Survey for developing the traffic management solution for Tallinn ring road on highway No. 11

2017

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1. INTRODUCTION

The objective of this survey is the development of the traffic management solution for national main road No. 11 (E265) Tallinn ring road. Extensive reconstruction works shall transform Tallinn ring road into a two-carriageway highway in the upcoming years and the survey forms a basis for planning and developing various ITS solutions which make traffic on the ring road smoother and safer and enable to better manage various incidents that cause traffic obstructions.

This survey is also one of the work packages that is part of the international FinEst Smart Mobility (FESM) project. FESM is a project funded to the extent of 85% by the European Union regional development project Central Baltic, intended for improving mobility between Helsinki West Harbour and Tallinn Old City Harbour via smart solutions.

The survey has been divided into three stages, which will result in one collective report. Topics addressed in the survey are:

- **Stage I** – analysis of current situation and proposals;
  - overview and assessment of continuous operation plans;
  - development plans for the ring road and entrance roads to the city;
  - effects in the perspective of 15 years;
- **Stage II** – modelling incidents and bypass routes;
  - modelling probable accident scenarios;
  - possibility and locations of possible traffic jams;
  - preparing bypass routes;
- **Stage III** – feasibility of dynamic traffic management;
  - description and typical cost of ITS solutions;
  - cost-effectiveness analysis for three scenarios;
  - selection of optimal ITS solutions and equipment;
  - optimal stepwise realisation plan for ITS solutions.

2. CURRENT SITUATION IN THE MANAGEMENT OF TRAFFIC OBSTRUCTIONS

This chapter provides an overview of the management of traffic obstructions on Tallinn ring road as well as entrance roads belonging to the area of government of the city of Tallinn. The overview was assembled by conducting interviews with the representatives of the Road Administration (Siim Vaikmaa, Andres Urm, Maria Ossadtšaja) and representatives of the Tallinn Transport Department (Andres Harjo, Talvo Rüütelmaa).

2.1. Continuous Operation Plans

The guidelines for preparing a continuous operation plan[1] were established by Regulation of 21 June 2010 of the Ministry of the Interior, which was based on subsection 37 (5) of the Emergency Act (currently invalid, new version of the act entered into force on 1 July 2017).

According to subsection 37 (2) of the Emergency Act, which entered into force on 1 July 2017, authorities that provide vital services shall establish under the regulation the description of vital services included in their area of government and requirements for continuous operation thereof.[2] Continuous operation is the capability of consistent functioning of the service provider and the ability to restore the consistent functioning after an interruption in the vital service.[3] Regulation No. 29 of 21 June 2017 “Requirements and procedure for a continuity risk assessment and plan of a vital service, for the preparation thereof and the implementation of a plan” has been established under subsection 39 (5) of the Emergency Act (RT I, 28.06.2017, 6).

Road Administration had prepared Continuous Operation Plans of the Vital Service in regard to the continuous maintenance of national main and basic roads across different counties and areas of roadmasters. The objective of the continuous operation plan is to ensure an immediate response to interruptions regarding the functioning of road maintenance and ensure the taking of appropriate measures for quick elimination of interruptions and restoration of the continuous operation of the service.[4]

A situation during which traffic is estimated to be interrupted for more than 12 hours on a main road or for more than 24 hours on a basic road is considered an imminent threat for causing a serious interruption of the functioning of road maintenance. Corresponding

[1] Guidelines for preparing a continuous operation plan. Regulation No. 17 of 8 June 2010 of the Minister of the Interior. RT I 2010, 33, 180. In force until 30 June 2017
[2] Guidelines for establishing the description and requirements for continuous operation of the vital service for authorities organising the operation of the vital service. Ministry of the Interior
[3] Guidelines for preparing the continuity risk assessment and plan of a vital service for providers of the vital service. Ministry of the Interior
[4] Ensuring maintenance of national main and basic roads. Continuous operation plan of the vital service. Road Administration 20 July 2016 Decree No. 0146

measures shall be taken under the continuous operation plan of road maintenance in the event that the interruption of traffic is estimated to be at the relevant level as a result of an accident or extraordinary weather conditions. [5]

According to the risk analysis carried out by the Road Administration, critical events that may cause a serious interruption in the provision of a vital service are:

- collapse of a road infrastructure (erosion of a road embankment, collapse of a culvert/bridge/overpass due to heavy rain or human activity);
- continuous snowing or blizzard.

