Department of Mechanical and Industrial Engineering

Design and Technology Futures

BUS STOPS IN THE ERA OF SMART TRANSPORT SYSTEM

BUSSIPEATUSED TARGA TRANSPORDISUSTEEMI AJASTUL

MASTER THESIS

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AUTHOR'S DECLARATION

Hereby I declare, that I have written this thesis independently.
No academic degree has been applied for based on this material. All works, major viewpoints and data of the other authors used in this thesis have been referenced.

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ABSTRACT

Transport systems are becoming intelligent and this will require a corresponding transformation of their infrastructure in cities.

The master's thesis considers bus stops today and in the future. The importance is placed on how the stops should be changing with advances in the transport system in the direction of improving mobility and greenery in terms of the use of smart technologies. The study focused on the typology of bus stops and their role in the urban environment. Most of it is designed to give an idea of the focus of innovative developments for a smart transport system.

Schematic diagrams for bus stop were developed, which were supplemented by vehicle combination options for a quick transfer in the “bus-shuttle” mode. The new concept is aimed at providing maximum comfort for passengers, reducing the area of the roadway and increasing the space for people.

CONTENTS

ABBREVIATIONS

BRT: Bus Rapid Transit

DDM: Double Diamond Model

ITS: Intelligent Transportation Systems

FM/LM: First Mile / Last Mile

NACTO: National Association of City Transportation Officials

PT: public transport

V2V: vehicle-to-vehicle

INTRODUCTION

Development of the city is closely related to its transport system. Transportation plays an essential role in people's daily lives and has significant economic importance in meeting different social needs. Many people every day have to move somewhere with different types of transport. Majority of people are using public transport, which is economical enough, but, unfortunately, not always comfortable. Its comfort as a mobility option is mostly determined by the created infrastructure, which includes bus stops.

It is an element of the urban environment, which is directly connected with its transportation system and creates conditions for everyday life.

The thesis includes analysis of the bus stops and the transport system today to search for promising smart solutions to change them in the future. Therefore it is necessary:

- to study today's bus stops, their limitations and trends;
- to understand the problems of the transport system and direction of its development;
- to study new technologies for transport and scientific trends in this sphere;
- to choose a focus for the development of new project solutions of bus stops;
- to develop a conception of the bus stop for the conditions of the smart transport system.

Already today, the future is not seen without smart technologies which are increasingly spreading in our lives. This spreading changes the way people are living and gives them new opportunities. Therefore there is interest, as they will change stops.

Many inventions and things have come to our real life from science fiction books or movies - solar panels, credit cards, video communications etc. By modelling the future, the key values for society can be determined, which need to be developed. Today it is already clear that if the transport system does not change, cities in the future will have even much more significant problems with traffic and the environment. Therefore, it is necessary to look for possible solutions and realise them in life. My thesis is only an attempt to make city life better. This is my view of the future transportation system and an idea of what a comfortable bus stop can be.

1. METHODOLOGY

In this chapter, my objective is to clarify and illustrate the methodology that was adopted for this thesis. I have drawn inspiration from the Double Diamond Model (DDM) (Figure1-1). A design method in which the design process is represented in a simple visual map, which includes four distinct phases as follows:

1. Discovery / Research – insight into the problem.

2. Define / Synthesis — the area to focus on.

3. Develop/ Ideation — potential solutions.

4. Deliver /Implementation— solutions that work.

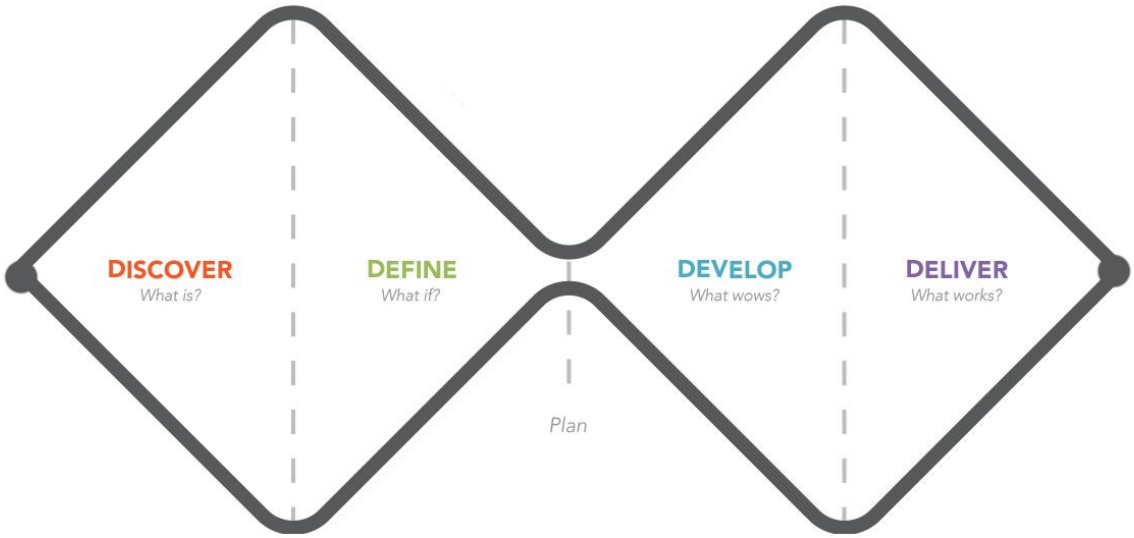


Figure1-1: Design Council's Double Diamond [1]

The four sequential phases walk through an extensive process of divergence and convergence. During the divergent phase, I have tried to engage in discovering the larger problem arising out of the theme at a broad level, without limiting myself to any specifics. However, during converging phases, I have tried to concentrate and narrow down on the observations to generate effective ideas.

To discover which ideas are best suited, the creative process is iterative in nature. This is reflected in the cycle in which the ideas are developed, proved and polished multiple times and the better options are selected to continue with the process. This cycle is an essential requirement in correct and empathetic design.

1.1. Discovery

The first phase of the DDM is the initial step for the project. Mainly this segment covers the point of view of a designer, in which it tries to look for novelty in the world, that allow to grasp a new concept and gather a different perception of the world [2].

In this stage, an understanding of the goal is formed, user needs are identified and initial ideas are being developed. Designers collect solutions and ways to meet the needs of the user through new paths.

Objectives of the “Discovery” phase includes:

1. Identifying problems and opportunities for users;

2. Determination of the solution space that is, a set of analogues of any nature that can be used to obtain a design solution - technology, associative concepts and images, and so on;

3. To form a base of analogues that solve similar problems.

By choosing the bus stop as the main object of my study, first I had to understand: what is it today and what they are. The analysis of existing design guidelines for stops in different countries helped me with this. To identify the problems that users face today I used mind mapping, observations, interviews.

Mind Mapping is a creative and logical tool that displays and helps develop ideas. With the help of Mind Map, I identified the key factors that influence people at bus stops. The determination of their stable behavioral models was carried out through observation without direct contact with

passengers at the same time, photographing the behaviour of passengers at bus stops was used for the subsequent analysis of various facts.

To supplement the results of observations and to identify the emotional reaction of people to the bus stops, semi-structured interviews were conducted.

1.2. Define

The second phase represents the definition stage, in which designers try to make sense of all the possibilities identified in the discovery phase- “What is the most relevant? What is achievable? Which one is workable now? The purpose is to clarify the goals of the project and the direction in which will guide the construction of the necessary frames, to continue the development for the design challenge [2].

To give meaning to obtained results, one needs to synthesize the research by following steps:

1. Analysis of data collected at the “Discovery” stage.
2. Summary of results.
3. Development of instructions, containing:

   the purpose, main tasks and requirements for the product being developed.

It is crucial at this point of the methodology to find insights, which are the sleeping truth about the motivations, wishes and/or annoyances of consumers in a topic.

The identification of such insights is necessary to develop areas of opportunity or potential areas of action, and come up with guide questions, such as “How could we solve this with that?”. The questions must help us to understand what can be done or solved in a given field of action.

1.3. Develop

The third phase is the process where possible solutions or concepts are created, developed prototypes, mock-ups and tested. This cycle of trial and error nourish the designers to grow, improve and filter their ideas.

Since at the previous stage, the question itself was identified that needs to be solved or challenged, the ideation begins. This is part of the divergence phase. The designer should forbid to limit himself/herself in any way and approach the process openly. No judgements should be made during ideation. It is necessary to use "yes, and ..." instead of "no ..." or "yes, but."

At the end of the ideation phase, an assessment of ideas is done, and the best ones are selected. As a result, the designer gets one or more ideas that can be prototyped and tested later on, with the objective to asset the most desirable solution or interpretation to the question or problem.

At the Develop stage, ideas were generated based on previously collected information. Thoughts were being formalized and analyzed. Various situations in the urban space of Tallinn were considered to develop potential solutions for stops.

1.4. Deliver

The final phase of the DDM is the stage, where the resulting project (a product, service or environment, for example) is finalized.

When potential solutions are developed (sets of ideas), it is necessary to evaluate the final decision and how to achieve or implement it. To do this, one can use the flexible approach of three steps:

- Development / Prototyping
- Testing / Analysis
- Iteration / Repeat
- The result is a final offer, product, answer, or solution

At the stages of elaboration of my conceptual idea, I made drawings of plans for placing stops, taking into account the real scale of their placement in the conditions of specific spaces of Tallinn, Sketches

and 3D models created for visualizing my design solution. The specificity of the work is that it includes foresight - a description of the situation and objects in the future. Evaluation of the solution at the current stage can only be carried out by discussing it, not by testing it.

2. BUS STOP AS AN ELEMENT OF THE URBAN ENVIRONMENT

This section shows the results of the literature study. These are scientific articles, guidelines that reveal research on improving the urban environment and designing bus stops.

The purpose of this phase of the study is to answer the following questions:

- What is the bus stop?
- What are the types of bus stops?
- What are the basic requirements for bus stops?

The answers to these questions are extremely important because they form the base on which further research is built.

2.1. Determination of bus stops

The attractiveness and convenience of the city for its residents and guests largely depends on the development of the urban public transport system, which performs several essential social functions. This transport is designed primarily to ensure the mobility of the population, the territorial integrity of the city, the availability of all elements of the urban economy.

An important element of the urban public transport system is a public transport (PT) stop.

In Accessible bus stop design guidance, London [3] says that "Bus stop design and location is recognized as a crucial element in the drive to improve the quality of bus services. The concept of 'Total Journey Quality' recognizes that bus passengers are also pedestrians at each end of the bus trip and requires that all aspects of the journey are considered. The convenience and comfort of bus

stops must not be overlooked. It is important to view the bus stop as an interchange, rather than simply a location along a bus route where buses stop".

According to experts of Texas Transportation Institute «The spacing, location, and design of bus stop significantly influence transit system performance and customer satisfaction» [4], [5]. Therefore, with the development of transport technologies, bus stops should also be improved. Before specifying this task and searching for possible solutions, it was necessary first to determine what is meant by a bus stop.

Summarizing the definitions from the considered sources [3], [4], [5], [6], [7], I gave the following definition. Bus stop - an element of the urban environment, which is an integral part of the city transportation system that serves as a waiting point and connects people with public transport.

2.2. What determines the type of stop?

In modern world practice, there are used different bus stop points depending on their purpose, location, capacity, and space-planning characteristics.

In this part, I systematized information about what determines the type of stops. The analysis was carried out using mainly material from various bus stop design guides [3], [4], [6], [7].

According to service Wikipedia, there are three main types of stops [8]:

- Scheduled stops - Transport arrives at a stop according to schedule (at fixed intervals regardless of demand).
- Request stops - Bus will stop if the passenger requests a stop.
- Hail and ride - stops, at which a vehicle will stop anywhere along the designated section of road on request.

In general, in the urban environment, including Tallinn, scheduled stops are used.

The type of stop can be determined by analyzing its destination at various points on the route map. In this case, it can be divided into three general types. (figure 2-1)

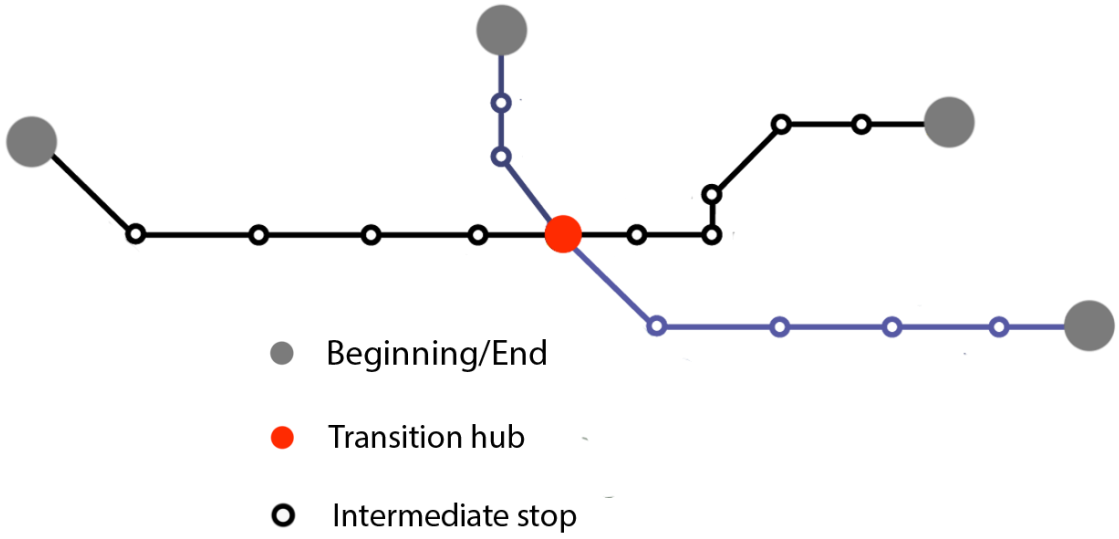


Figure 2-1: Types of bus stops on route maps

Beginning/Endpoints. It is simply the point where vehicles stop, turn or reverse, and wait before departing on their return journeys. Usually, it is a large space and can have several numbers of buses from different routes. It also may be a place to change the mode of transport, for example, near the railway station or airport. In this case, there can be significant passenger traffic.

Transition hub - a place where different numbers and modes of transport cross. These types of bus stops can be seen in any city and are similar to each other as they have a large flow of passengers. They can occupy more space, have a higher number of shelters, or one large structure. Moreover, they can offer a variety of services.

The intermediate stop located along the route of public transport between Beginning/ Endpoints and Transition hubs. Passenger traffic in this case primarily will depend on the location of a stop. If it is in the centre of the city or another place where people gather, then the number of passengers will be large, in the case of outskirts, it is less.

National Association of City Transportation Officials (NACTO) present in "Transit Street Design Guide" tips and proposals on how to improve streets through urban design, identifies these types of stops according to the plan for their placement in urban space.

(Figure 2. a)

(Figure 2. b)

(Figure 2. c)

Figure 2-2: Types of stops according to "Transit Street Design Guide", NACTO [9]

• "In-lane Sidewalk Stop (Figure 2-2. a). This is the most common type due to its low economic cost and time it requires to be made. Almost all bus stops in cities are referred to this type.

• Median Stop, Side Boarding (Figure 2-2. b). In many cities around the world, it has become more common to see center lanes of wide streets designated as bus lanes for public transport.

NACTO classifies this design as something that gives identity to the service and offers some of the following functional advantages; greater safety to passengers, allows buses to pass more frequently by reducing the presence of other types of vehicles and gives a more orderly visual appearance.

• On-street Terminal (Figure 2-2. c). Streets referred to as terminals can be those close to intermodal stations or where a bus route begins or ends. It is common for crowds of passengers to be present on the sidewalks and for buses not to travel with a fixed frequency" [9].

The main factor that determines the spatial solution of a stop is its location and the most difficult conditions determine the places of potentially large passenger traffic.

The planned location of the stop and the passenger traffic will determine whether a shelter should be there or not as well as its construction and the presence of various by-products in it. Practice shows that it is a result of systemwide policy among transit agencies. The main principle of which is the optimality of bus stop design decision in terms of the need for such an object and the cost of its creation.

“Many criteria exist to determine shelter installation at a bus stop. In most instances, the estimated number of passenger boardings has the greatest influence. Suggested boarding levels by area type used to decide when to install a shelter are as follows (these values represent a composite of prevailing practices):

Location	Boarding
Rural	10 boardings per day
Suburban	25 boardings per day
Urban	50 to 100 boardings per day

Other criteria used to evaluate the potential for inclusion of shelter include:

- number of transfers at a stop

• availability of space to construct shelters and waiting areas

• number of elderly or physically challenged individuals in the area

• proximity to major activity centres

• frequency of service

• adjacent land use compatibility" [10].

Ultimately, it is the passenger traffic that determines the required capacity of the bus stop. According to the article [12], differentiation could be these:

- low capacity stops (5-10 people);
- medium capacity stops (10-20 people);
- high capacity stops (more than 20 people).

The capacity type of a stop and the characteristics of a place where it is necessary to place it determine its volumetric-spatial solution. For example, with a small required capacity, this is usually a small light shelter. The capacity of 20 people requires more space to create a pavilion and in this case, the design decision depends on the ability to place it in the decided spot. It can be either one large shelter or several small ones.

A shelter can be distinguished according to the characteristics of design solutions:

- open type (without enclosing walls);
- semi-closed type (with walls without enclosed space);
- closed type.

According to studied information, the type of a bus stop firstly depends on the characteristics of its location in the city, which determines the size of the passenger traffic and the characteristics of the space (figure 2-3). Altogether, these are the initial conditions for the design of a bus stop, which at the end must determine whether a shelter is required or not and what it will be (its appearance, construction, size and location). Thereby the main factor that determines the spatial volumetric solution of a bus stop is its location. At the same time, the most difficult conditions set the places that can have large passenger traffic.

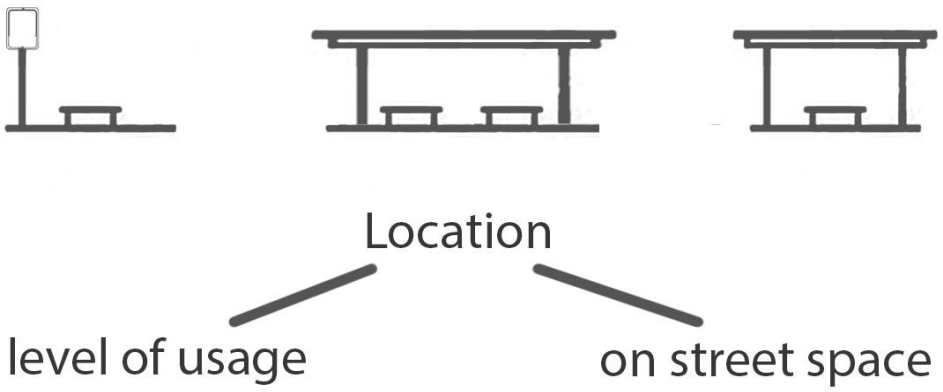


Figure 2-3: Primary design factors for a bus stop

2.3. General requirements to build modern bus stops

The modern world is rapidly changing as well as different areas of our lives. Today, a bus stop is often not just a place where passengers are waiting for public transport, it is also a place where they can take advantage of various accompanying benefits.

