction

Figure 1. Bus Stops in Bilecik (Original, 2020)

In this section, the findings of the research, the results obtained, and the design stages are given.

4.1. Identification of User Needs

Identification of the process of user needs is an inseparable part of the products development. To identify the user needs;

- Collecting raw user data (VOC)
- Commenting on the raw data from the point of user needs
- To determine the importance of need-relative
- To reflect the duration and conclusion are required.

4.2. Identification of Users

The local people of Bilecik and the university students who live in the city were interviewed and carried out a survey to determine the user needs. The sample size is limited to 100 people and the survey is conducted with 58 males and 42 females.

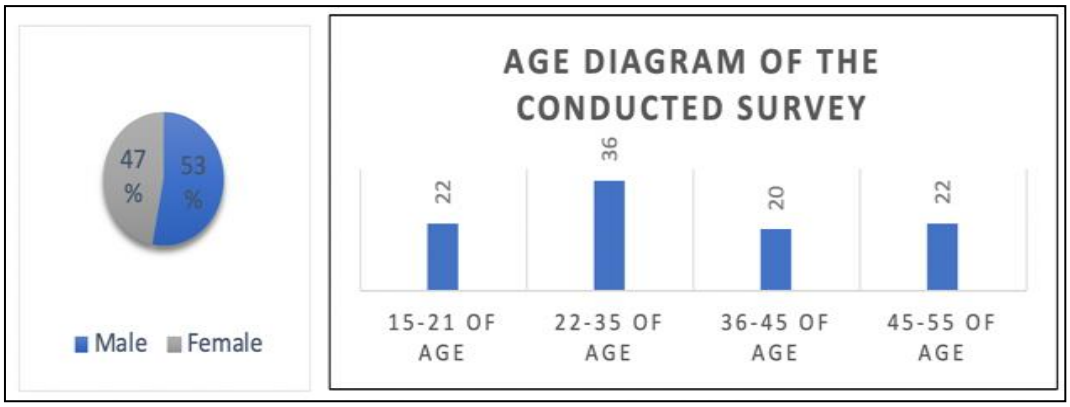

Figure 2. The gender and age diagram of the people who participated in survey.

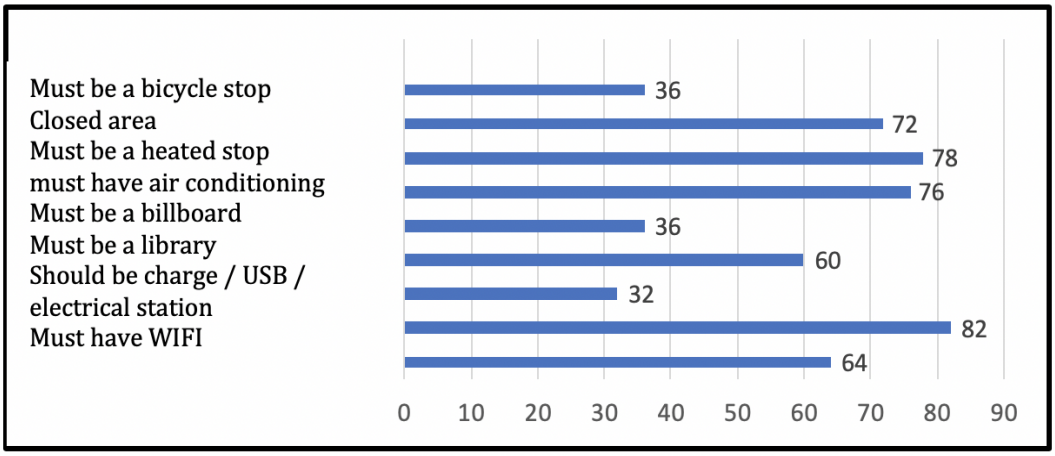

Figure 3. The scatter diagram of the items predicted to be needed

As a result of the conducted surveys, the expectations of the users from the bus stop are determined. According to this, %82 of the users answered as "There should be USB/Charging/Electricity station". The least needed item was determined as the library with 32%. Effective communication is needed between all the parties to produce sustainable products and human needs should be taken into consideration. A well-established process is needed for matching human needs (ergonomics) with the characteristics of the product. A way of carrying out this well-established process is to use Quality Function Deployment (QFD). Also, one of the main targets is to ensure incorporating the customer needs (Voice of Customer or VOC) in the design.