Recovery plans have been prepared in regard to both events. The interruption of the vital service was presumed to be short-term in the case of severe traffic accidents or occurrence of extensive environmental pollution on the road. In the event that either of the aforementioned events cause a long-term traffic obstruction, the recovery scenario “Collapse of a Road Infrastructure” described in the continuous operation plan shall be applied.

High-risk areas concerning functioning of the vital service have been listed in the continuous development plan:

- sections of main and basic roads that pose a traffic hazard;
- critical objects of the infrastructure of main and basic roads (bridges, overpasses, large culverts).

2.2. Tallinn Ring Road

Bypass routes have been prepared for critical objects of the infrastructure in case that critical events occur. By analysing the continuous operation plans of three roadmaster areas (Keila, Kose and Kuusalu) prepared for consultants by the contracting entity, it can be concluded that even though these plans fundamentally overlap, the traffic management side of the plans (bypass routes) have, however, been prepared at an individual level for each area:

- option 1 – the critical object is displayed on the map and possible bypass routes have been schematically displayed;
- option 2 – furthermore, the part of temporary traffic management along with necessary signs has been prepared as well.

A questionnaire was prepared and sent to enterprises engaged in traffic maintenance in Estonia in order to obtain an assessment of the continuous operation plans. 11 responses

[5] Ensuring maintenance of national main and basic roads. Continuous operation plan of the vital service. Road Administration 20 July 2016 Decree No. 0146

were received. Nearly half of the respondents have experienced a need to use this document, however, 2/3 have managed to cope without it (presumably thanks to prior experiences). The recovery plan for the collapse of a road infrastructure has been used the most (5 respondents), whereas the recovery plan for continuous snowing has only been used by 2 respondents (this is certainly partly due to the last couple of winters with relatively little snow). A couple of respondents have also utilised a recovery plan for a traffic accident. Bypass route schemes were deemed to be in need of improvement, however, it was also pointed out that the schemes are prepared on a rolling basis and in accordance with the situation, while also taking into account the stocks of road signs that the maintainer is obligated to have under the contract.

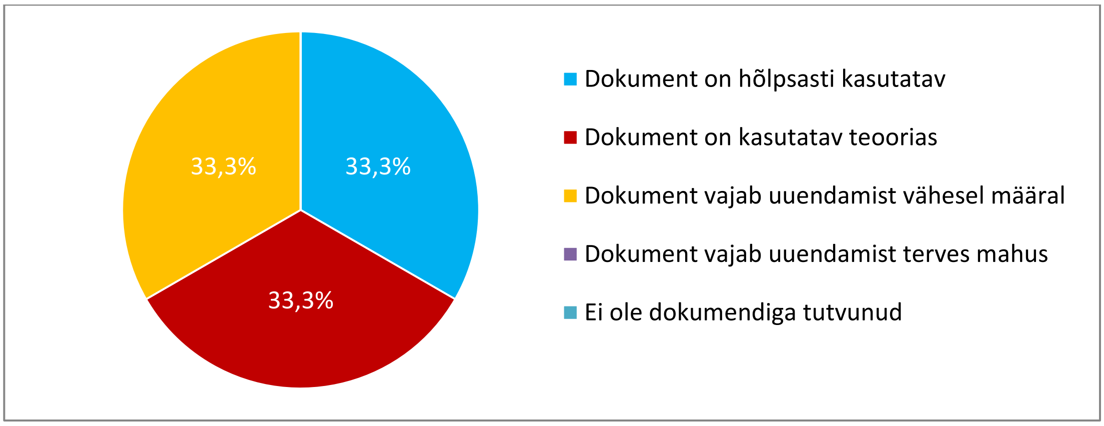

Figure 2.1. Overall evaluation of continuous operation plans by road maintenance providers who responded to the questionnaire