At this stage of the study, it is crucial to get acquainted with the advanced experience of designing stops in different countries of the world in order to understand the new requirements and tendencies of creating modern, comfortable bus stops.

The Opinions presented in the following documents considered the most interesting for the development of the concept of my project.

The Memphis Bus Stop Design Guide [10] says that an important aspect for each transit customer is to wait for the bus in a comfortable environment. In order to do this, it is necessary to follow these general principles of design.

- Bus Stops Should be Visible and Easily Identifiable

- Bus Stops Should Provide Information on Available Services
- Bus Stops Should Have Good Pedestrian and Bicycle Access
- Bus Stops Should be Well Integrated with their Surroundings
- Bus Stops Should Provide Amenities to Make the Wait Comfortable

Providing amenities, such as benches, lighting, bike facilities, trash cans, etc. at stops make waiting for the bus more comfortable. For many reasons, particularly cost, it is not practical to provide all amenities at all stops. Typically, more extensive amenities are provided at the busiest locations.

The developers of the London UK bus stop design guidelines [7] believe that, when reviewing individual bus stops, and their immediate environment, designers need to take account of the wide range of issues and that each site is a unique location, with unique bus stop environment characteristics (see figure 2-4).

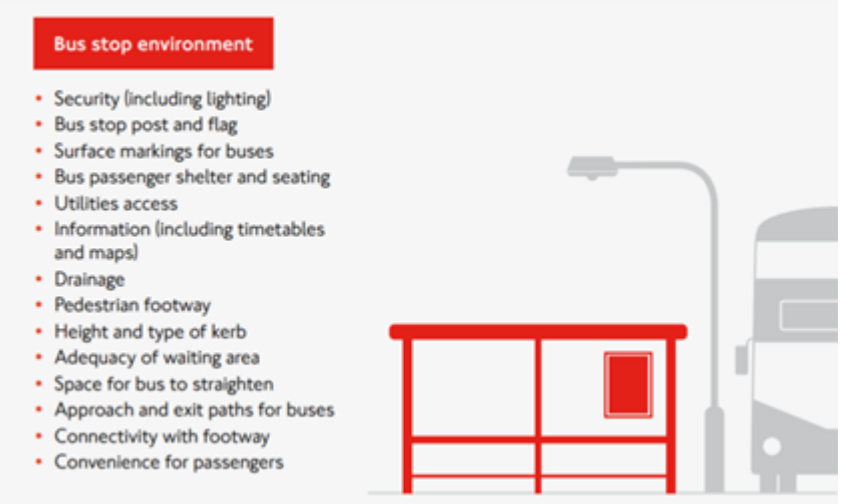


Figure 2-4: Features of the bus stop environment [7]

The National Association of City Transportation Officials (NACTO) developed a series of guides in which they propose design guidelines to make urban spaces more accessible and safe for all road users. They offer six recommendations to design bus stops (figure 5).

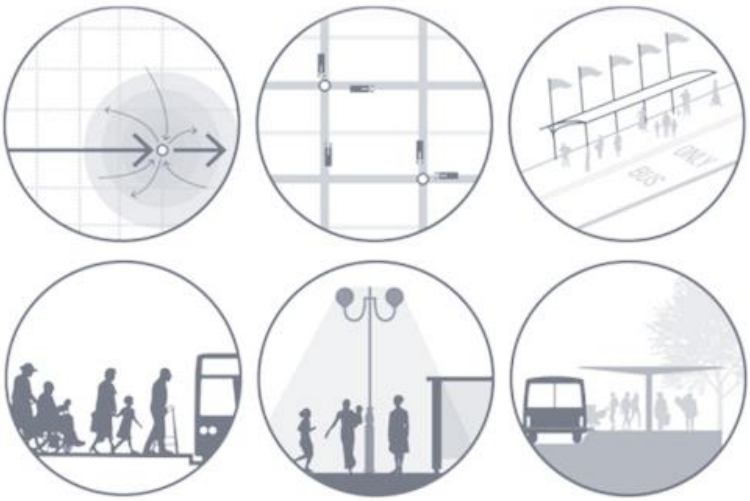


Figure 2-5: 6 Tips for Designing Accessible and Safe Bus Stops [13]

- "Stations are Gateways.

A stop interacts with its environment determines whether or not it's an appropriate access point to the transit system. In addition, if the stops have elements to make the passengers' wait more pleasant such as trees, seats, and a shelter to protect them from the rain, it is possible to positively influence the perceptions of public transport for the pedestrians and drivers in the surrounding area.

- Facilitate Movement, Ease Interactions.

The role that public transport stations can play in a neighbourhood goes much further than just being where people get on and off a bus. In fact, if the design and location of the stops are well planned, it is possible to reduce travel times and thus increase confidence in the transit system. This is possible if the stops become intermodal centres distributed throughout the city that offer public bicycle rentals as well as opportunities for ride shares and other services.

- In-lane Stops Save Time.

Stops in bus-only lanes make it possible to reduce delays for the other traffic by concentrating stops in traffic flow to a single lane. This also offers an opportunity to create a safer space where passengers can board buses more calmly. They also contribute to condensing activity to a single point on the sidewalk without affecting the flow of pedestrians.

- Universal Design is Equitable Design.

Differently-abled passengers and people of any age can safely board buses if the bus stops' designs are people-centred and accessible to all from the outset. Intelligent design improves the trip experience on public transport not only for those who have reduced mobility but for all users. Planning a design well from the start can reduce time spent on future overhauls as well as costs for upkeep or accident repairs.

- Design for Safety.

NACTO offer some design elements that help to achieve a safe transportation system., including taking into consideration that the stops be close to areas of all-hours activity, that shelters and stands are seen as places for waiting and human-scale lighting, in other words, light fixtures designed for people and not cars.

- Integrate Vehicle and Platform Design.

Designing stops to be level with buses and the sidewalks is a basic feature so that boarding is first and foremost accessible and fast. This situation, which NACTO considers as a key part of any system, requires that they have a flexible design able to be used with different types of buses.

After reviewing the guidelines for the design of bus stops in different countries, it can be concluded that they all aim at creating convenience and safety for all user groups. The basic concept of all studied documents is the attractiveness of using public transport by ensuring its comfort and an important role in this belongs to the bus stops." [13]

The bus stop is considered as an element of the transport and urban environment, which connects people with public transport and serves as a point for its waiting. The main factor that determines the spatial volumetric solution of the bus stop is its location.

The design of bus stops should be aimed at providing convenience and safety for passengers, which affects the attractiveness of public transport.

3. USABILITY EVALUATION OF BUS STOPS

3.1. Study of a bus stop influence on a person

The environment with all its constituent elements has a strong influence on a person. Improving its organization, designers and architects should strive to make better living conditions for people. This is not an easy task, which boils down to creating an optimal urban environment and it is complicated by the need to take into account a large number of factors and different interests in society.

Stops are elements of the urban environment, therefore, in my opinion, a study of the possibilities for their improvement should be carried out by assessing how they affect people.

At the first stage of the research, I built a map in which I depicted all the factors that influence a person who regularly visits the bus stop. (figure 3-1).

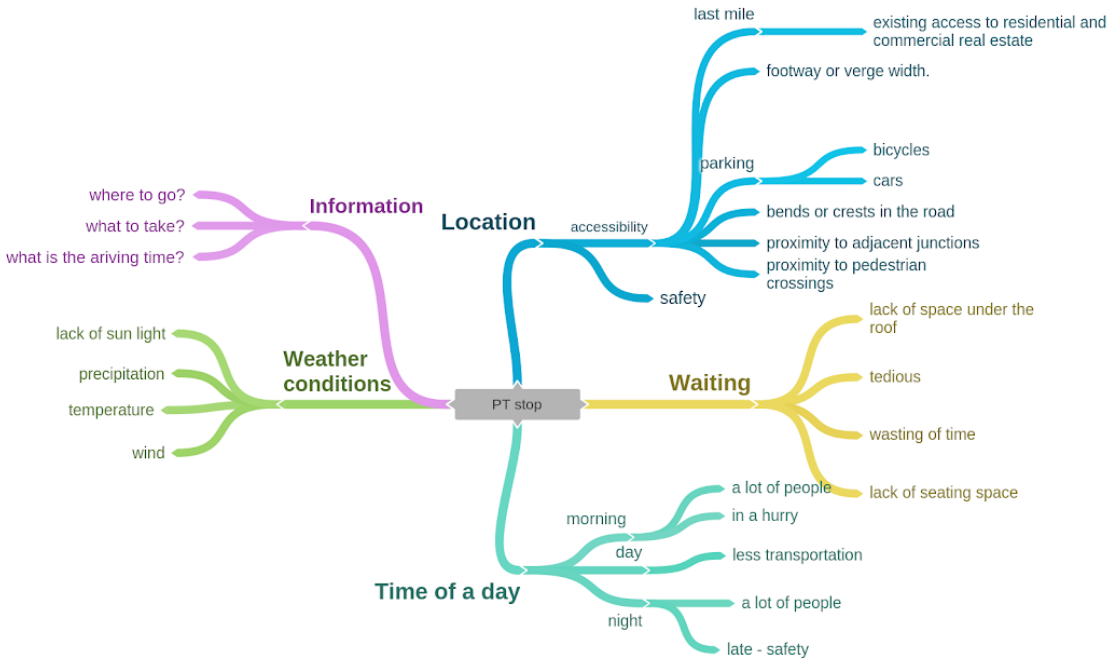


Figure 3-1: My mind map

All these factors can have a different influence on specific users, although the waiting time plays the central part in it.

To narrow down the focus of the study, it was necessary to study the influence of selected factors.

Later I focused on the fact that the stop is a physical, visual object and a place of social interaction. Precisely in such representation, I studied its influence on people, based on the results of various studies.

First of all, the bus stop as a shelter creates the physical conditions for a feeling of comfort and safety. A person, if necessary, can hide from the weather, if tired - sit down. Such components are created for the convenience of passengers, for a positive impact on people and ensuring loyalty in relation to public transport.

The design, the content of the stop by certain elements and the quality of its content contribute to the appearance of a sense of security in people. It is proved in research called Crime Prevention Through Environmental Design (CPTED).

"A bus stop could feel safer and, more likely, be safer if it provided more than one exit to allow for flight. The bus stop could also foster interaction between people by the placement of benches, information or enhancements. Routine maintenance could make the bus stop feel safer, suggesting that another person cares for and is occasionally in attendance at the stop. By contrast, the stop could appear less safe if it had garbage, graffiti, multiple old posters, a residue of tape from posters or cloudy and dirty appearing plexiglass from cleaning solvents used in removing poster tape residue" [14].

The below are general parameters for Bus Stop as gleaned from the research.

• "Resemble a building with pitched roof and overhang

• No sides (only posts) or two or three-sided

• Open, glass or clear (not smeared) plastic sides

• No advertising or flyers

• Brick or materials used in buildings- not metal

• Low walls for sitting or leaning

• Simple and clear details

• Not high art Position

• Adjacent to street

• Facing street Identification and signs

• Name a stop on a roof

• Maps a bus route and perhaps a map of area Benches

• Keep in mind mothers, children and strollers

• Designed not for sleeping" [14].

A "visual turn" took place in the modern world and the value of the visual components is becoming more and more important [15], [16]. Therefore, stops as visual objects are also under scrutiny.

The study of the visual impact of bus stops on people should not only consider passengers. It should include all other population, which, from the side of the viewer, who consciously or unconsciously assesses created stops, which relate to street furniture.

"Street furniture is a term is used in a number of countries, including Canada, the United Kingdom and Australia. It is objects and equipment installed along streets and roads for various purposes. The design and placement of furniture take into account functionality, pedestrian mobility road safety, aesthetics and visual individuality"[16].

According to V. Filin [17], the visible environment surrounding the human determines the quality of his life. It is customary to call the environment comfortable when it has a large variety of elements in the surrounding space. It is characterized by the presence of curved lines, sharp corners, a variety of colours, thickening, rarefaction of visible elements and their different distances.

The most comfortable visual environment is considered the natural environment (forest, mountains, rivers, seas, clouds). That is why today bionic, ecological architecture is popular.

The city should be a visually pleasing environment where you want to be. However, the bus stop, as part of the visible environment of the human surrounding, is not given enough attention. The stop is basically an industrial product that lacks the environmental component. People generally see little greenery and a lot of asphalt.

Street furniture is an important element of urban identity. Thus, by the phone booth, we can recognize London, by the bench - Copenhagen. Such elements of the urban environment create the representation and image of the city. Bus stops as objects of street furniture can also give individuality to the planning organization of the territory and have a significant influence on the emotional state of a person, because they are in a constant field of vision, they influence the formation of aesthetic taste, therefore, they must meet all the requirements of modern design.

The environment that surrounds a person, together with the elements that make up space, has a powerful influence on a person's vital activity, as well as on his mental state. It is very important to properly organize the urban environment so that it is not only comfortable to use, but also has a positive impact on the individual. Today, the design of outdoor furniture, including stops, requires a unique approach. To address this issue, it is necessary to take into account the features of the human perception of the environment and the particular sensations of being in it.

As noted earlier, one of the dominant factors of a negative impact on a person when he/she is at a stop is waiting. The importance of this factor is confirmed by numerous studies that were conducted in different regions of the world [18-27].

In some cases, the human mind can perceive time longer than it is. "A 1993 study found that one minute of wait time felt closer to 4.4 minutes of travel time. That means that if you have a 20-minute commute, you might feel like you should have been home already after a 5-minute wait" [28].

"The presence of some type of shelter as well as real-time information can reduce perceptions of waiting time for actual waiting of 10 minutes or less. Within the first 10 minutes, however, the greatest impact on estimated waiting times appears to come from any shelter versus no shelter"[27]. Moreover, it is without taking into account weather conditions which increase the negative aspect of waiting.

Waiting time is a major factor in the attractiveness of public transport.

B. Ferris wrote in his thesis: "Regarding the relationship between satisfaction and wait time, we found that overall satisfaction with public transport is highly correlated with decreased wait time amongst survey respondents" [27].

The study of how it affects people is the subject of common scientific interests of psychologists, transport workers and designers.

The sense of time can vary in different scenarios and perceived differently (feel) longer or shorter (figure 3-2).

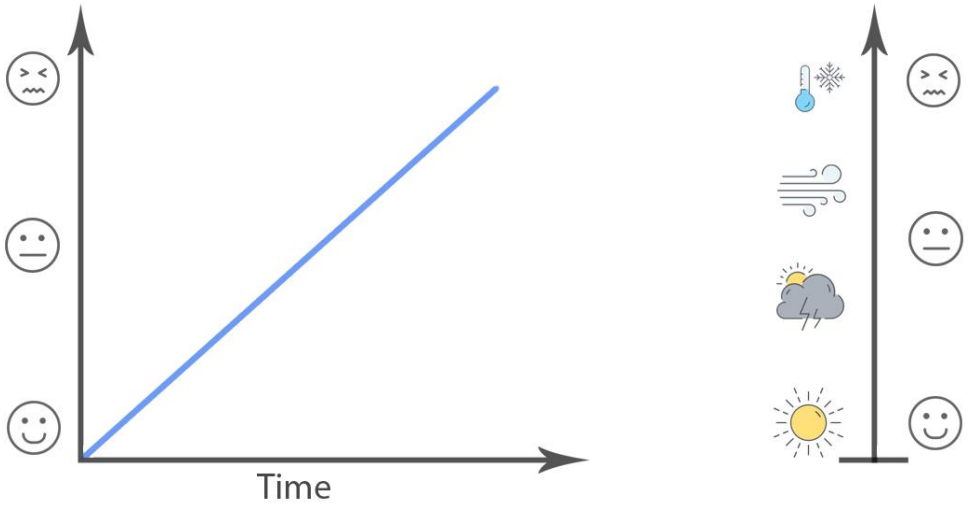


Figure 3-2: The effect of waiting time on a person

The attentional model of time [25] [26] [41] [42] is based on the concept of subjective time evaluation. In accordance with this concept, the subjective assessment of time differs from the objective assessment of time, because it takes into account the speed of information processing and is influenced by events that people may encounter.

"It can be argued that value of time in terms of utility or disutility depends on how passengers experience time (i.e., positively or negatively). The differentiation between objective (clock) time and the subjective appraisal of time seems promising because it offers an opportunity to influence the psychological value of time." [31]

Thus, it turns out that the benefits that are offered to passengers at bus stops are, for the most part, aimed at levelling the negative impact of the waiting factor and reducing the waiting time itself.

Studies on the railways in the Netherlands [31], [32] have shown, that consciously perceived stimuli, such as music, infotainment, provide a distraction which means that it is pleasant to wait and time passes unnoticed when special conditions are created for this.

Today, much of the research in the transport sector is aimed at creating high-quality information support at bus stops. This helps existing riders and encourage new ones and enhancing the usability of public transit.

"It is essential that the bus stop have adequate informational elements. Without this information, it is possible to feel disoriented and unable to get to the desired destination. For information to be effective, it is crucial that it is coherent and comprehensible. Also, public transport in a city with many tourist attractions must meet two types of people:

Locals - use public transport regularly, moving for work, study or pleasure, but probably not needing much information at the bus stop.

Visitors and tourists - generally have little or no knowledge of the city and need a lot of information to get around. The behaviour of these two types of users is different and each values different attributes in the urban transport system". [33]

The bus stop - also a social environment where people are located - individuals, each with their own character and mood. Therefore, in order to ensure genuinely comfortable conditions for a person to stay at a bus stop, it is crucial to take into account various psychological factors that arise in a place where people gather. In particular, we are talking about the desire of a person (often subconsciously) to preserve privacy in a public space. In this part of the research, I support and develop the ideas of Salome's Todria master thesis "Privacy in public spaces, Enabling working outdoors" [34].

One of the negative features of public transport, which reduces the loyalty of the population to it, is the crowding of people and often the lack of conditions to meet a person's biological need in a personal space.

As known, each person has an invisible personal space (figure 3-3), and when it shrinks, a person feels discomfort.