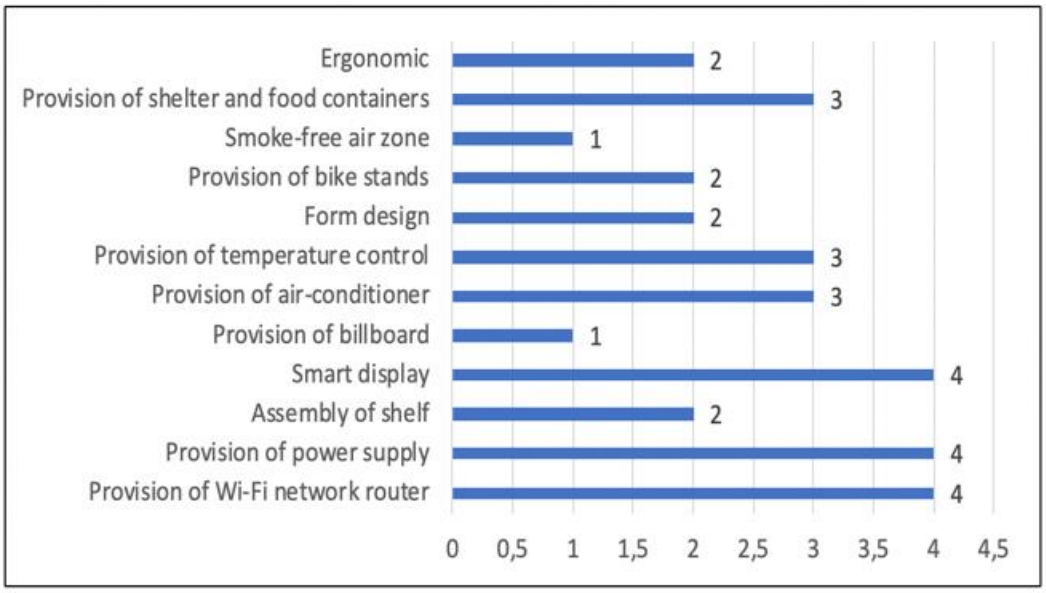

Figure 4. The preferable scatter diagram of Quality Function Deployment (QFD) according to user needs

The preferable scatter diagram according to user needs of Quality Function Deployment (QFD) shows that the primary elements preferred by the users are the existence of smart display, provision of power supply and wi-fi network router. Secondarily, there are provisions of shelter and food containers, temperature control and air-conditioner. The least preferred features are the provision of billboards and a smoke-free air zone. QFD is based upon a range of standard matrixes. The most applied one is the House of Quality (HoQ is similar to a house). HoQ associates the requirements of a design with the means by which these requirements are met. In this way, it allows identifying the priorities before the technical requirements are applied to the product. In the simplest form, HoQ is a matrix that defines the relationship between the design requirements (it is determined by the perspective of the customer.) and the product characteristics (from a technical aspect). The relationship is identified on a simple scale based on the user approaches. In the application phase, the HoQ matrix is worked through. The core of the matrix does not change fundamentally but there are some important additives;

- **User Perception:** This box defines the user's perception of use on a 5-point Likert scale (1 = very negative, 5 = very positive). The perception of the competitors is overlapped.
- **Upper Limit matrix:** Upper Limit matrix indicates the relationship between different product designs characteristics.
- **Importance:** The importance level is a figure that is dedicated subjectively to customer requirements 1-10 (most important is 10) or 1-5 (most important is 5) on the scale.
- **Technical Evaluation and Target Values**: This section provides technical information about the characteristics of the product. This section, also, presents the target values in regard to product characteristics with a focus on improvement.
- **Creating Concept and Concept and Focus Design Process**

Concept creation, evaluation of concepts according to consumer needs and requirements criteria, comparison of the relative strengths and weaknesses of the concepts and for the following stages; is the process of evaluating one or more selections for review, testing or development. The method of choosing a concept in this section is based on the evaluation of each concept according to a set of selection criteria and the use of the decision matrix. For the design and development of a smart bus stop, the following selection criteria have been completed considering the needs of the customer. These are; a) Ergonomic b) Ease of Use c) Performance d) Cost e) Stability f) Design for assembly g) Safety

In accordance with the focus design processes for Smart Bus Stop Design and Development, the team focused on developing a product and process plan and carried out the following activities:

- **Limiting material processes for the basic component**

Selecting the proper material and the process for the primary components plays a key role in developing a successful and process plan.