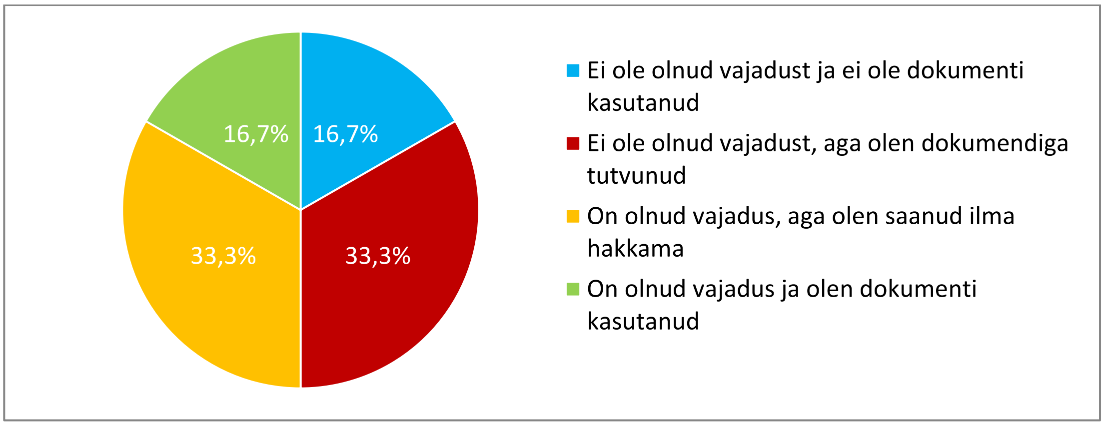

Figure 2.2. The need for and use of the continuous operation plan

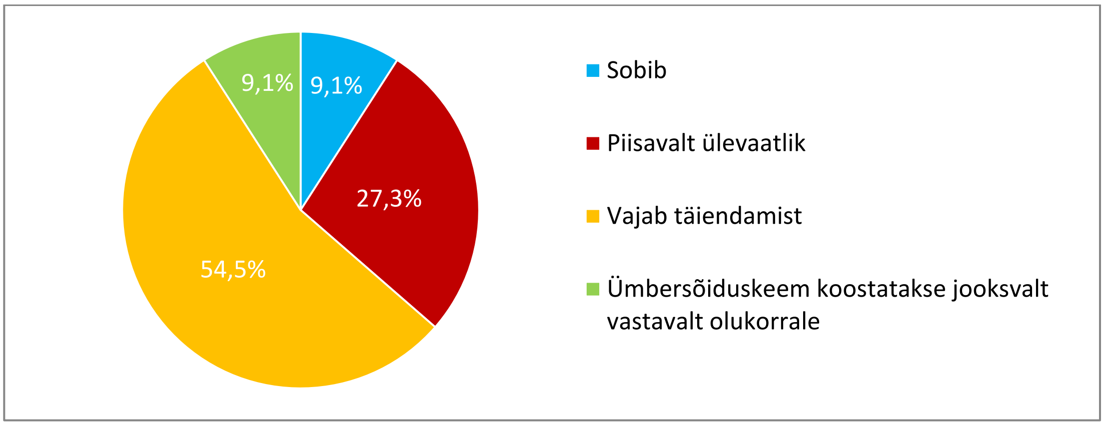

Figure 2.3. Evaluation of bypass routes set out in continuous operation plans provided by road maintenance providers

Continuous operation plans have been prepared in accordance with the requirements set out in the regulation, which makes this document a relatively extensive one (currently 70–100 pages). This is also most likely the reason that several road maintenance providers mentioned that a summary version should be prepared in addition to the primary document, which would briefly and clearly set out a specific code of conduct.

Some of the comments provided by respondents:

"I personally believe that the continuous operation plan in its current form is a useless document. If a situation calls for quick actions and decision-making within 15 minutes, no one is capable of finding anything from a 100-page document. The continuous operation plan must fit onto a maximum of two A4-sheets and include a specific code of conduct."

"Simplify (create a summary version in addition to the main document, if necessary); attempt to describe in theory, what could actually be achieved in practice."

"The document is too long (nearly 100 pages). The document includes too much specific data regarding persons responsible and technical resources, amendments are rarely made."

Representative of the Road Administration (Maria Ossadtšaja) mentioned that trainings are organised every year, during which various bypass routes are established and maximum amount of signs are taken into account. The overall objective is to ensure that recovery plans have a common format, which could be used to determine the bypass route. All situations cannot necessarily be addressed in the recovery plan, current description includes the most important objects (bridges, overpasses or other critical sections), for which specific bypass routes have been prepared.