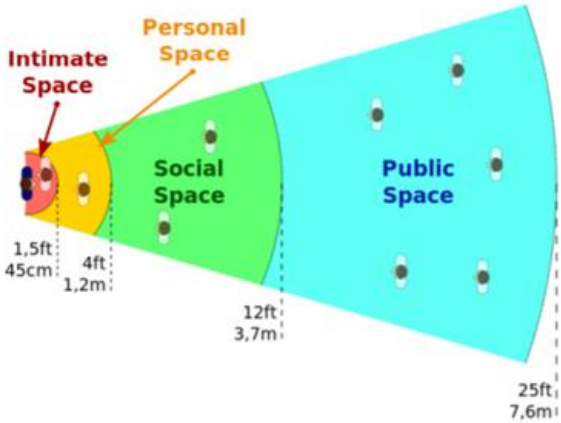


Figure 3-3: Personal Spaces in Proxemics by user: Jean Louis Grall [34]

Thus, as a result of the conducted research, the effect of a bus stop on a person, such a conclusion can be made.

The bus stop as an element of the urban environment surrounding human, as well as the physical, visual object and place of social interaction, has three types of influence:

Physical; Visual; Psychological

These influences have connections among themselves and determine the level of comfort for a person (figure 3-4). Moreover, the level of the last one as a result essentially depends on the conditions created at the bus stop and its ability to level the expectation factor and ensure the safety of personal space.

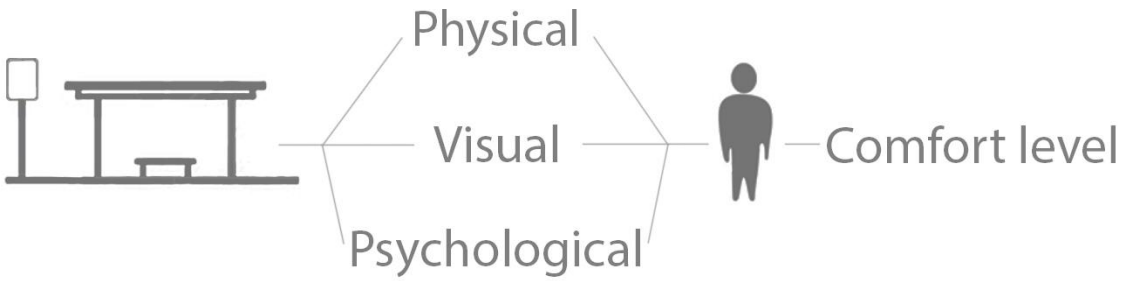


Figure 3-4: The concept of a bus stop impact on a person

3.2. Results of field research in Tallinn

3.2.1. Tallinn case study

According to city municipalities, there are altogether 982 public transport stops in Tallinn (figure 3-5). The surroundings of the stops are maintained by the Tallinn Municipal Engineering Services Department (TMSD). Some of these stops that have ads belong to JCDecaux Eesti OÜ The surroundings of the stops are maintained by the Tallinn Municipal Engineering Services Department (TMSD).

Figure 3-5: Map of PT stops in Tallinn [35]

In 2007, the City of Tallinn signed a lease agreement with JCDecaux Eesti OÜ. The agreement granted the company to install bus stops on city-owned land and to use the pavilions for advertisement purposes. The agreement was signed for the next 15 years, with 320 bus stops to be built across the city. JCDecaux Eesti OÜ maintains the installed PTpavilions. The remaining PT pavilions are under the supervision of the Transport Department and are maintained by the TMSD.

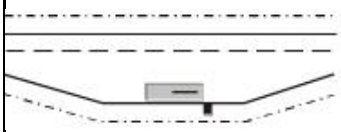
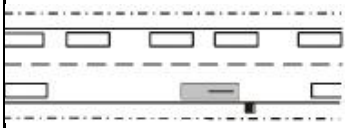
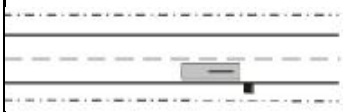
Transport Department is preparing a new concession contract to find private companies that will build all PT stops in Tallinn. TMSD will continue to deal with maintenance in the future.

Construction of stops is carried out according to the official standard: Eesti standard EVS 843 : 2016 „Linnatänavad [36].

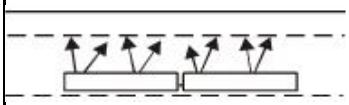
3.2.2. Analysis of bus stops in Tallinn

According to norms in Tallinn, there could be such layouts (see table 3-11) [36].

TABLE 3-1 - Types of PT stops

Peatuse tuup (Stop Types)	**Pohimotteline skeem (Schematic diagram)**	**Korvalekalle pohisuunast, m (From the main direction)**	**Peatunud uhissoiduk takistab muud auto- ja jalgrattaliiklust (Stopped bus is blocking the way)**
I Suletud tasku (Closed bay)		**>6,0**	**Ei (No)**
II Avatud tasku (Opened bay)		**3,0-4,0**	**Ei (No)**
III a Peatus soidurajal (Stop on the roadway)		**2,0-3,0**	**Vaike takistus ulejaanud liiklusele (Small disturbance to other traffic participants)**
III b Peatus soidurajal (Stop on the roadway)		**Ei voi tuhine (up to 2)**	**JAH (Yes)**

Continuation of the TABLE 3-1

Peatuse tuup (Stop Types)	**Pohimotteline skeem (Schematic diagram)**	**Korvalekalle pohisuunast, m (From the main direction)**	**Peatunud uhissoiduk takistab muud auto- ja jalgrattaliiklust (Stopped bus is blocking the way)**
III c "Liivakella" peatus (Hourglass)		**Kuni 2 (no or not significant)**	**Peatab**
IV a Platvormi ja unlekaigurajaga (With a platform and pedestrian crossing)		**-**	**JAH (Yes)**
IV b Platvormiga, foorjuhitav (With a platform and traffic light)		**-**	**Ei* (No)**
V Platvormita (tramm) (Without a platform)		**-**	**JAH (Yes)**

To understand the situation in Tallinn, a photo fixation of stops was carried out and their typology was analyzed (see table 3-2).

TABLE 3-2 - General Types of bus stops in Tallinn

Appearance	Characteristic
	Standard construction which is mostly used everywhere around the world. It has a simple design, consists of a metal frame and glass. They are installed mostly everywhere (in the center, in sleeping areas).
	Outdated kind. Still, exist in some parts of the city and mostly in living districts. The shelter has some more space, but overall, it does not meet modern design requirements. It is located at loaded places.
	Outdated kind. Still, exist in some parts of the city and mostly in living districts. Has some more space but overall it does not meet modern design requirements.
	Custom design. It is part of the architectural composition in the city center. Has a large capacity.
	Median Stop, Side Boarding. There are central lanes for trams and buses that can move without interference. The disadvantage is that the passenger must cross the road.
	Simple pole and flag type. Located mostly on the outskirts and suburbs of the city. Has small passenger traffic.

For further research, I chose the first bus stops type. These type is continuing to be installed in Tallinn because they comply with modern rules. These new stops have a lighter construction. They consist of a metal profile forming the frame on which the roof is mounted, glass partitions for good visibility and advertising. Inside there is a small bench, light on the top, transport information map on the back wall, and advertising medium. This design is used in many cities around the world, as it is easy to manufacture, install and maintain.

Depending on the size of the space in the installation site, such shelter could be placed in different ways. (figure 3-6).

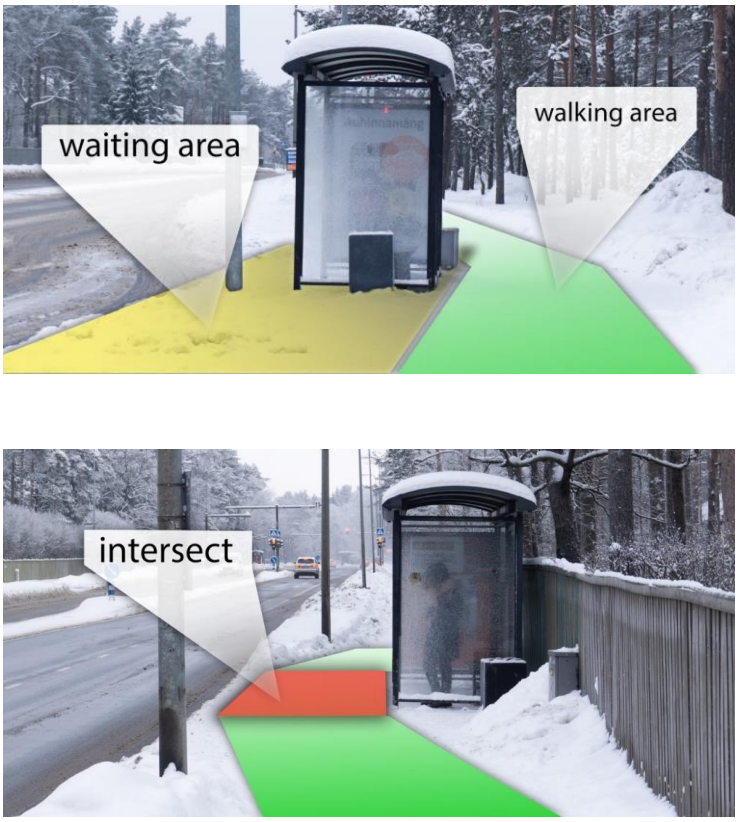


Figure 3-6: Placing options

Cons of these shelters are Lack of seat place and small capacity (without crowding only three people can sit freely). Also, these stops have poor protective properties from wind and rain, slanting rain can get inside and the wind can come from open parts. The weather in Tallinn is rarely extremely cold, but it is often windy and rainy. At the same time, Tallinn bus stop shelters also look like in warm European cities.

Thus, there are different types of bus stops in Tallinn, but they do not all meet modern design requirements and must be replaced. Shelters are not well adapted to local climatic conditions.

There are no interesting design solutions for stops in the city that could add some attractiveness.

Standard bus stops of the first type are designed only for small passenger traffic and they make sense to be in places where there is not much of street space.

3.2.3. Stakeholder Interaction

Bus stop customer objective is formed by main stakeholders, which include: public transport passengers, city authorities, the advertising agency. Furthermore, the interests of the last two should eventually converge on the passengers.

City authorities strive to create a convenient transport model of the city and thus make citizens interested to use public transport more and more. In the implementation of this aspiration, an important role belongs to the stops, which are designed to ensure comfortable movement of people in the city's transport system. Besides, the city government should take care of the image of the city, seeking to create its attractive, individual appearance.

The efforts of advertisers are aimed at people who are at stops or pass by / drive by. Thus, both the city government and advertisers should be interested in creating such stops that will attract people.

What will ultimately be a stop is determined by the understanding the idea of the comfort that it can create and the balance in the choice between its possible consumer properties and the economics of creating.

3.2.4. People's behavior analysis and interviews

At this stage of the study, it was necessary to collect data on people behavior at bus stops to understand their problems and needs. This opens up opportunities for the continuation of the project and creates the basis for the emergence of ideas.

Methods such as observations and interviews were chosen to collect the analytical material.

Observations during field research is a descriptive study in natural conditions, the purpose of which in this case is to study the behavior of people at public transport stops without direct contact with them.

The observation was carried out in several directions:

1. Approaching a stop
2. Actions during waiting
3. Boarding
4. Disembarking

Observations results.

1) When people approaching a bus stop, they generally look at direction of a bus, coming closer looking at schedule screen if there is one. If there is no screen, people look at the schedule on the pole or mobile version.

2) What do people do at a bus stop?

- People look lost in thought, thinking about something.
- Observing surroundings (watching people, houses, passing by cars, etc.).
- Using phone (chatting, talking, reading, watching videos, surfing the internet).
- Listening to music.
- Majority of people facing the direction where a bus should come from.

- Benches more used by seniors. Also, women tend to put their begs on the bench (this way occupying sitting place).

4) More people are waiting for a bus outside the bus stop shelter.

3) Usually, people scatter around along the stop trying to keep distance (shows a desire to keep private space), see photo (figure 3-7).

Photo 1

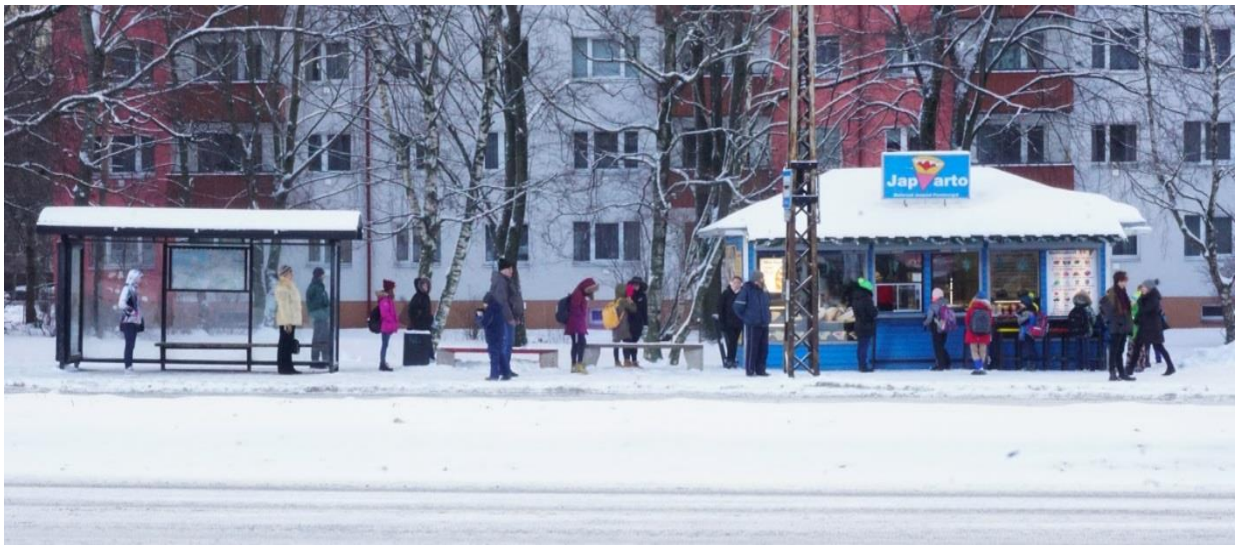


Photo 2

Figure 3-7: Photo fixation

Interviews were used to supplement the conclusions made after the observations and to reveal the emotional reaction of people to bus stops.

A total of 18 semi-structured interviews were conducted with different users. Respondents were people who belong to different age groups, regularly use public transport and spend at bus stops an average of 5-10 minutes.

Interview questions.

How often do you use public transport?

Why do you use public transport?

Do you need to make a transfer to another bus?

Do you check in advance when a bus comes, or you look the schedule table at the bus stop? If check by app - how much min before the bus do you come?

How much time do you usually spend on the bus stop? On the second?

What do you usually do at the bus stop?

Do you usually wait in a shelter (pavilion) or outside?

When do you use shelter pavilion for waiting? Why, When?

Do you prefer to sit or stand?

How do you react when the shelter is full of people? How often does it happen?

What do you think about the quality of protection from different weather conditions?

What is important for you at a bus stop?

How weather conditions impact your mood?

Do you feel safe on a bus stop?

What is a good bus stop for you?

How often do you wait for a bus more than 10 min? What bus stop is it?

How do you feel if you realize on the bus stop that you need to wait too long?

Can you tell me any positive or negative experiences?

What would you change about bus stop?

What would you leave the same about the bus stop?

Tell me what is your opinion on current bus stops, what do you think of them?

Do you like them? Why?

Do you sometimes get cold? How often? How long does it take to you to get cold?

To the question: "What could cause irritation?" such answers were received.

A bus comes earlier than it says at the timetable and I have to wait for the next one.

A bus is late.

Cold weather.

A Bus does not come on time

When there is no information if the bus is late.

Losing time and getting cold.

From the answers, it is clear that the irritation of passengers arises mainly due to the shortcomings of public transport. Because of them, people have to wait and lose time.

The opinions of the respondents confirmed my own observations and conclusions about the critical values of users that need attention.

3.3. Innovative bus stops. Evaluation of examples.

In recent years by way of developing technology the bus shelter industry is changing. Specialized companies proper projects of various purposes and functions: both traditional places of waiting for public transport and innovative stops.

The study collected examples of various stops from around the world. The most interesting projects are presented in table 3.

TABLE 3-3 – Description of innovative bus stops

Appearance	Characteristic	Links to an external site
	Magazine Kiosk Bus Stop. Found in Mexico, this shelter lets you kill time with reading material.	https://www.trendhunter.com/trends/magazine-kiosk-bus-stop
	The transportation system uplift is inspired by the laid back cafe environment where people can sip coffee while they wait, grab a sandwich, break out the tunes, charge a cellphone or even borrow a book, rent a bike.	https://www.trendhunter.com/trends/station-diderot
	The Yahoo bus shelters have been outfitted with touch-capable digital video screens. These screens house a handful of games from shape puzzles to trivia. You can amass up to 100 points playing and select which neighborhood you want to donate those points to.	https://www.trendhunter.com/trends/yahoo-bus-shelters

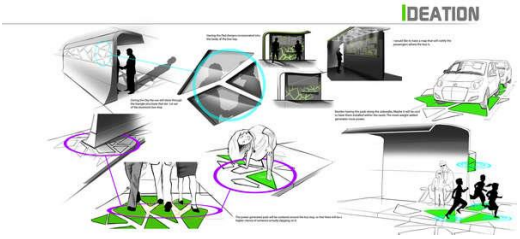
Continuation of the TABLE 3-3

Appearance	Characteristic	Links to an external site
	We've all been in the situation where we had to take an unknown bus route to get to a certain destination, only to get off after and forget the route home. There is nothing worse than standing at a bus stop without a map of only kind and then blindly stepping on board not knowing where you'll end up. The Eye Stop Bus Shelter could be the answer to relieving that stress and anxiousness.	https://www.trendhunter.com/trends/eye-stop-bus-shelter
	Harnessing energy from solar panels on the roof, they power an interactive touchscreen map and sockets to charge your mobile phone and laptop, also, they're equipped with a coin changer and a vending machine as well.	https://www.trendhunter.com/trends/solar-stop

Continuation of the TABLE 3-3

Appearance	Characteristic	Links to an external site
	This bus stop-like screen holds a host of information about its city, from maps and weather forecasts to local news and public transportation routes.	https://www.trendhunter.com/trends/naviq-digital-city-guide
	A new concept bus stop at Jurong East designed to “make waiting fun” demonstrates how ground-up energy and creativity can be harnessed for urban and social innovation.	https://landtransportguru.net/project-bus-stop/
	Seasonal affective disorder can be a serious condition that leads to more than depressive moods during the winter season, especially in different cities throughout the world, and the Umea Bus Stops hopes to alleviate some of the symptoms. It involves specially illuminated shelters that provide light therapy.	https://www.trendhunter.com/trends/umea-bus-stops

Continuation of the TABLE 3-3

Appearance	Characteristic	Links to an external site
	A low-tech transit refuge is certainly a lower cost option, but this Detroit LED Bus Stop proposal demonstrates that hi-tech features might not require added funds. The illumination and the digital signage that this bus shelter offers does not need to leech power out of the urban grid.	https://www.trendhunter.com/trends/detroit-led-bus-stop
	Caribou Coffee bus shelters are warming commuters while promoting the new 'Hot 'n Wholesome' breakfast menu. The toasty bus stops look like giant ovens, complete with actual heat-producing coils.	https://www.trendhunter.com/trends/caribou-coffee-bus-shelters

The study of innovative bus stops made it possible to identify the main changes, which occur under the influence of new technologies and trends. (figure 3-8).