- **Development of Product Architecture**

Product architecture is a diagram in which the functional elements of the product are organized into logical groups of physical elements called parts. Functional elements are the individual processes and conversions that contribute to the general performance of the product. Physical elements are the standard designed parts that carry out product functions. A carefully planned product structure can be easily customized and developed to meet customer requirements. Preparation of product architecture consists of the following steps:

Step 1: Creation of Product Scheme

In Smart Bus Stop Design, electrical energy is provided by solar panels and floor tiles that convert motion energy into electrical energy. The electrical system produced in the places is sent to operate electricity billboards, information

screens, chip bike system, heated seats, electric chair charging system, phone charging systems, clock, road route screens and drip water system.

Step 2: Grouping of schematic elements

Grouping of elements for smart bus stop design and development involves the following processes:

a) Sharing the function, b) The similarity of production technology, c) Portability of interfaces

Step 3. Creating the Geometrical Regularity

The geometric regularity is created to find the relationship between the applicable basic relationships and the parts.

Step 4: Identifying the basic and possible interactions

Basic interactions are interactions that correspond to the lines that connect schemes together. Possible interactions are interactions resulting from the physical application of functional elements or geometric arrangement of parts.

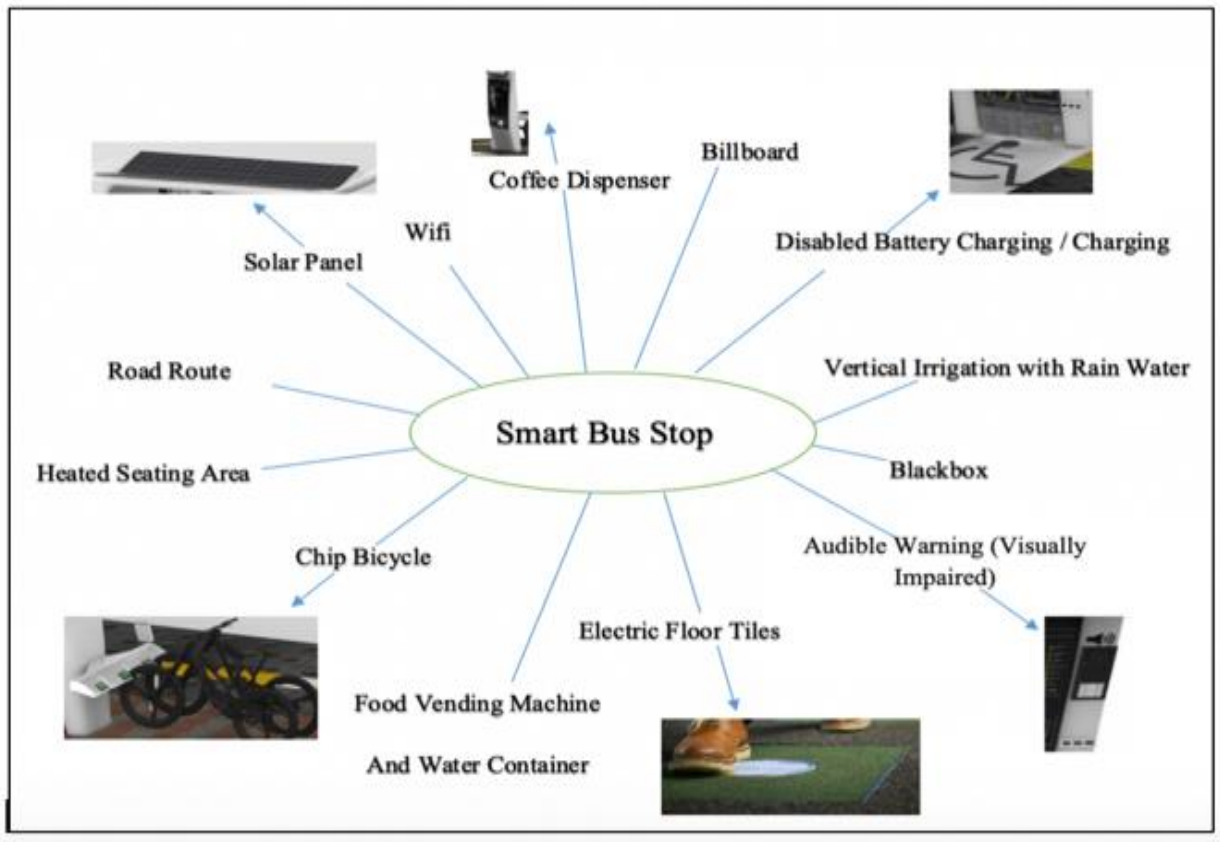

Figure 5. Smart Bus Stop Interaction Set Diagram in the Urban Furniture

- **Assembly Concept**

The assembly concept determines the way the components are assembled to form the final product. This assembly consists of two parts including the assembly structure and the assembly plan. In Smart Bus Stop Design, the assembly structure is established as a frame-based assembly. The assembly plan consists of the order in which the components/parts are assembled and the processing, assembly and revision of the components during assembly.