It is certainly not practical to prepare bypass routes for the whole of Estonia, however, important criteria which needs to be taken into account must be set out. The areas/roads where traffic is not recommended to be directed to must definitely be recognised as well. The number of road signs, along with their stands, that can be loaded onto the trailer of a vehicle must be taken into account as well. In regard to Tallinn ring road, bypass routes must be prepared in detail.

Proposals regarding continuous operation plans and recovery plans:

- it is recommended to prepare a short specific code of conduct for resolving a crisis situation;
- road maintenance providers should have more opportunities for using temporary VMSs (e.g. transported on a trailer); if something were to happen on a road with high traffic volume, it is necessary that the information is visible to road users from as far as possible, distributed as operatively as possible and could be changed or supplemented (VMSs have these functions unlike regular road signs).
- prepare a detailed temporary traffic management solution for critical objects of the infrastructure.

2.3. Entrance Roads to the City of Tallinn

This project is also very important in regard to the principles and strategies of the traffic management of Tallinn. Accordingly, one of the objectives of the project is to conduct an interview with experts who are responsible for the traffic management of the city of Tallinn in order to get their opinion on the links and objectives of this project and whether these coincide with the traffic management strategies of the city of Tallinn. Explanations of A. Harjo, Head of the Transport Department of Tallinn, and T. Rüütelmaa, Head of the Traffic Management Department, are set out below.

One of the main objectives of the project is to find a modern ITS-based solution for bypass options in case that some section/part of the Tallinn ring road is closed for traffic.

Does the city have any proposals that are linked / not linked with his objective?

The vision of the city regarding the capacity to use the city's street network for rerouting traffic flows in case of possible traffic problems or obstructions on Tallinn ring road is that such opportunities are virtually non-existent, as most possible bypass routes are already overburdened and could not take on increased traffic volume or burden. Moreover, the city is strategically focussed on utilising traffic management methods (e.g. regulation of the traffic light system) to limit the capacity of major roads coming into the city from nearby areas in order to avoid traffic jams in the city centre and influence people to use other transport means aside from driving cars.

If the option set out in the question is to be discussed at all, it would require the establishment of a major strategic traffic management system (that would include nearby areas of the city, incl. Tallinn ring road), which would direct entire traffic flows to routes suitable at a certain point in time, and that means in regular as well as emergency situations.

In case that there is an unforeseen obstruction on Tallinn ring road in one direction, the Transport Department of Tallinn considers the first possible measure/option to direct traffic flow to the oncoming lane. This would require temporary openings in the median barrier, the opening of which could be used to rearrange traffic. This should be done as operatively as possible (NB: capacity of the police), however, such options could virtually be prepared beforehand and used, if necessary.

Another option and necessity would be to establish car parks for heavy vehicles alongside the ring road, which could be used for parking by vehicles in case of traffic obstructions and from where further transportation of people could be organised (a sort of car park + ring road solution). In this case, parked vehicles would not hinder the elimination of the traffic obstruction.

Instead of explicit rerouting of traffic, the Transport Department of Tallinn considers it much more important to provide road users with information on an upcoming traffic obstruction, which would enable drivers to independently select a suitable alternative route beforehand. An example of this is, for instance, variable-message boards that display the travel time to a certain interchange in normal circumstances and currently. Experiences of the city of Tallinn have shown that instead of prescribing a specific (one) bypass route, solutions where road users are warned about the upcoming obstruction, but are given the opportunity to find a suitable alternative route themselves, have proved to work far better.

The Transport Department of Tallinn also found that the use of such variable-message road signs is also extremely necessary in places where the permissible speed limit is operatively changed in advance in order to avoid vehicles from entering the danger zone at a high speed. It is important to keep in mind that restricted speed limits also increase traffic capacity in streets.

Does the city have certain views on where the traffic SHOULD NOT be rerouted to under any circumstances? According to the city, what could be the impact elsewhere if something were to happen on Tallinn ring road? What could be the effects in the future?

Virtually, Tallinn currently lacks the opportunities to redirect traffic flow from Tallinn ring road through the street network of Tallinn in normal circumstances, except for Väo interchange and possibly small Tallinn ring road (cf. first question).