Figure 3-8: The main directions of changes of the bus stops today

Overview of existing bus stops and future concepts showed that today's shelters are being equipped with different features such as real-time schedule updates, modern advertising techniques, additional information, advanced weather protection, and eco-friendly elements.

It shows that most of the changes are directed to create comfortable conditions for waiting. Moreover, some of them serve like distraction and entertainment, but they do not eliminate the waiting factor itself.

Conclusion

This part presents the results of the study of bus stops, which are created and correspond to today's transport system. The convenience of a bus stop should be determined through its physical, visual and resulting psychological effect on a person, which ultimately determines his/her loyalty to public transport. In the present conditions of the city's transport system, one of the main negative factors of psychological influence that is present at the bus stop is waiting for a bus. Waiting is a waste of time, which causes discontent among people and its degree increases over time. There are already many bus stop projects that improve the comfort of waiting. However, they cannot completely remove it. This negative factor can be removed only by improving the transport system and its changes will affect the stops.

4. URBAN TRANSIT SYSTEM AND URBAN MOBILITY

4.1. Characteristics of the transit system

The transit network of a city is one of its life-supplying systems, comprising different methods of transport and movement, transit routes and other associated infrastructure (including transit stops).

The transit system forms the profile of cities, allows people to interact and address personal and social goals. The ease and comfort of a person's daily commute, moving between their home / work/ school / other destinations, influences their productivity, feeling of stability and quality of life in a city.

The main purpose of an urban transit system is to provide an efficient transport solution for transporting its inhabitants. The best way of addressing this goal is through balanced transit systems, which fulfil the social and economic requirements of the society, are sustainable and economically effective. A well-balanced transit system comprises the following [37]:

- Equal access to mobility
- Ability to plan journeys
- Minimal effect of transport on the urban environment
- Ability to reach any point within the city in the least possible time
- Availability of affordable, safe and comfortable transport

However, today a perfectly balanced transit system does not exist. Present-day cities face a collection of inter-connected problems, rooted in an increase in transport units on urban roads. The information provided by the European Transport Safety Council suggests that in the last ten years, traffic on the roads has increased by 27% [38]. For example, statistics for Estonia show that every second inhabitant owns a car [39].

A large number of vehicles increases traffic, reduces transport efficiency and results in time lost in transit. It also has a significant ecological impact.

Vehicular transport is a source of noise and pollution. All of this has a negative impact on the environment and people's health.

Besides, the growing number of transport units takes up an increasing amount of urban space - roads become wider and car parking space has to be increased. Some estimates suggest that up to 30% of urban space is dedicated this.

Today, there is a wide-spread belief (which I support) that the way to reduce the traffic on the roads is through encouraging urban dwellers to use public transport. This will reduce congestion on roads, improve travel speeds and significantly limit the negative environmental impact of transport.

What is the way to achieve this?

In my opinion, the solution lies in making public transport more attractive. To do this, it is important to understand the users' requirements and analyse tendencies in everyday urban mobility.

4.2. Everyday mobility and methods of transportation

Intensive daily mobility of urban dwellers is one of the key components of a contemporary city.

Daily mobility is the physical movement of people which results in transit with the aim of reaching a certain geographic point. The points of destination are places of activity (home, work, shop and others) for fulfilling people's needs. The more points can be reached in a certain timeframe, the higher the mobility.

Mobility comprising "purely time in transit" is a factor that I believe determines the daily life-cycle of an city: the amount of tasks that can be accomplished in a day, the choice of the time for travel, the planning of a route, the ability to adapt to a situation and change the route.

This set-up depends primarily on the chosen method of transportation. Those can be categorised as follows: on foot, by bicycle, by car, by public transport. To analyse those methods of transit, I used the book "Transportation for Livable Cities" by Vukan R. Vuchic [36] and my personal experiences of mobility.

Vukan R. Vuchic defines the category of "private transportation" which includes three methods of transport: pedestrian, bicycle and private car. Each of those methods gives the users a great deal of freedom, allowing them to freely choose the time and place of travel.

Pedestrian is the main, most widely available method of travel. It is most effective for short distance. Each journey starts and ends on foot, even if this means just crossing the distance between one's door and car, or walking from the car to the door. Pedestrian travel is more comfortable, cheaper and often faster than any other means of transport where short distances are concerned. If the transit stop is 2-3 minutes away, then pedestrian travel is easily perceived by the person as part of the daily mobility route. This method of travel becomes more problematic with the increase of duration, as a rule, from five minutes onwards (which can be at the start of the route — before other transportation is involved, or in middle — where change-overs are involved, or at the end of the route — after all journeys have been taken). For long distances, pedestrian loses its attractiveness as it is slow, involves considerable physical effort and is uncomfortable in bad weather.

Travel by bicycle is most economic and, in case of traffic jams, fastest way of mechanised travel. However, a bicycle is less comfortable than a car, requires physical effort, may be uncomfortable in bad weather or in hilly locations, and is unsafe if there is no associated infrastructure in place. At the same time, it is attractive to people who are not afraid of physical effort and prefer the convenience of bike travel for shorter distances in a city.

Over 80% of bicycle journeys are taken for distances below 5km [39]. The illustration below (figure 4-1) shows the relative spread of bicycle trips in Flanders (northern part of Belgium). In other countries and regions, a similar spread can be seen. Bicycle is, above all, a local method of transport.

Private car gives the user independence in terms of time and route of travel, saves time in transit (assuming no traffic jams) and makes the journeys comfortable. Those advantages make the car incredibly attractive as a means of transport, either for personal or family journeys. It is the attractiveness of car travel that results in high numbers of vehicles in contemporary cities and the appearance of a transportation system discussed earlier.

Today, the choice of bicycle or personal car as a means of transport raises the need to find a parking spot, which becomes complicated in places where transportation devices are congregated. For example, this can be problematic in city centre. The lack of parking spaces, especially for private cars, may void its main advantage — ability to travel "door to door" — and reduce mobility.

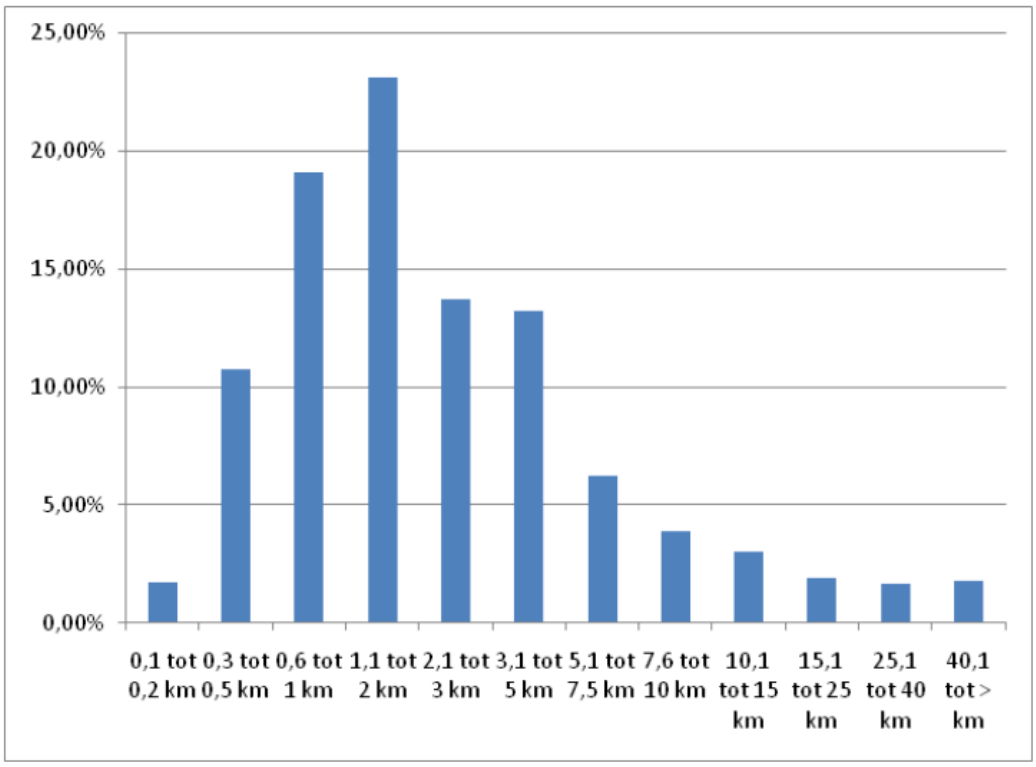


Figure 4-1: Spread of bicycle trips by distance [41]

Public transport is one of the most popular means of travel. For example, as seen in figure 4-2, in Tallinn 43% of users choose public transport as a means of getting to work. However, this is almost equal to the amount of people choosing personal car journeys.

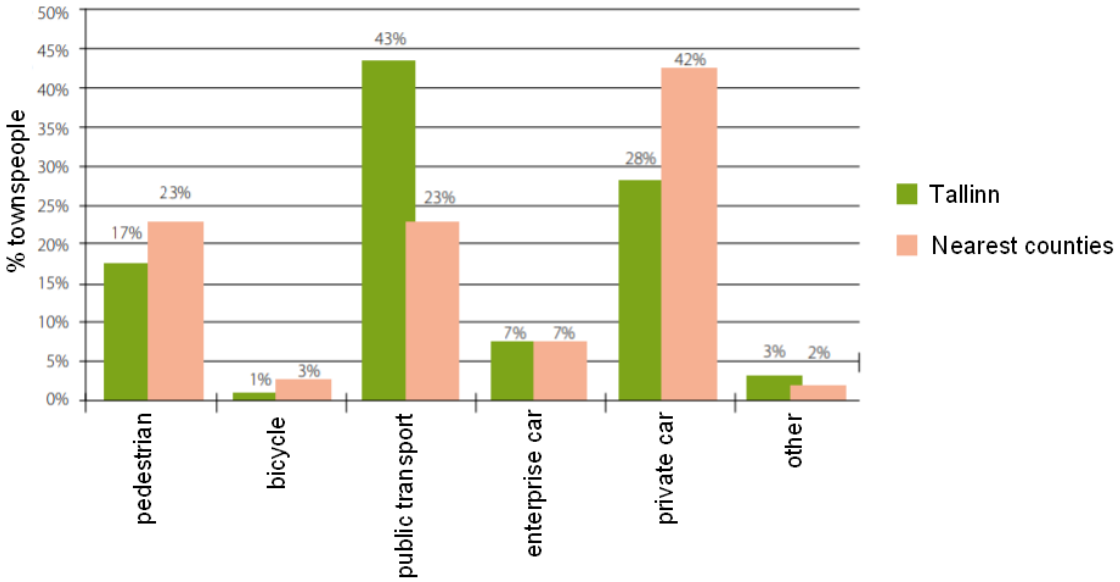


Figure 4-2: The main way to go to work [42]

At its core, public transport is more accessible to all categories of urban dwellers, has higher transportation capacity, and is safer. However, public transport today is often less comfortable and slower than travel by personal car.

First, public transport operates at fixed routes with clearly defined stops, which one has to walk to and / or from. This means that public transport does not solve the issue of the first / last mile.

Second, public transport does not always cover the city effectively. For people, especially those living on outskirts of a city, it is often difficult to get from one end of the city to another, and a direct and fast route does not exist (see figure 4-3). One needs to change the means of transport, which results in time loss.

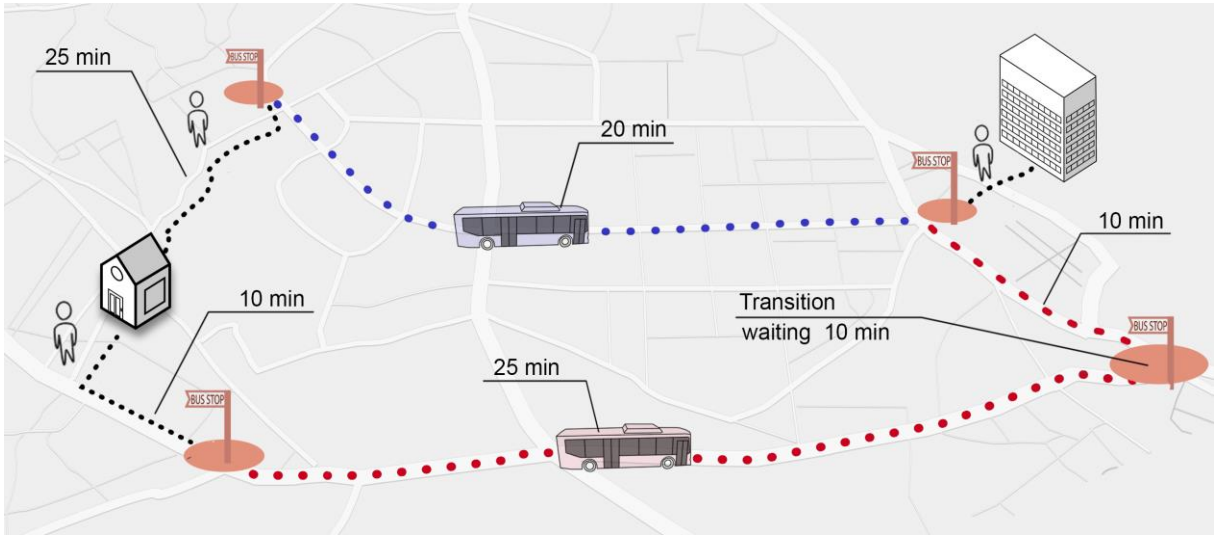


Figure 4-3: Abstracted model of a complex travel route

Third, public transport is not always reliable. Bad traffic disrupts transport timetables and people have to spend time waiting at transit stops. This disadvantage of public transport means passengers cannot plan their time accurately.

The life-cycle of a contemporary urban dweller is characterised by a high intensity of movement, so the way routes are organised and priorities set has a significant impact.

For example, the route from home to work — a sort of "in-between" place in space [48], is part of un-changing mobility that repeats on a daily basis, is routine.

When going to work, people usually take a comfortable route, selecting the route and means of travel depending on the circumstances. As a rule, those are reliable and repeated methods of travel (pedestrian, car, bus, other) and a certain, un-changing route.

However, a person's daily route is not always the same — they can have a whole variety of making up their routes depending on specific conditions, circumstances and plans throughout the day.

When choosing the methods of transport and their combinations, a person "weighs" various circumstances, and while in ordinary conditions the combinations may be stable, in special or unforeseen conditions a passenger is required to change their movement plans rapidly.

Today, the process of using transport is closely connected with other daily activities, such as the use of mobile devices. Smartphones, sat-navs, dedicated mobile apps expand the potential for planning a person's daily mobility. They allow one to develop a strategy of transportation and select the optimal routes for reaching a destination.

Based on my research, I have defined the key characteristics of public transport which will, in my opinion, increase its use (figure 4-1).

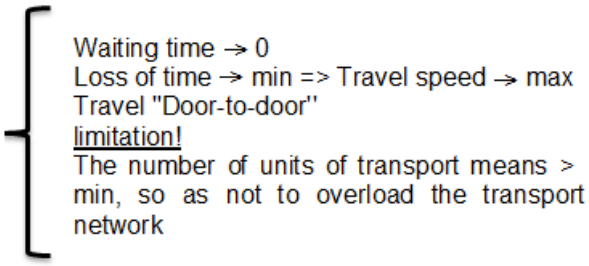


Figure 4-4: Public transport target model

Perfect public transportation minimizes the waiting factor, provides high speed of movement, solves the problem of the first / last mile and at the same time the transport network is not overloaded with transport.

At this point, it is important to address the issue of first / last mile, which has not been solved in present-day use of public transportation and which affects the quality of people's mobility significantly.

4.3. Public transit's first-mile/last-mile

The combination of words "Last Mile" are used in different spheres of human activity and it has many definitions. Considering transport system, last mile is part of the way «from a transportation hub to a final destination in the home» [43]. «The Last Mile» is generally used to describe difficulties in the movement of people from the transportation hub, especially railway stations, bus stations to their final destination. Many urbanists that deal with the problem of planning transit add the word "first" to the "last mile". In this case they consider difficulties which users experience from the starting point to the transport network.

According to Alex Gibson: «The problem arises when a potential rider is further than a "comfortable distance" to the necessary fixed-route stop» [44].

For a person the "comfortable distance" is mostly connected to the time needed to cross it. Timely costs spent on first-mile/last-mile depend on type and time of transit. According to the research done by Jarrett Walker, people walk further to faster services, such as metro [45].

In this case, if a person has to travel a long time in public transport, then going far to a stop or from it, makes this type of transit uncomfortable and is negatively affecting the mobility.

The most commonly cited standard for walking distance to transit is 400m or ¼ mile. Of course it is not a hard boundary. According to studies of different cities in North America, Jarrett Walker shows such results [44] (see figure 4-5).

Graph shows that in different cities same distances are crossed by different percentage of people. And that depends on the amount of public transportation in the region. Few people walk more than 200m in downtown Washington, DC because in such a densely served area, few people would need to. In low-density Calgary, at the opposite extreme, many people have to walk fairly long distances. In different cities own transit is made, with unique characteristics. But there is also something in common. In the center of the city transit is higher than in starting points. Which means, that for people moving to the center the problem of the first mile is much more important than the issue of the last mile.