- **Production Parts**

The designed smart bus system is not unsuitable to use in one part. It is required to produce as parts and subjected to integration. Technological screens, solar panels and other systems should be assembled accordingly.

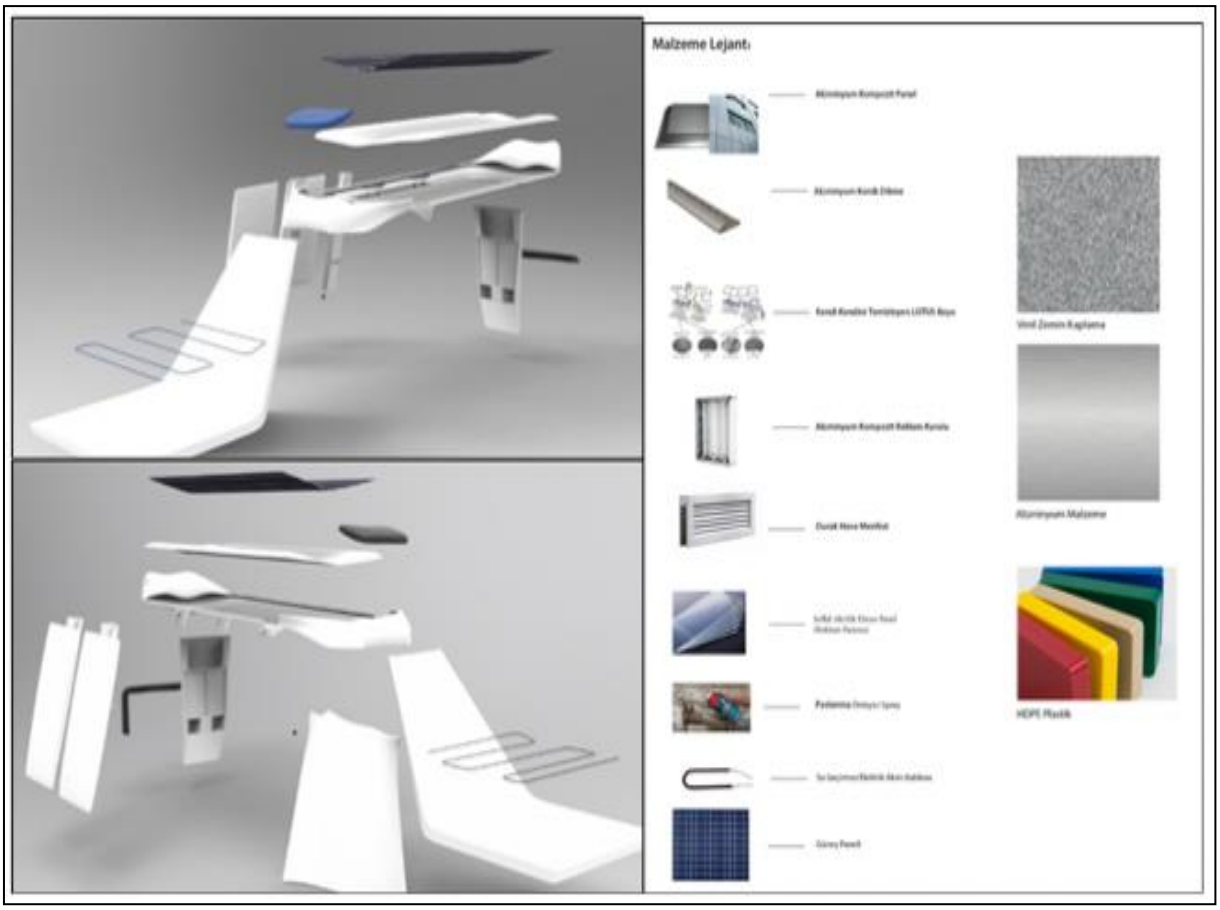

Figure 6 Smart bus stop system design sample (Original, 2018)