Should the ITS solution planned for Tallinn ring road also be compatible with the traffic management solutions in Tallinn? In what way? In which perspective?

Essentially, yes, however, the city's vision in regard to the creation of such a uniform management centre would be that the volume of regular management of the city street network would be significantly larger than the volume of highway management. It would therefore entail that the ITS solution in question could be one of the functions of the possible traffic management centre of Tallinn (and nearby areas), not vice versa. Traffic problems in the city are much more specific and greater than the management solutions of highways. However, this solution could be beneficial in the long-term and the city of Tallinn is interested in developing such cooperation.

2.4. Proposals for Future Development of Traffic Management

As became clear from the topics addressed in the previous chapter, this project, the main objective of which is the development of a traffic management solution for the national main road No. 11 (E265) Tallinn ring road, is also very important in regard to developments regarding the area of influence of other road network developments and traffic management solutions. The following parts of this survey address the search for optimal solutions for possible incidents that could occur on specific sections of the Tallinn ring road in more detail. The first tactical solutions brought out here include solutions regarding bypass routes and redirecting traffic onto those routes.

However, if solutions are analysed in more detail, as they have been in the following chapters of this survey, it becomes clear that direct solutions for redirecting traffic flow to a specific bypass route in case of traffic obstructions is relatively limited due to the lack of suitable routes as well as their traffic capacity.

Therefore, one of the strategic results is also the fact that one of the main objectives regarding the occurrence of any incidents, aside from rerouting the traffic flow that has already entered the road section, is to also simultaneously provide timely information on the obstruction on the selected route of vehicles that have not yet entered said road section, including vehicles that are travelling in the horizontal direction, so that drivers would be able to choose another route before arriving at the place of obstruction. Since Tallinn ring road is essentially located in the area of influence of the traffic system of Tallinn, possible solutions are also significantly associated with opportunities to redirect traffic flows before drivers exit the traffic network of Tallinn. The feasibility and efficiency of such a solution is, of course, also largely dependent on the time and location of the incident. These opportunities may be rather limited during rush hour traffic, yet significantly greater at other times.

Therefore, one of the long-term objectives should also be to coordinate traffic management strategies and applicable technical solutions between the Road Administration and the city of Tallinn. One of the objectives of the long-term strategy could be the establishment of a uniform traffic management centre, which could be created on the basis of the Tallinn Traffic Management Centre and the relevant unit of the Road Administration. It is clear that the physical connection of these units is difficult in the short-term, however, the objective of the first stage could be to establish the development of data exchange, which would make the traffic information collected by the city of Tallinn and traffic information collected by the Road Administration quickly accessible to both parties.

The next step should be to find opportunities to extend the functions of the automatic traffic information collection system (which collects time-specific data regarding the characteristics of traffic flows, e.g. traffic volume, composition of the traffic flow, average speed, etc.). Since the coverage of the automatic traffic counting system includes mostly the city centre, it would be crucial, especially in the context of the traffic management system of Tallinn ring road, to extend the system to the city's peripheral areas as well, in particular to this project, to those major roads that are headed towards Tallinn ring road. Currently, such information regarding the traffic situation in nearby areas of the Tallinn ring road as well as on major roads in Tallinn is lacking, which is why the options for utilising an optimal bypass route in regard to incidents that may occur on Tallinn ring road, in case such a bypass route were to include the street network of Tallinn, are limited as well.

The same issue can also be addressed from the opposite viewpoint, i.e. what are the options for rerouting traffic flow to Tallinn ring road in case that a serious incident were to occur on a major route in Tallinn? At later stages, this issue could also be resolved by uniform traffic surveillance and the existence of a uniform traffic management system, which would centralise all national roads as well as the roads and streets of the city of Tallinn.

3. ROAD NETWORK DEVELOPMENT PLANS

3.1. Current Situation on Tallinn Ring Road and Development Plans

Currently, several sections of Tallinn ring road have been constructed into a two-carriageway highway, some sections are still under construction, projects have been designed for others and the section between Saue–Keila will most likely remain a one-carriageway highway for the upcoming years.

An overview of the current situation of the Tallinn ring road and projects planned is set out below. Tallinn ring road has been divided into four sectors on the basis of intersections with main and basic roads.