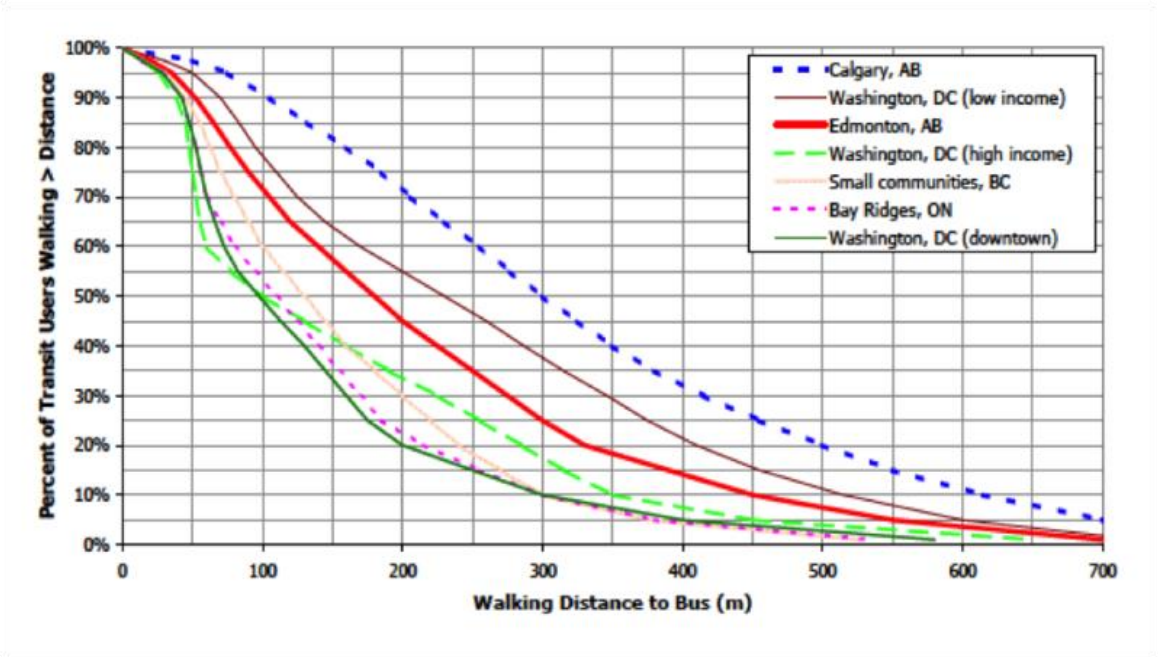


Figure 4-5: The breakdown of local bus passengers by the distance they walked to get to the service [46]

Jarrett Walker also says that the question of how much people are ready to walk until the bus stop is very complicated and depends on each separate person. He says: “If 1/10 of Calgary’s bus riders walk 600m or more, does that mean they’re willing to? Or does it mean that these people are so lacking in good alternatives that they feel forced to walk that far? ” [45]

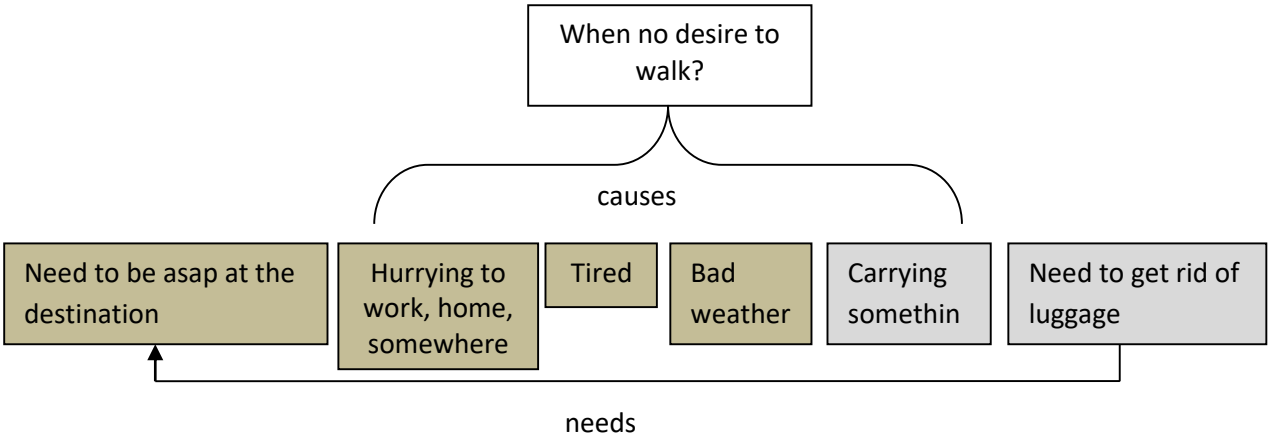
Authors of the work “Transit use and the work commute: Analyzing the role of last mile issues” conclude that the last mile problem is a complex multidimensional problem that has physical, place-based, social, and perceptual components [47].

Therefore, one side of the FM/LM problems is determined by its physical, place-based components. First of all, it is features of a city's transport system which are determined by its territorial location. The FM / LM space itself can also be an important component of the problem. Such spaces include large industrial estates, technological parks, hospital complexes, ports, airports and university campuses. A person who has reached the edge of the territory by some transportation usually walks to the final destination for a longer time. Besides those places that have high concentration of human activity, there is usually additional user needs for FM/LM problem. These needs are associated with the need for a large number of movements across the territory during the working day.

Another side of the FM/LM problem is discovered by analysing the needs and situations of transit users, which fills its social and perceptive components.

The main questions that determine the FM / LM problem for a user are:

When is the travel time important? Or When a person is not ready to walk?



To summarise the results of different studies, the main reasons for this are below (figure 4-6):

Figure 4-6: Reasons and needs of the FM/LM problem

"Comfortable distance" may vary based on uncontrollable variables such as weather and time of day [53]. Besides we all are sometimes in a situation where we have to rush, when you feel tired and/or you need to carry something. In any case, this is the result of one need: you need to get to the destination as fast as possible. In situations like this, on-demand transport is required, to pick you up from a certain point and bring you door-to-door to your final destination.

When addressing the issue of the last mile for public transportation, the solution should focus on the transit stop, which is the place where the method of mobility changes. Today, this is primarily the public transport - pedestrian transition, which determines the problem of the last mile. To improve this, solutions that involve changing transport stops are required to create new on-demand opportunities for everyday mobility.

Conclusion

In present day, urban development faces multiple inter-connected issues related to public transit. Increasing the amount of transport lowers mobility and severely affects the environment: creating harmful emissions and greenhouse effect, increasing noise. Besides this, the transport system takes up large parts of the land, reducing land availability for pedestrians and cyclists, while limiting the

potential for green spaces. To change those issues, the current system has to change. One of the effective ways of doing this is to increase the attractiveness of public transport, so that less people rely on personal cars. To do this, solutions are required to reduce waiting times, increase speed of transportation, offer door-to-door transport possibilities. Within this, the bus stop plays a key role, becoming the centre for changing mobility and offering new possibilities.

5. SMART TRANSPORT SYSTEM

5.1. Smart systems for a city

Transformations of the city's transport network will be facilitated by the development of the Smart City concept, which aims to create an infrastructure based on intelligent networks.

"Smart Cities are urban areas that make use of information technology to address social, economic and environmental issues, creating sustainable economic development and a high quality of life" [48].

To address the issues of transport planning and to control the traffic flow, a lot of countries are now using Intelligent Transportation Systems (ITS) wich is becoming increasingly popular every year.

ITS means the use of modern communication technologies, control, computer equipment and software to improve the efficiency and safety of ground transportation. This system can effectively manage the street network of roads, taking into account its density and throughput [49].

Currently, these systems are successfully operating in many cities around the world.

For example, the LADOT system works successfully in Los Angeles (USA, CaliforniaIt includes traffic lights and detectors that improve the process of managing passenger traffic. The OPAC automatic motion control and dispatching system is implemented in Chicago (USA, Illinois). It provides benefits to public transport at intersections and increases its speed [50].

The VICS system operates throughout Japan. This is a set of equipment and software, with the help of which information on the available capacity condition of roads is accumulated in databases, and then sent to onboard navigation systems of vehicles, including public transport. Also, Japan has SmartWay system. By using «vehicle-to-vehicle» (V2V) technology, this system creates information support for effective traffic control, which includes preventing collisions and ensuring safety when driving at high speeds [51].

Many ITS development projects work in the European Union such as TEMPO, CVIS (Cooperative Vehicle-Infrastructure Systems) and other projects. The purpose of these projects is to improve the safety and quality of passenger traffic. The TEMPO programme is an umbrella program for a number of integrated transport-related iniseatives incluading ITS Streetwise, Viking, Centrico, Arts, SERTI, Corvette, Connect. The CVIS project is a symbiosis of cooperative intelligent vehicle-to-infrastructure(V2I) and V2V transport systems [52].

There are many close concepts: Smart Transportation, Smart mobility.

Smart Transportation – a transportation management system that helps to identify opportunities for increasing throughput, improve operations, and identify strategic investment priorities to maintain optimal transportation performance [53].

Smart mobility – technological passenger transportation management systems. The main trend of ITS – integration of software and individual structural components of passenger and freight traffic, namely road interchanges, highways, stops and so on. It is evident that the introduction and further development of ITS require spatial transformations as well, including the design of bus stops.

One of the interesting projects of the transport system of the future is the project of the designer of Philips Cheaw Hwei Low [54]. By this project, street lights, as well as users' smartphones, were included in the general concept of public transport stops. The concept of the project is presented in figure 5-1.

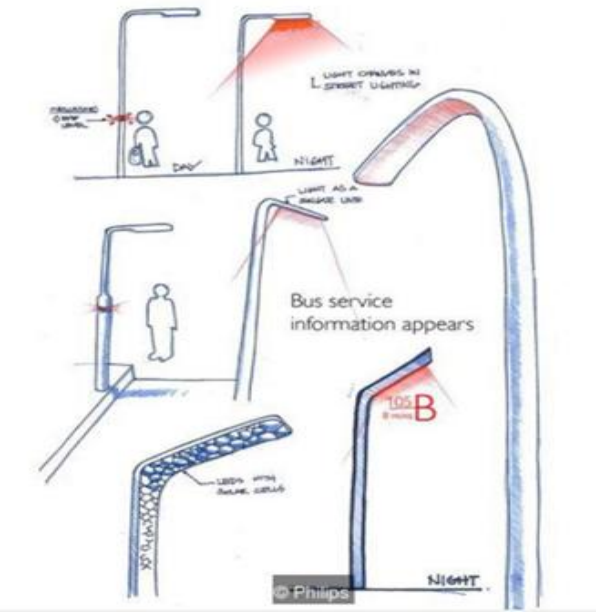


Figure 5-1: Lighting languageStreet with bluetooth technology [54]

The software part of this concept is based on Bluetooth technology. This technology allows integrating transportation and smartphone applications into a single system for managing the process of passenger traffic and transport infrastructure. Street lights are included in the infrastructure part of this project. With the help of Bluetooth technology and special equipment placed on street lights, the data is being accumulated on the availability and number of passengers on each part of the route. These data are transmitted to the transport company, which promptly makes changes to the routes, specifically to the frequency of sending buses to the trip. Streetlights in the presence of potential passengers are transformed into mini-stops. Thus, a transport infrastructure is created that is convenient for both passengers and transport companies: bus stops occur in a convenient place for passengers and public transport routes meet the needs of passengers. Transport companies will be able to avoid running insufficiently full, or crowded buses.

Obviously, the unimpeded spatial movement of passengers requires the introduction of a smart mobile ecosystem. One of the variants of its functioning is shown in the figure 5-2.

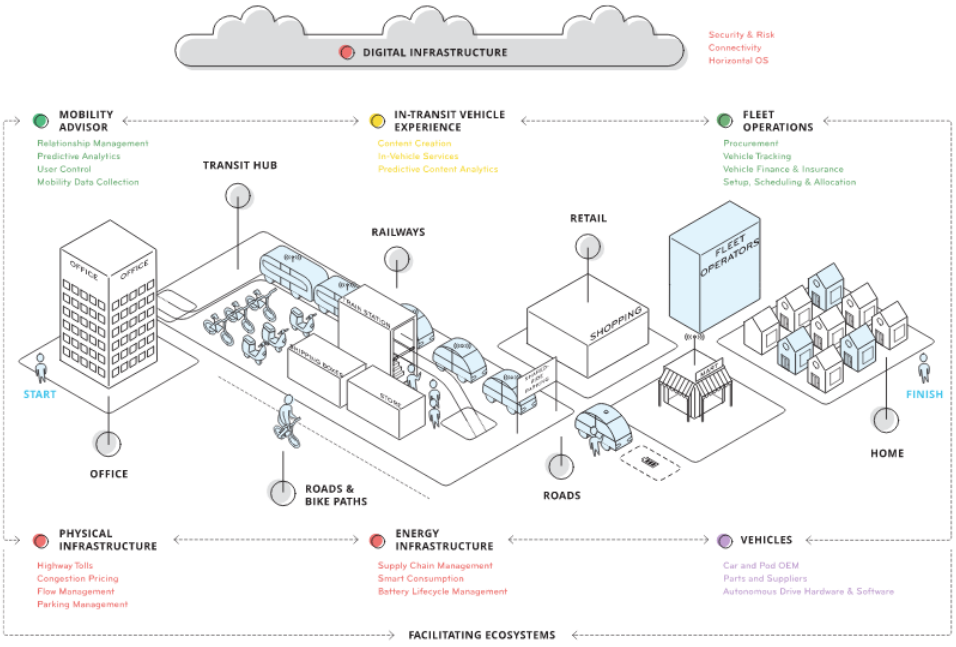


Figure 5-2: The future mobility ecosystem and required capabilities [55]

The introduction of this smart mobile ecosystem will serve as an incentive for the development of both the automotive industry and transport providers. By changes in consumer demand, these companies will offer new products and services, that is, new vehicles, new equipment, new approaches to routing (route planning) will be created. In other words, these companies will also change the framework and design of the future mobility ecosystem [55].

It is clear that the transport system will be transformed. Transport concepts of the “Smart City” will significantly improve the quality of these services and will provide comfort to passengers. Also, it will free passengers from the need for long waiting for public transport, which will significantly save their time. By the expected passenger traffic transport companies will be able to plan routes rationally and optimally combine different vehicles on different sections of the routes. This will allow transport providers to use resources most efficiently, so the results of their work will improve.

Obviously, in these conditions, the role of bus stops will change. They will be an important place for combining and organizing routes for getting around the city.

5.2. Smart transport system paradigm

In my understanding the smart transport system – a system that includes Intelligent Transportation Systems with all its elements, different Smart Transport and objects of transport infrastructure (including stops).

That is, the Smart transport system is represented as a set of subsystems and elements connected to each other as a whole, which have their own properties and solve their specific tasks. Such a system is already appearing, but it is still at an early stage of development.

The introduction of new technologies in different areas of our lives and their intensive improvement will create a near-perfect model of the smart transport system. Information and communication technologies, equipment of Intelligent Transportation Systems will interact with Smart Transport, which will have new features and capabilities.

EuroScientist Journal presents the concept of Smart Transport this way (see figure 5-3) [58].

The concept of Smart Transport features is very similar in different sources. Such transport will be effective, safe for people and nature.

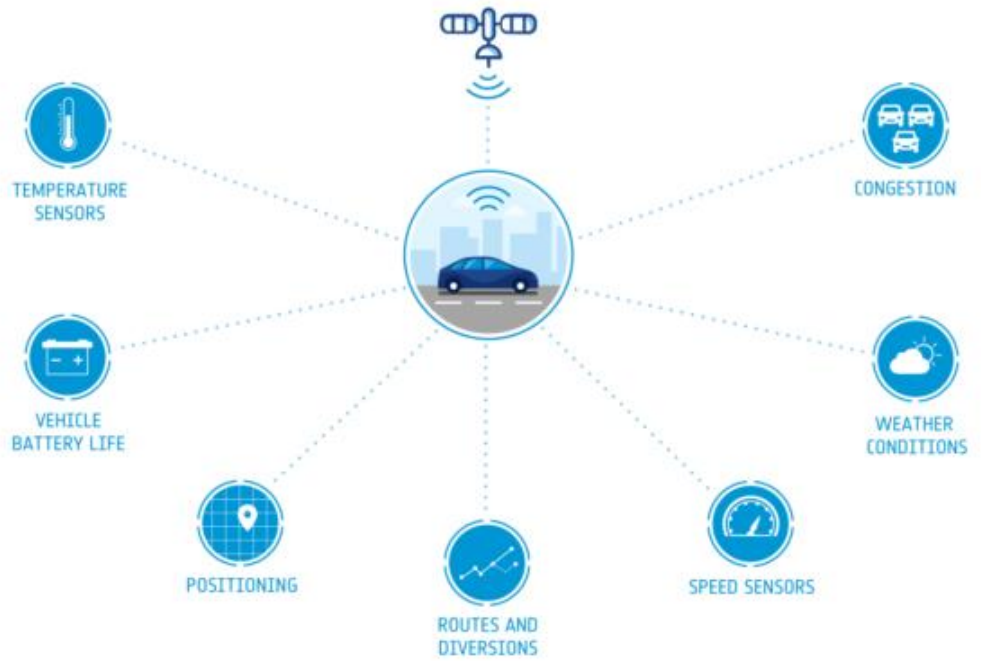


Figure 5-3: Smart Transport [56]

An important characteristic of smart vehicles will be their ability to communicate with each other, infrastructure facilities and record the presence of a person on the roadThese systems are developed for this: vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2X), vehicle-to-pedestrian (V2P), vehicle-to-grid (V2G) *и* vehicle-to-device (V2D) (see figure 5-4) [57].

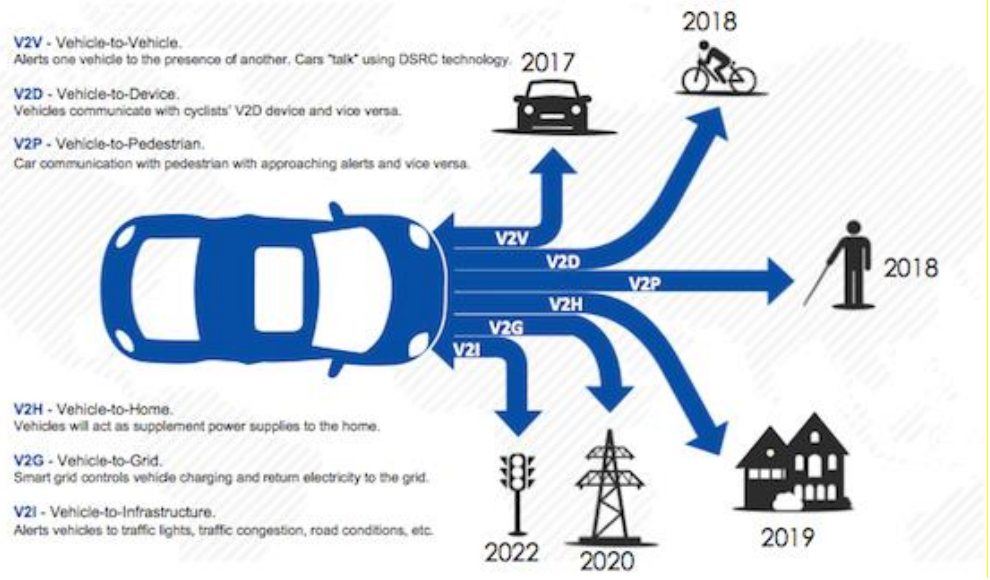


Figure 5-4: Vehicle to everything [58]

Summarizing and analyzing different points of view [56] [59] [60], I made a list of what Smart Transport will be able to do.

- Communicate with each other, with objects of transport infrastructure and navigation systems.
- Communicate with a person and fulfil his/her requests for mobility.
- Self-drive.
- Recognize damage and report damage to repair services.
- Rationally use energy.

Smart Transport in combination with Intelligent Transportation Systems and Smart objects of transport infrastructure will significantly increase mobility in cities and will allow creating more comfortable conditions for people's life. This will be possible as a result of three fundamental changes in the transport system of the future. [62].