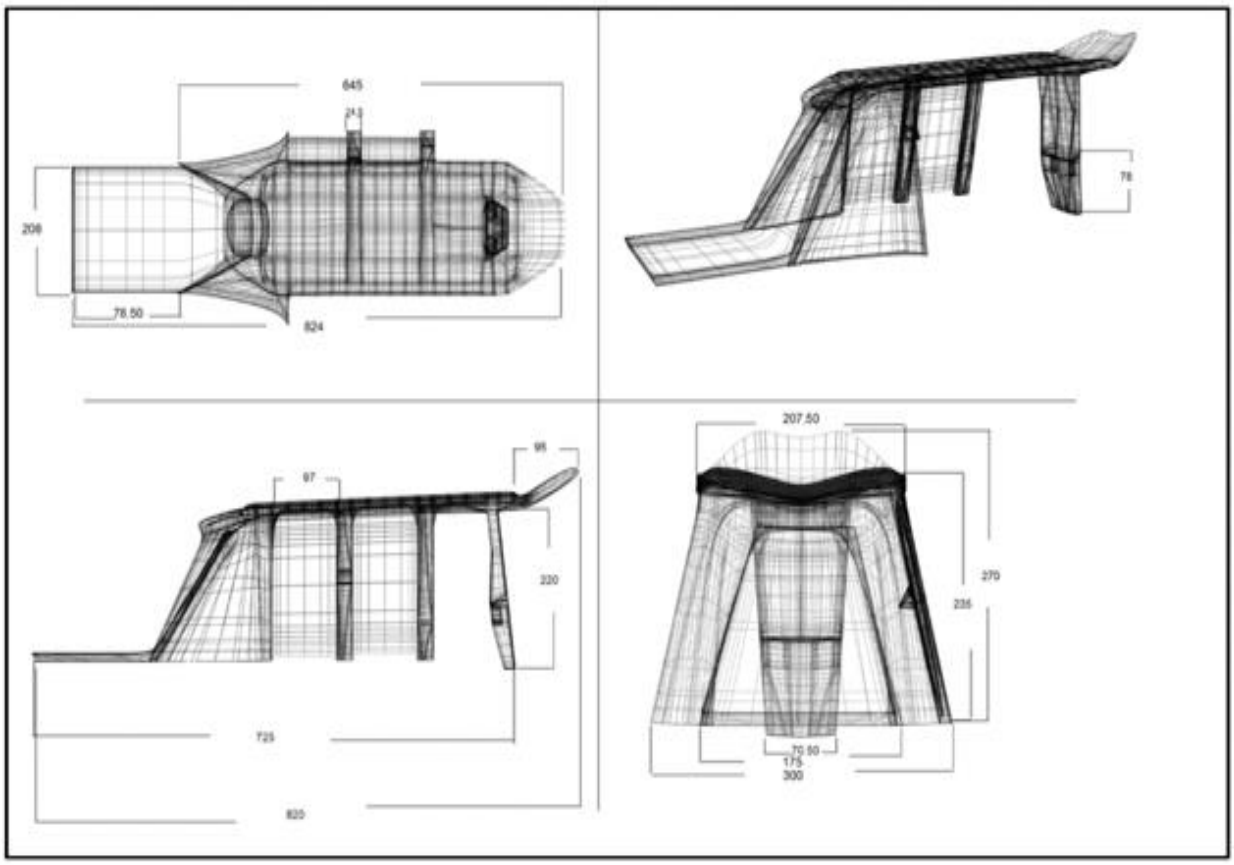

Figure 7. Smart stop system dimensioning presentation board (Original, 2018)

Figure 8. Design of Sustainable Smart Bus Station (Original, 2018)

5. Conclusion

Urban furniture makes positive contributions to social life as the elements that make urban life more enjoyable and meaningful, creating urban comfort and urban aesthetics and they should be examined on social, cultural, psychological, economic, anthropometric, ergonomic and demographic aspects by considering the differences in the needs and cultures of the people living in the cities (Akyol 2006). Damages to the environment caused by the use of petroleum and its derivatives in automobiles, which cannot be renewed in the new century, cannot be ignored. Designing the smart bus system is a way to direct people to public transportation smart stop systems in order to eliminate the deformation caused by the carbon gases emitted by the vehicles in the air and on the other hand, to construct new roads to meet the increasing need for vehicles. In this way, people in different seasons will have taken the first step for a comfortable and pleasant journey without being chilled or sweating, bored, thanks to smart stops.

Figure 9. Presentation sheet of the completed project

Acknowledgements

This research was prepared within the scope of the Research Project Course with my students in Bilecik Seyh Edebali University, Fine Arts and Design Faculty, Department of Industrial Products Design.

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