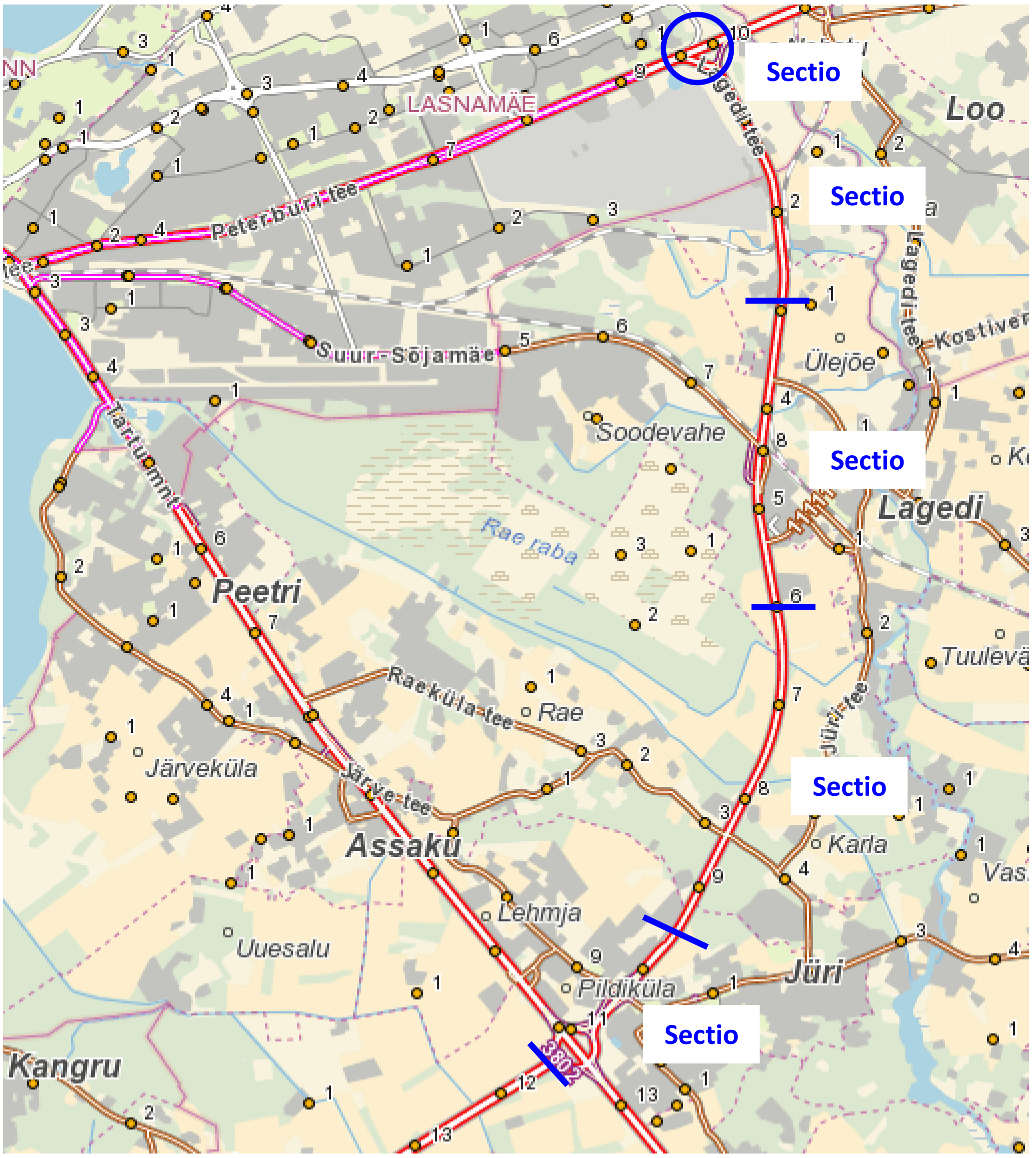

Figure 3.1. Sector 1 – Väo interchange ... Jüri circular intersection

Section No.	Beginning, km	End, km	Name	Current situation	Year of construction/ completion
1	0.0	0.3	Väo interchange	Design stage	Unknown
2	0.3	3.0	Väo–Lagedi road section	Project completed (Selektor Projekt OÜ) Under construction (Nordecon AS)	2017–2018
3	2.8	6.0	Lagedi interchange and road section	Project completed (Selektor Projekt OÜ) Under construction (Lemminkäinen AS)	2016–2018
4	6.0	9.7	Lagedi–Karla road section	Project completed (Škepast&Puhkim AS) Under construction (TREV-2 Grupp)	2016 2017–?
5	9.7	11.6	Põrguvälja interchange and Jüri circular intersection	Completed (2+2)	2017