1. Road width reduction. The road lane will decrease to the size close to the width of the transport, which will be able to move safely in such conditions. This will reduce the roadway and give more space to pedestrians and cyclists.

2**.** Distance reduction. With smart vehicles, there will be no need for a great distance between their bumpers. Therefore, instead of a distance of several cars, transport will be able to move with a distance of several tens of centimetres. As a result, there will be reserves for additional vehicles on the road.

3. Time reduction. Smart vehicles will be much faster. They will drive confidently, have complete information and move without fail. The time of any movement will be significantly reduced.

All considered changes in the transport system in the era of large-scale use of smart technologies will increase the attractiveness of public transport. Thus it will displace private cars from the streets of the city. Changes will also happen with bus stops. In the conditions of a well-functioning Smart transport system, the priority of its functional purpose will change. Where it is now a place where one must wait, then in the future it will be a place for changing the mode of mobility and waiting at will. The introduction of smart technologies will expand the opportunities for bus stops to provide services to the population, which will make life in the city more convenient.

5.3. Vehicles for Smart public transport system

In this part of the study, it was important to understand which transport would be part of the Smart public transport system. To accelerate mobility in the city today there are already various transport technologies that will develop further.

Cities around the world try to create better conditions for buses to make the system faster and more efficient. We can see it in the Bus Rapid Transit system (figure 5-5) which has its line (corridor) separated from traffic, usually in the middle of the road. Due to features similar to a light rail or metro system, it is much more reliable and faster than regular bus services [61].

Figure 5-5: Bus Rapid Transit system. Quito, Ecuador [61]

Also, another important thing in addition to the speed of public transport is the last mile problem.

Micro Mobility is considered as a solution. Today, this type of mobility is provided by electric scooters and bicycles that have become popular recently. According to the authors of the publication [40] "They have the potential to better connect people with public transit, reduce reliance on private cars, and make the most of existing space by “right-sizing” the vehicle, all while reducing greenhouse gas emissions".

This is a good mobility option and one of the possible solutions to the last mile problem. However, scooters and bicycles cannot meet all the needs of people that arise in the last mile.

Such a vehicle will not fulfill the request on demand, having independently arrived at the point you need. It does not protect against bad weather and in most cases is unsuitable for the transport of

baggage. Besides, not all categories of the population (in particular, the elderly and people with disabilities) can and want to use such means of transportation. I support the idea that the transport system should be balanced and humanistic. It should allow citizens to choose between different ways of mobility, means of transport and meet the diverse needs of different people. As a result, autonomous vehicles (AVs) will allow developing a transport system in this direction. According to experts, they will be widely distributed as a result of their sharing. (see figure 5-6) [62].

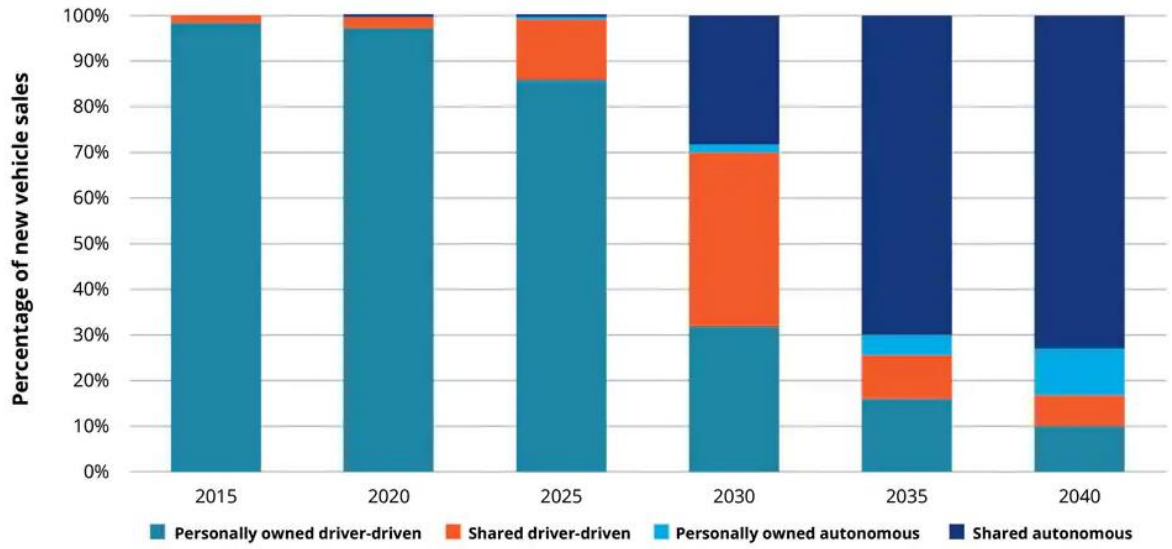


Figure 5-6: Forecast of new vehicle sales distribution in urban areas in the United States [62]

Such low-capacity transport has already appeared in some cities of the world, providing valuable experience for others. Bloomberg Philanthropies and The Aspen Institute “spent 2017 scouring the globe to understand how cities are preparing for AVs.” The results of these studies in 38 cities showed that “the most anticipated role for AVs is the bridging of existing gaps at the edges of transit systems, a crucial link that planners call the ‘last mile.’ Almost every city indicated interest in using AVs for last-mile solutions, and for a majority of cities it was the highest priority.” Researchers explain it this way "Autonomous solutions can be deployed with minimal new infrastructure, and when integrated with public transit can allow agencies to reach growing neighborhoods and hard-to-reach areas with smaller, nimbler vehicles that run on fixed routes or that can be summoned on-demand." [63]

Already today there are many projects to develop models of autonomous vehicles, which are called shuttles. Some of them are presented on figure 5-7.

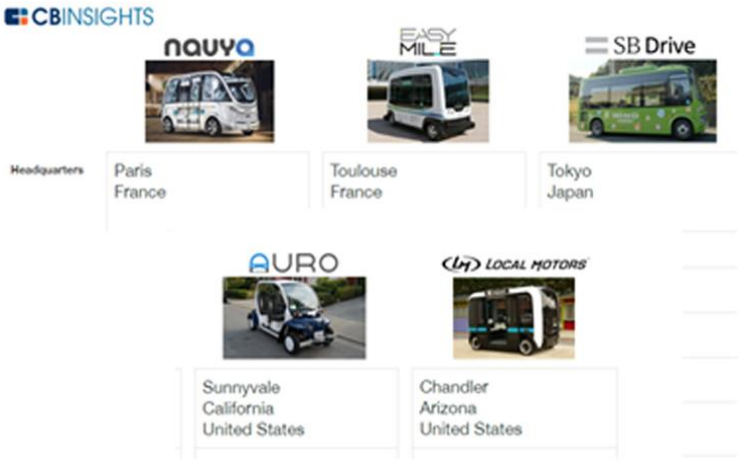


Figure 5-7: Development companies and project data [64]

Tallinn University of Technology together with the Florida Polytechnic University have a similar project (see figure 5-8).

Figure 5-8: Autonomous bus project of Tallinn University of Technology [65]

All prototypes are tested and at the moment can move only on fixed routes in certain areas of cities. In the future, the development of technologies will expand the capabilities of the shuttles and will allow to use them for the “mobility on demand” service.

These new vehicles are compliant with the Smart transport system and can be integrated into the public transport system, taking people to large bus stops (and away from them) for long-distance travel around the city. Their advantage is comfortable last-mile mobility for people with different needs and in different life situations.

Conclusions

The development of the transport system and the emergence of new types of vehicles will lead to the need to revise the organization of their movement and will make changes in the urban infrastructure.

The future transport system will be different from today's one in that it will increase the speed of travel and will allow solving the last mile problem in an accessible way. In the new conditions, new types of stops will be required, which will combine different ways of movement and will provide highly mobility as a service to the new era (see figure 5-9).

Figure 5-9: The last mile transport

Furthermore if today a bus stop is a place of waiting, then in the future the bus stop will be a place of transition from one type of transport to another or a change of type of mobility. The functional and special transformation of the transit stop will continue to take place because even today there is a need to combine several modes of transportation. For further development of the conceptual design solution, the focus is made on stops that will connect high-capacity buses with autonomous shuttles to overcome the last mile.

6. NEW MOBILITY CONDITIONS

6.1. External conditions

In "EU Green Paper: Towards a new culture for urban mobility" [66] it is noted that improving urban mobility means:

- increase and improve the quality of life in the city;
- respect everyone's right to mobility;
- reduce the impact of transport on the health of citizens;
- reduce the environmental impact of transport;
- guarantee and promote the economic development of the city.

The previous study showed that the urban public transport system is changing, acquiring new opportunities and will be changing to be more profitable and more convenient than cars. A fundamental shift is also taking place towards the prevalence of general mobility and the priority use of smart vehicles without a driver. To achieve full coverage of the city by public transport and solve the problem of the last mile, the model of public transport should include the combination of large main buses with shuttles to ensure micro-mobility in certain areas. The new type of bus stops will become a point for integration for shuttles.

To understand the external conditions for designing new bus stops, it is necessary to consider the possibility of placing them in different locations of a city. Here I would like to note that the location of the bus stops on the city map is a task of transport logistics and transport planning, the solution of which is not in my competence. Therefore, for the location of the new bus stop types, I can only consider the main characteristics of conditionally selected places in the city. These places should be close to the main roads where a dedicated lane for large buses will be organized.

The significant feature of the new transport system may be that it will have fewer main routes. (see figure 6-1).

Figure 6-1: Comparison of possible changes in the transport system

This system can be compared with the human circulatory system. The main passenger traffic will move in large buses along the "main arteries" – main routes, providing macromobility in the city.

Shuttles will operate in the “capillary” road network to meet the need for micro mobility (see figure 6-2).

Figure 6-2: Conceptual diagram of the collaboration of buses and shuttles

Considering that buses will be the part of high-speed public transport, it is likely that the distance between neighboring stops will increase, therefore the total number of stops on routes and the transport network as a whole will decrease. (see figure 6-3). It becomes clear that passenger traffic at bus stops will increase because one stop will have a larger service radius.

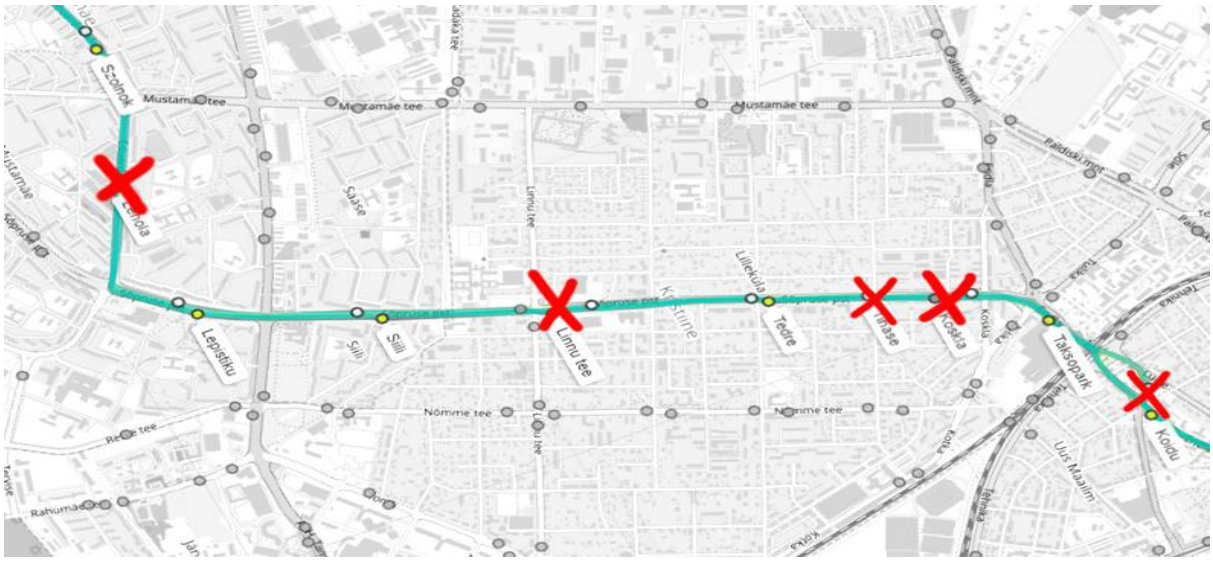


Figure 6-3: The conditional decrease in the number of stops

The concept should also be developed by taking into account different possibilities of the urban environment. In specific areas of a city, there are buildings, objects of culture and recreation, green areas, that create their conditions for placing a bus stop. The available space in a specific location can be quite generous or fairly limited. Therefore, different solutions are needed for each case.

All considered external conditions should be taken into account when developing solutions.

6.2. Setting a task for the concept

A bus stop is part of the transport system and urban infrastructure. Therefore, it will be changing in the future according to the global goal of creating a well mobile and environmentally friendly transport system.

All these changes will be aimed at creating physical, visual and psychological comfort for a person at the bus stop.

The goal of my concept is to organize the bus stop space and create comfortable conditions for people combining smart vehicle sharing. At the same time, the priority is the human-centered design of the bus stop, which will help to increase the comfort of living in a city. The combination should be organized in such a way that the transition from one transport to another is short, convenient and safe.

"Short" - implies accessibility in several steps. "Convenient" - means unhindered and in comfortable conditions. "Safe" - the absence of any risk factors for human health and life.

The rhythm of the new mobility system will depend on the correct placement of access roads to the bus stop. It is necessary to divide the transport space between the main buses and shuttles. It is necessary to divide the transport space between the main buses and shuttles giving priority to buses as a mass mode of public transport.

Shuttles need dedicated places near stops for embarking (disembarking) passengers and organized routes for their further trip. Planning of the bus stop space should also be focused on the interests of people who have chosen other ways of micro-mobility - on foot, by bike or some king of light electric vehicle. For them, the necessary elements of infrastructure should be provided: paths, bicycle parking. Here you can not only change the way of mobility, but also get other associated services.

The idea is also to include as much greenery which will provide visual comfort and improve the urban environment. All this requires new spatial and design solutions. Key design principles for generating ideas:

- divide the access roads to the bus stop for buses and shuttles;
- minimize the road area to create more space for people;
- provide a convenient approach for people;
- create conditions for a quick transfer from a bus to a shuttle (and vice versa);
- to provide places for recreation, bicycle parking and additional services;
- create green areas;

7. DEVELOPMENT OF CONCEPTUAL IDEAS

Changes in the transport system have already begun, and they will continue to evolve. These changes concern all the components of the system and will lead to new ways on the organization of the transport space, part of which falls on public transport stops.

Developing my concept, I relied on the conclusions and recommendations that Gustav Nielsen presented in his work "Traffic integration or segregation for the sustainable city - A review of current debate and literature"[67].

The key take-aways for me were that the use of urban streets should be changed in the interests of public transport, cyclists, pedestrians - all this can be achieved by changing the geometry of the street.

7.1. Bus stop space planning

The development of the initial conceptual proposals began with the consideration of possible options for combining access roads for buses and shuttles at the site of a bus stop. The presence of sidewalks and bike lanes were taken into account as an integral element. The ideas were generated by taking into account the understanding of the typology, requirements for the design of stops and the possibilities of a smart transport system, which were studied at the research stage.

Initially, by sketching, I was looking for optimal solutions for combining buses and shuttles and possible movements near a bus stop. (see figure 7-1).

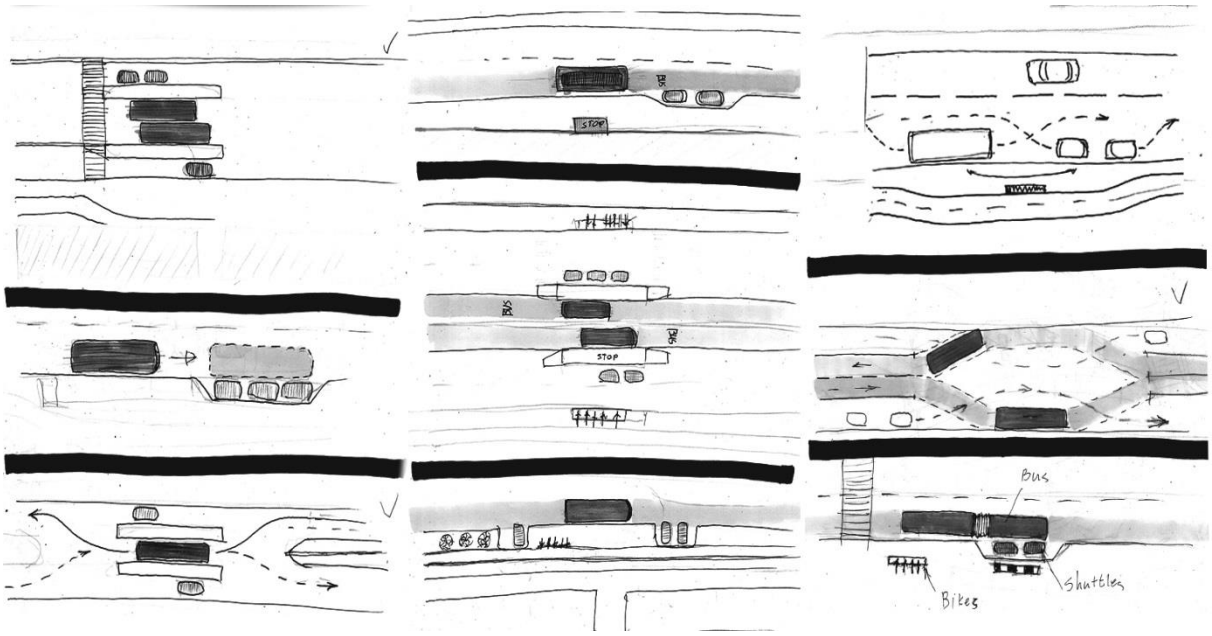


Figure 7-1: Drawing

Than 16 situations of lane locations, access roads and stops in different spaces were selected for consideration. (see figure 7-2). These situations were systematized in 4 options according to the location of the selected lanes for long-distance buses.

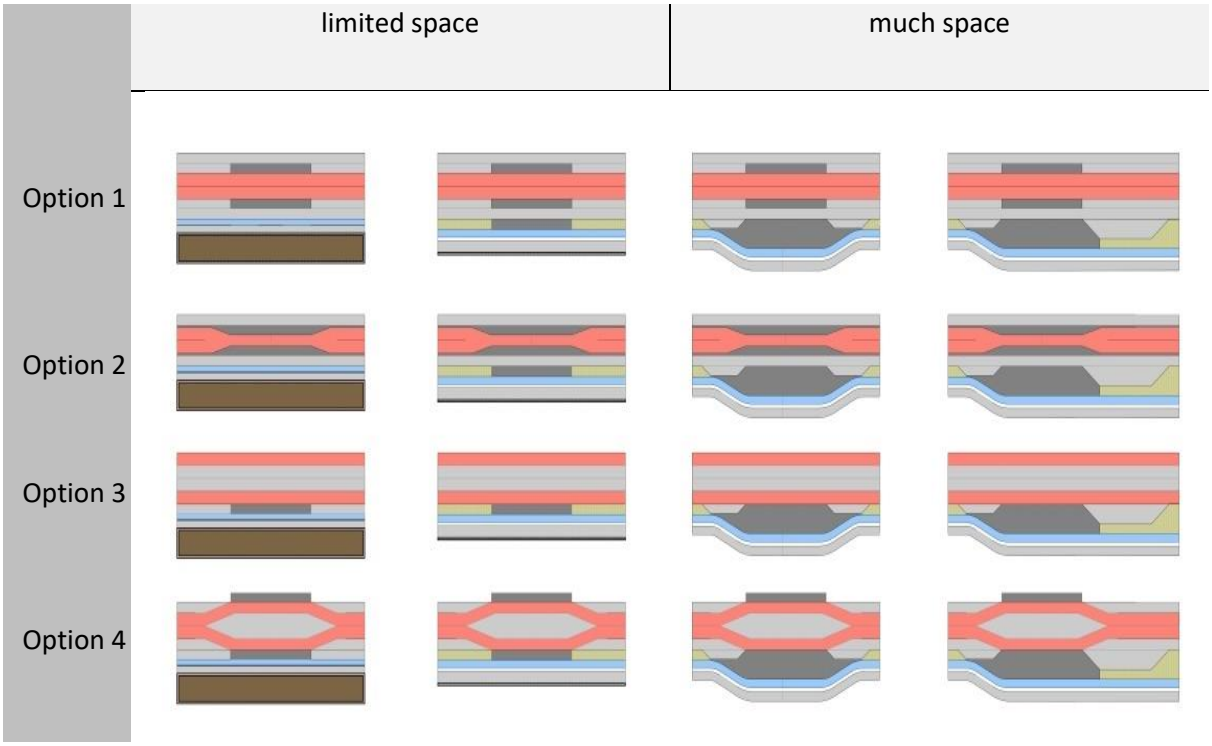


Figure 7-2: Road access layouts

Comparative characteristics of these options are given in the table 7-1.

Table 7-1. Characteristic of road access layouts

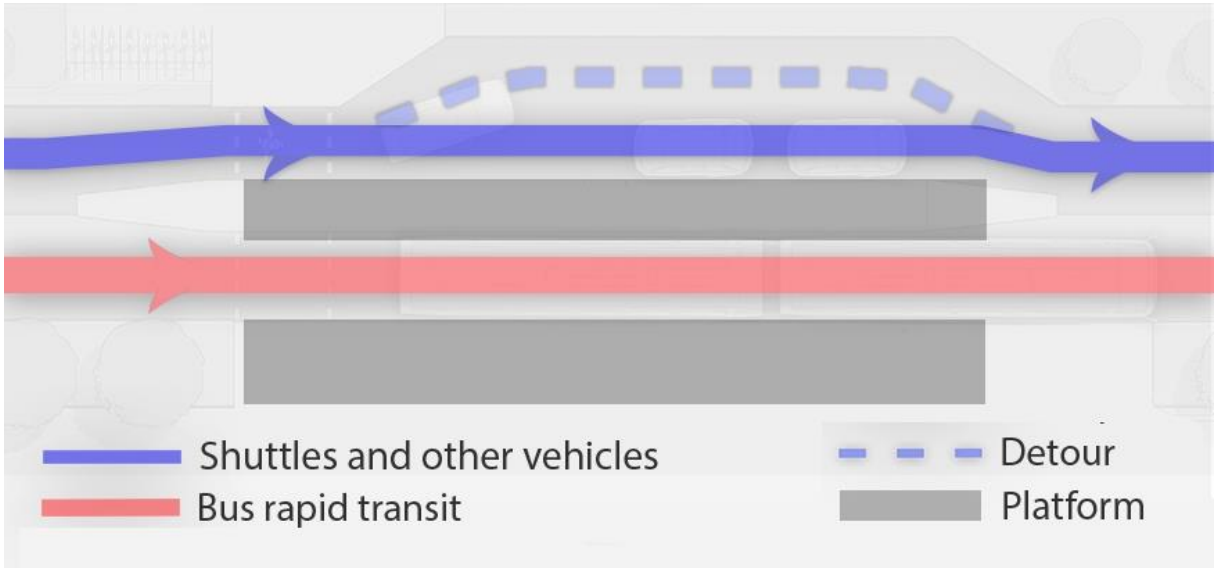
Accommodation options	Location of transport lanes		Stop Type	Advantages	Disadvantages
	bus	autonomous means			
Option 1	In the center	In the first lane	Median Stop	Vehicle paths do not intersect	Require crossing the road
Option 2	Converging in the center	In the first lane	Median Stop	Vehicle paths do not intersect. Double-sided bus exit	Require crossing the road
Option 3	In the first lane	In the center	In-lane Sidewalk Stop	No need to cross the roadway.	The intersection of bus lines with autonomous transport at the stop for boarding/disembarking passengers
Option 4	In the center and diverging at the stop	In the first lane	In-lane Sidewalk Stop	No need to cross the roadway.	The intersection of bus lines with autonomous transport at the stop for boarding/disembarking passengers

Depending on the conditions in a particular urban environment, the typology of stops can be extended based on these four basic options. Thus in places of sufficient space, it is possible to place bus stops in pockets. This option provides the conditions for creating a local identity in the place of a stop and placing various related benefits to increase comfort.

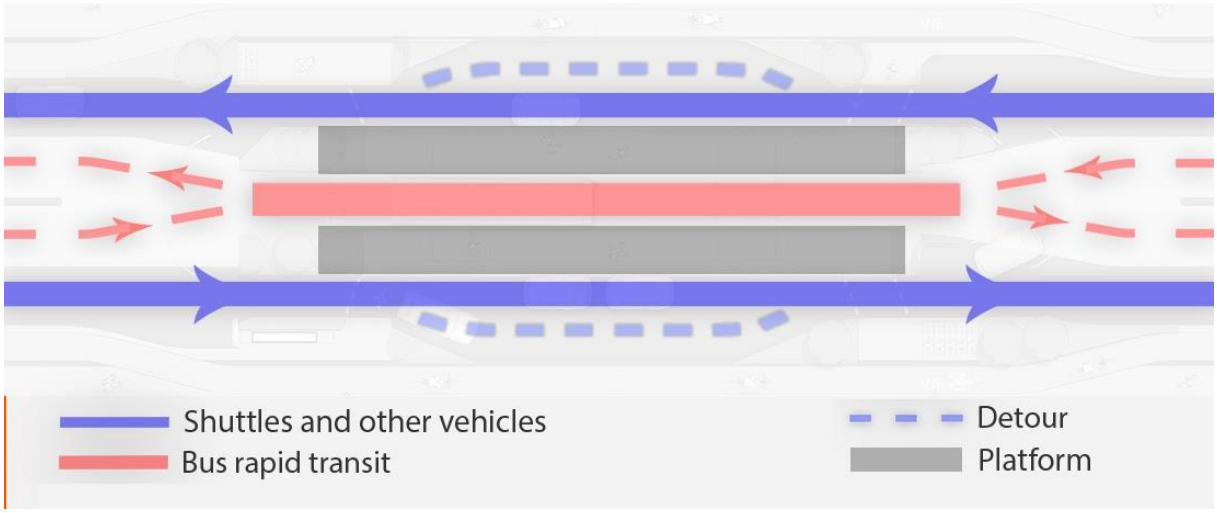
Developing the idea of creating a convenient stop for intermodal traffic, I focused on its accommodation options, which create the most convenient access to the boarding site and provide a quick transfer from the bus to the shuttle (and vice versa). For this, three different situations in the urban environment were selected.

- Street with limited space and one-way direction.
- Street with limited space and two-way directions.
- Street with wide space for different directions of traffic.

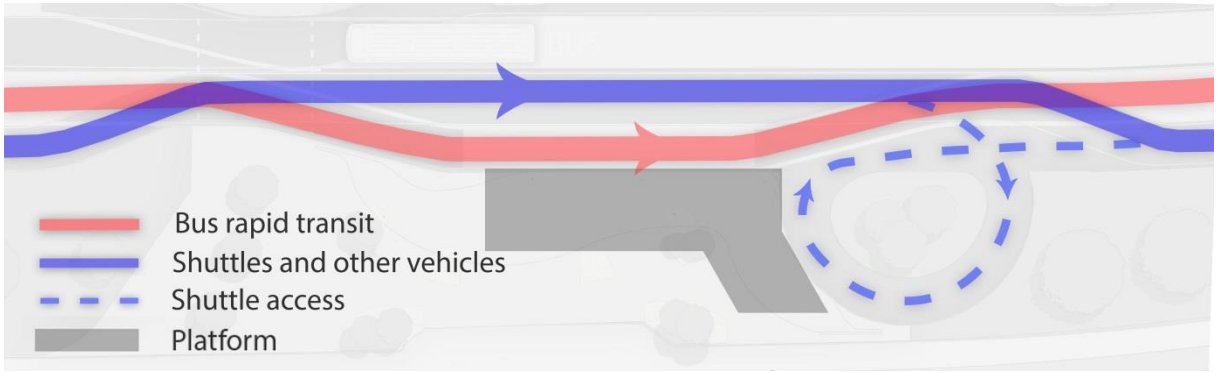
For these situations, three concepts of traffic were thought through with possible options for organizing secondary road and side street space. (figure 7-3).



A. Parallel traffic



B. Bus convergence



C. Traffic with intersection

Figure 7-3: Traffic Concepts

Each urban space has its physical characteristics, which are determined by the location of buildings, monuments, streets etc. They set the boundaries and conditions for the design of any objects.

Therefore, I decided to consider how my concepts fit into the existing space and what are the possibilities to place stops in a specific urban environment, taking into account its landscape, shape and structure.

Three locations were selected in Tallinn – Kaubamaja, Kaubamaja; Haava, Vabaduse puiestee; Lepistiku, Sõpruse puiestee. Each of them has its characteristics, determined by the value of the area of the city, its density and nature of the buildings and the number of passenger traffic. Google maps was used to determine the size of each place.

First location (see figure 7-4) – a city center with closely spaced buildings along the roadway and one-way bus traffic.

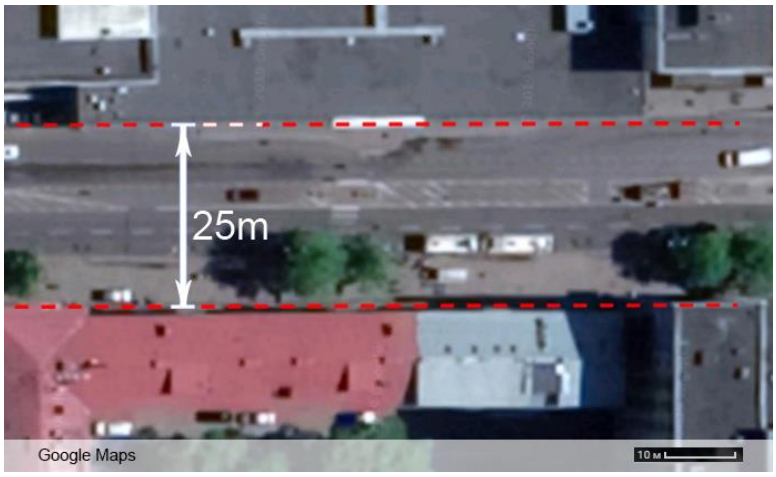


Figure 7-4: Location 1 Kaubamaja, Kaubamaja

Second location (see figure 7-5) – suburb area with private houses, which are also closely situated to the road.

Figure 7-5: Location 2 - Haava, Vabaduse puiestee

Both the first and second locations have limited possibilities for placing a bus stop and by this, they are interesting for developing solutions for such conditions. Third location (see figure 7-6) – dense housing estate district, which gives ample opportunity to implement the concept of the third type of bus stop

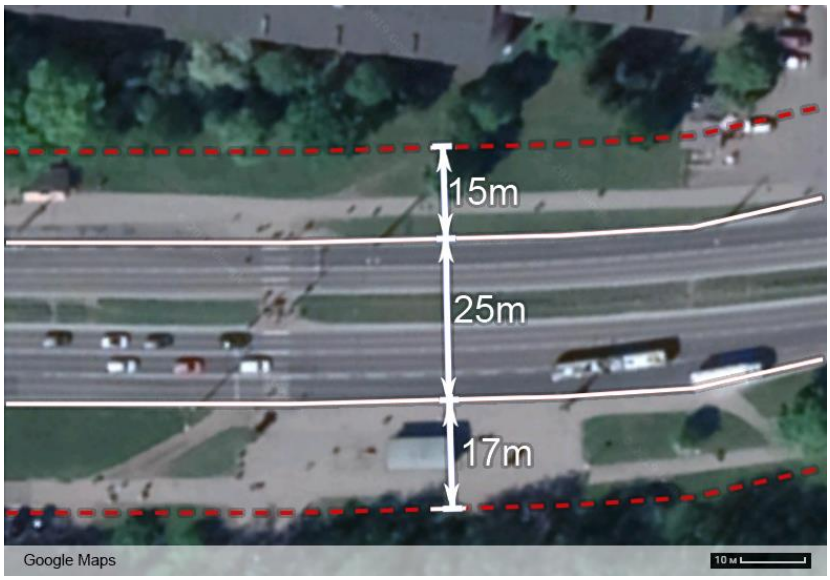


Figure 7-6: Location 3 - Lepistiku, Sõpruse puiestee

As a result, I identified three layouts for locating stops in different possible situations in the city. All of these layouts are based on the use of the future capabilities of a smart transport system and will require buses with two sides boarding and disembarking.

The first layout type is for limited space with one-way traffic or bus route. (see figure 7-7).

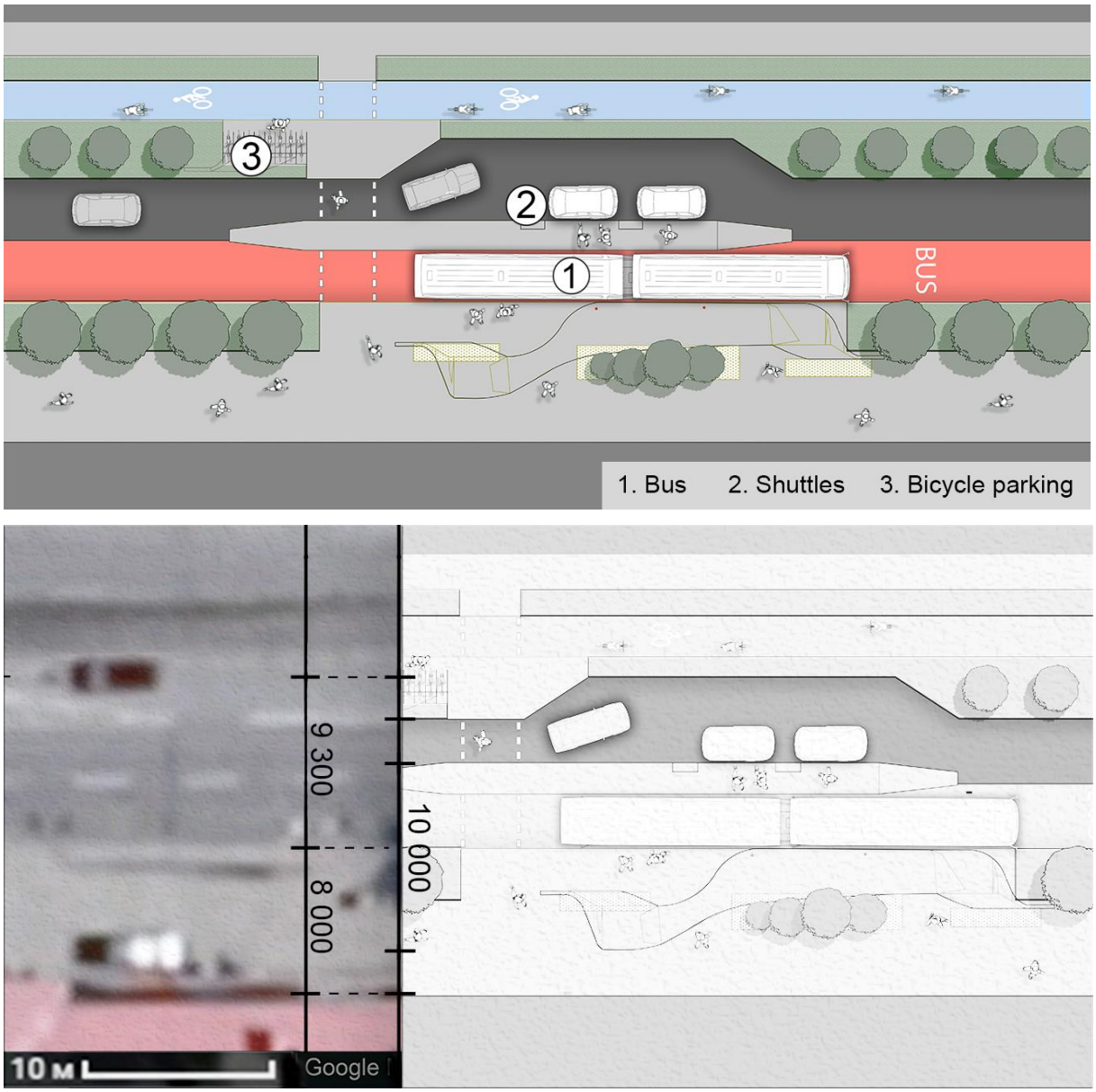


Figure 7-7: Layout for limited space with one-way traffic

In this option, there is an additional small platform in the center of the roadway to combine buses with shuttles. It has side detour for another kind of vehicles to provide unobstructed traffic. From the opposite side of the bus, an unobstructed exit to the pedestrian zone is ensured. There is a pedestrian sidewalk on both sides of the street and one bike path with parking for bikes near the bus stop. A second layout is proposed for a limited space street with two-way directions. (see figure 7-8).

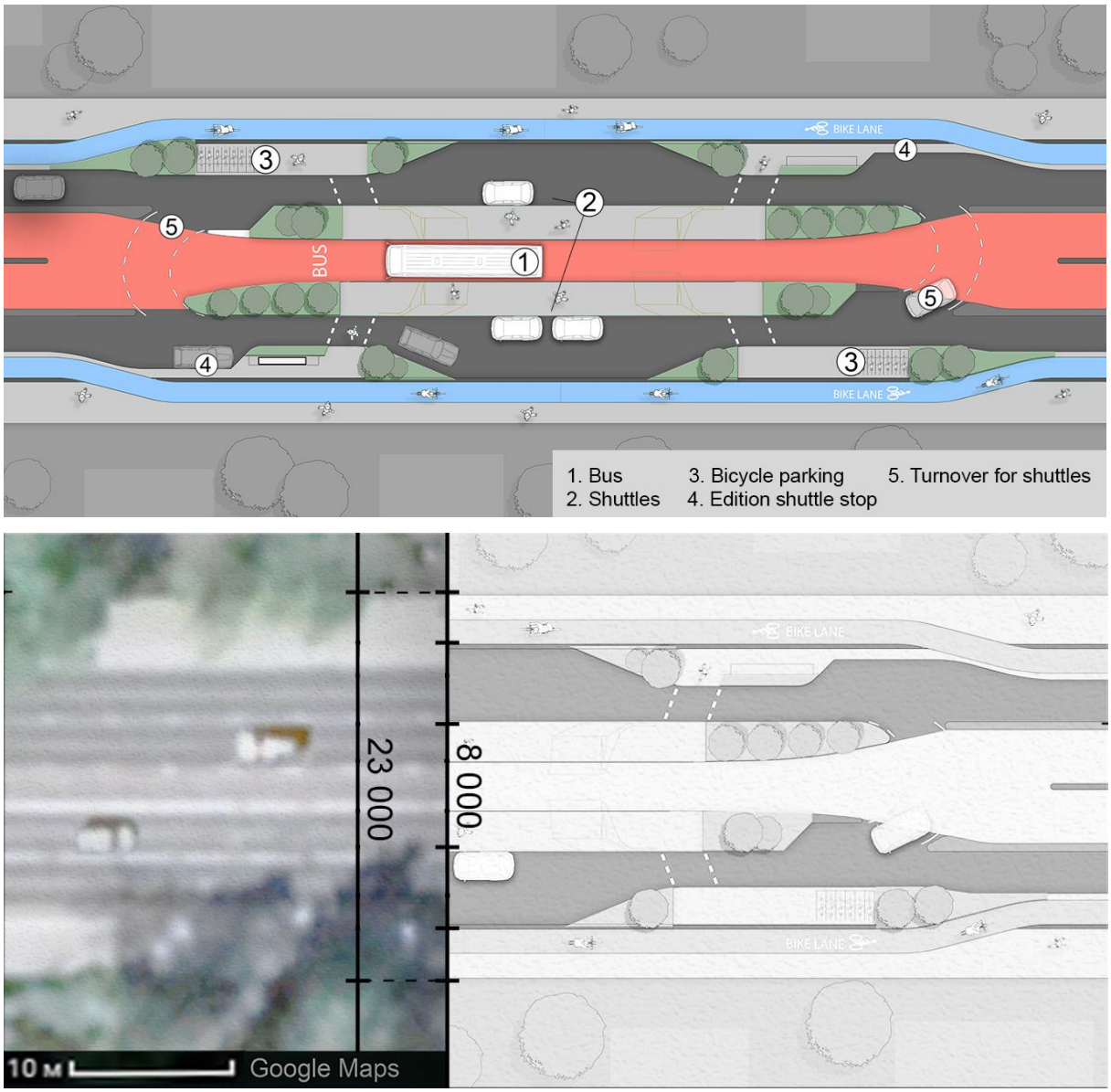


Figure 7-8: Layout for limited space street with two-way direction

The significant feature of this option is the convergence of bus routes in the centre. Thus buses that move in different directions share the same lane at the stop. This is a good solution to save space in a smart transport system, which allows you to create a stop without a large expansion of a street and provide short pedestrian crossings.

In this case, the bus stop is divided into segments. The boarding platforms are on both sides of the bus lane, which makes it possible to quickly carry out the embarking and disembarking of passengers in the direction necessary for them. There is a pocket on each side of the road which allows other vehicles to move without stopping.

On both sides of the roadway, there are places for bicycle parking and recreation. There are also additional stops and turnarounds for the shuttles. The turnarounds allow shuttles to change the travel direction at the same time, maintaining the priority of the bus traffic and without interfering with other vehicles.

The third layout is a solution for large street space that can be used for two-way or one-way traffic. (see figure 7-9).

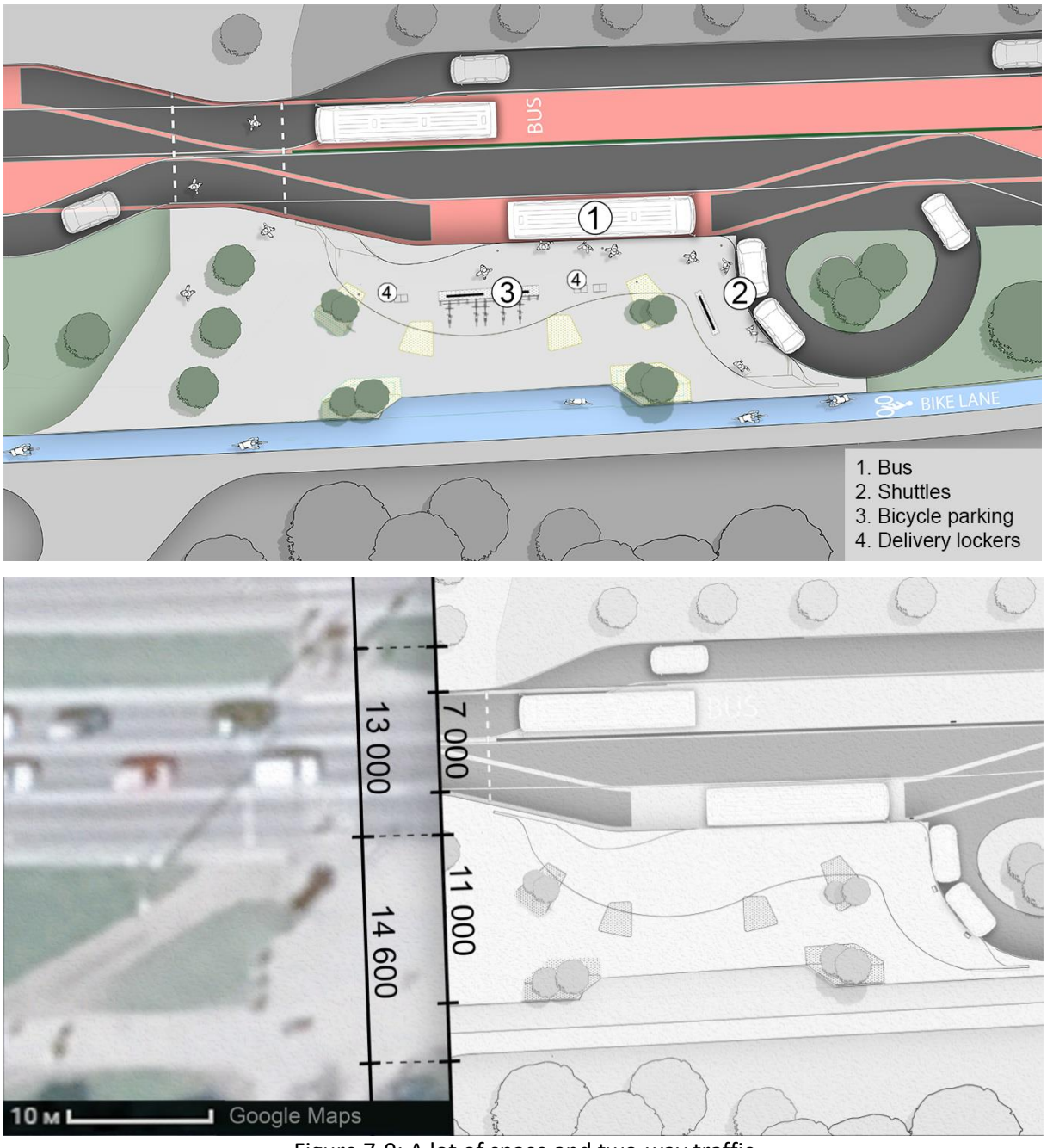


Figure 7-9: A lot of space and two-way traffic

The peculiarity of this layout - the change of lanes by vehicles when approaching a bus stop. Such a step makes it possible to organize a suitable combination of a bus and a shuttle on one side of the roadway and narrow it in the place of a pedestrian crossing. The circle for shuttles placed so that it close to the main bus platform. The main advantage of it is the ability to accommodate a higher number of shuttles and that is higher passenger traffic. Also, it creates the conditions for the shuttle to continue its way in the right direction. This type of stop placement has plenty of room for the pedestrian part, the recreation organization, bicycle parking and landscaping.

All schemes were developed taking into account the present size of vehicles and lanes. The combination with the real situation map showed that they fit well into the selected spaces. As a result, these areas, with their regular size, can be able to accommodate a new type of stops with additional mobility opportunities and improved comfort.

7.2. Visualization of the concept and its impact

The semantic content of my concept determines the idea that the daily movement around the city should be easy and enjoyable. The road to work or back home should give a person the opportunity to relax and positively adjust for productive work or personal life. Therefore the proper functioning of public transport and the favourable environment that surrounds along the way are essential. A stop as part of this environment should provide people with physical, visual and psychological comfort.

Traditional components create its physical comfort: a roof from rain, a seat if you need to wait for someone, and within the framework of my concept, there is also a quick, unhindered transition from one transport mode to another. Visual impact determines the design decision of the stop and filling it with elements of positive impact.

In order to develop the design of the stops, I decided to get away from the correct geometric shapes, adhering to the ideas of the video ecology, that the urban environment object is harmonious if it has few corners and many smooth lines. Plus, it was necessary to add greenery, which well performs the recreational function.

I made the first visualization in sketches, which later modified in 3D models (figure 7-10 – 7-15).

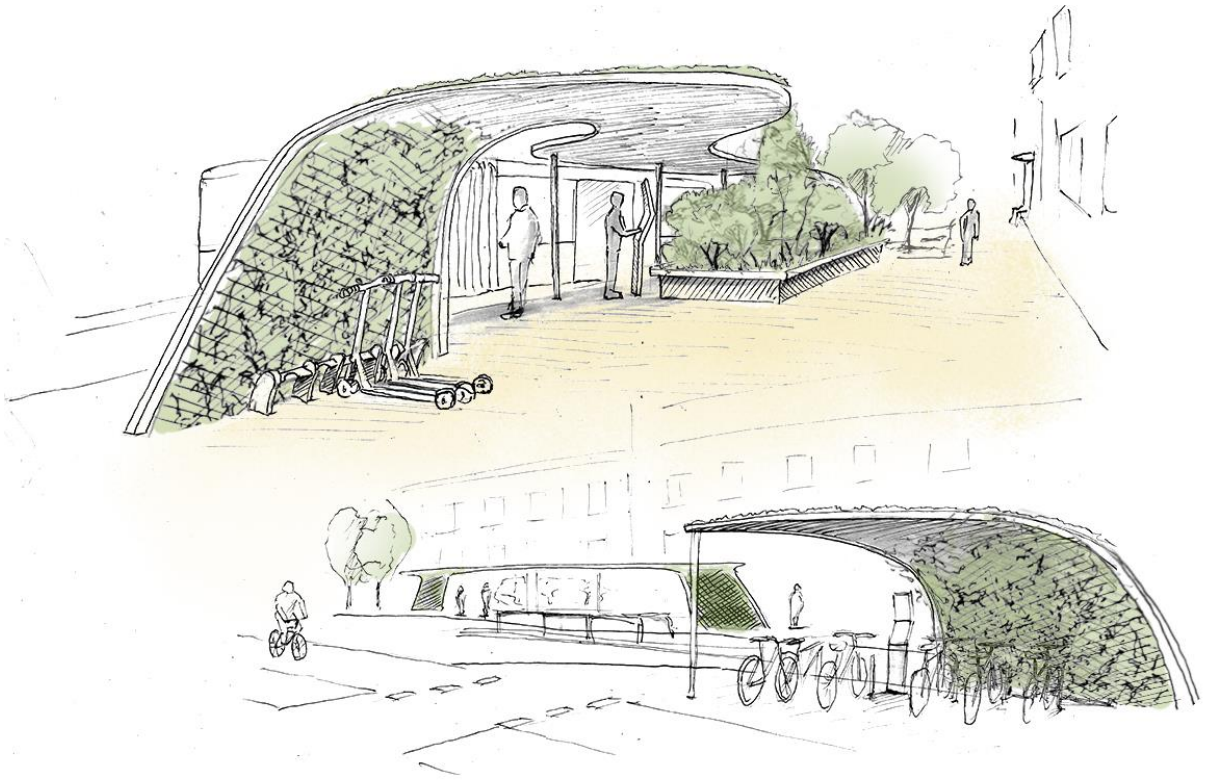


Figure 7-10: Option - Limited space and one-way traffic

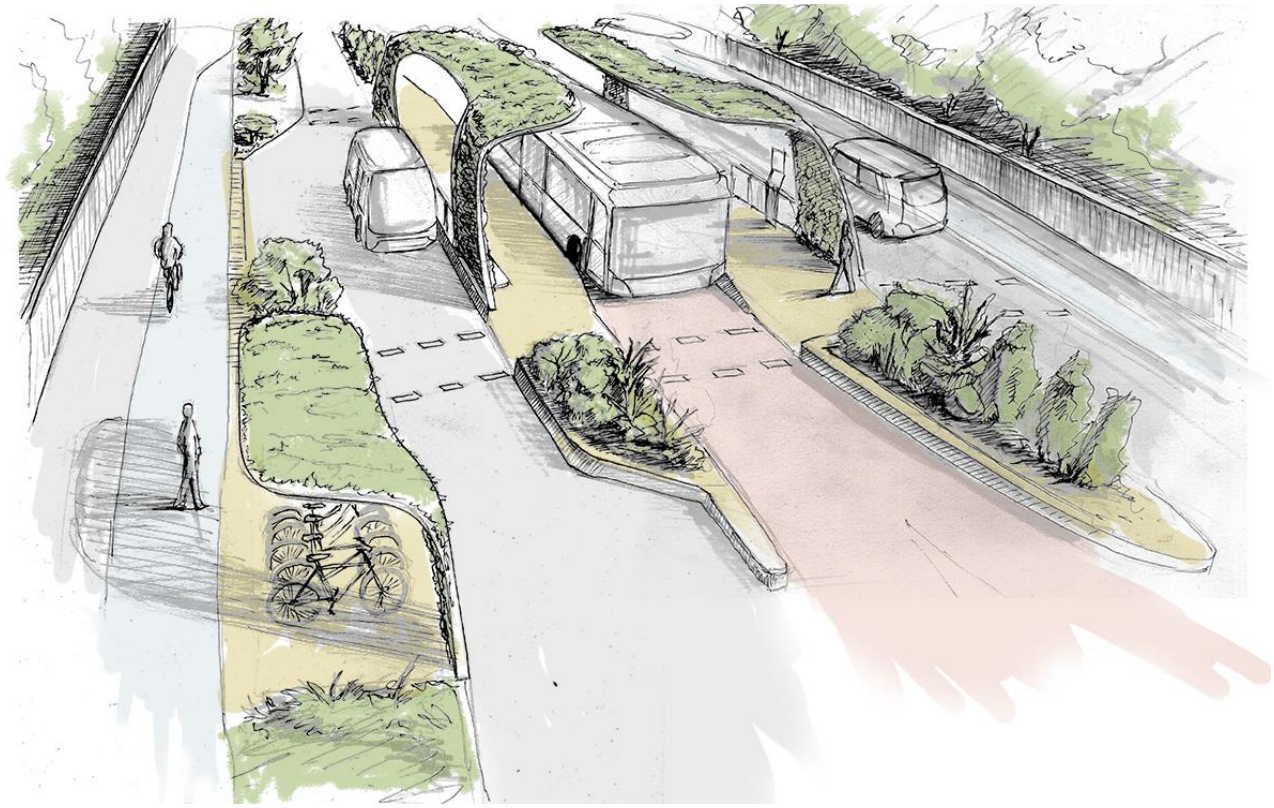


Figure 7-11: Option - Convergence in the center of the main bus tracks

Figure 7-12: Option - A lot of space and two-way traffic

Figure 7-13: 3D model - transition in conditions of limited space

Figure 7-14: 3D model – transition in terms of large space

Figure 7-15: 3D model – The recreation area at the bus stop in large space conditions

Taking into account the developed plans of placement, each option of the stop has its own structural features. Moreover, they all implement a common idea – creation of convenient bus stops.

Conclusion

The proposed concept changes the work of public transport, removing the waiting and solving the problem of the last mile, and therefore makes it more attractive to citizens.

Proper placement of vehicles near the bus stop, filling it with useful and visually pleasing elements. All this, in addition to a positive physical and visual impact, also has a beneficial psycho-emotional impact. This is especially important in conditions of increased tonus of modern urban life.

FURTHER DEVELOPMENT

My conceptual ideas of stops with the “Bus-shuttle” transition for different conditions of local spaces and the capabilities of a smart transport system are futuristic in nature and of course, require further development of technology. My drawings represent the concept of space zoning and the organization of the traffic beside it. Further development requires testing of each concept to see how the traffic flow of people and vehicles will actually happen within the suggested structure. Selected locations where the layouts were placed, do not consider that suggested concepts will be located exactly there in the future – they only take into account the spatial conditions of the specific areas. The choice of location for placing the stops should be the result of solving complex problems of transport logistics, which should be based on careful calculations and give form to a new public transport network that uses autonomous shuttles.

SUMMARY

This thesis attempts to look into the future and imagine what changes will happen in the transport system and how they will affect the bus stops, as the element of this system. The purpose of my master's work is to analyze future development of a bus stop in a smart transport system.

To achieve this goal, attention was paid to two interrelated components in the present and future conditions: the impact of stop as an element of transport infrastructure on a person and the transport system.

The study of the effect of a bus stop on a person was necessary for understanding how to evaluate its convenience. Using literature reviews, observations and interviews with passengers, it was concluded that the convenience of a bus stop should be determined through its physical, visual and resultant psychological influence on a person. The waiting factor was identified as the main factor of negative psychological impact on people today, which is explained by shortcomings of transport. Another study included consideration of problems and trends in the transport system and showed that increasing the attractiveness of public transport is an essential task to reduce the use of private cars and eliminate the problems that are important for modern big cities such as traffic jams and bad ecology. This requires solutions that minimize the waiting factor, providing high mobility and offering door-to-door travel option. A review of new technologies has shown that such solutions are already emerging and that they will lead to a rethinking of the organization of traffic and will make changes in the transport infrastructure. I focused on a promising, in my opinion, the possible combination of buses that operate on the Rapid Transit system and autonomous shuttles, which prototypes already exist in the world (including Taltech). Their integration can provide an increase in the travel speed and full coverage of the territory of the city by public transport, thus also solving the problem of the last mile. The combination point will be the new type of bus stops "Bus-shuttle".

The concept developed in the thesis offers various spatial solutions depending on the specific environment and is focused on maximum convenience for people. The semantic content of my concept is to make everyday mobility around the city easy and enjoyable. By the rational placement of access roads, I seek to reduce the area of the roadway and create more space for people.

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