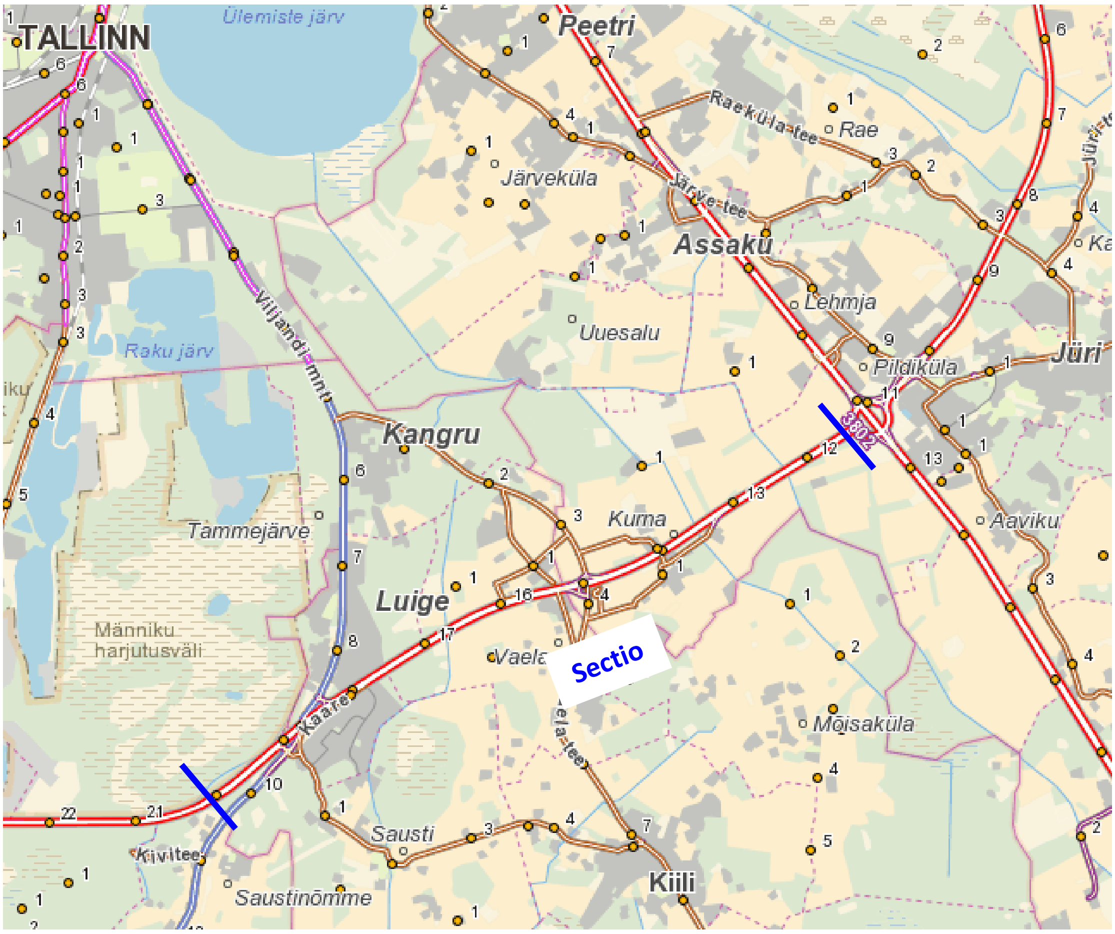

Figure 3.2. Sector 2 – Jüri circular intersection ... Luige interchange

Section No.	Beginning, km	End, km	Name	Current situation	Year of construction/ completion
6	11.6	20.2	Jüri–Luige	Completed (2+2)	2015 (Kurna interchange) 2013 (Luige interchange)

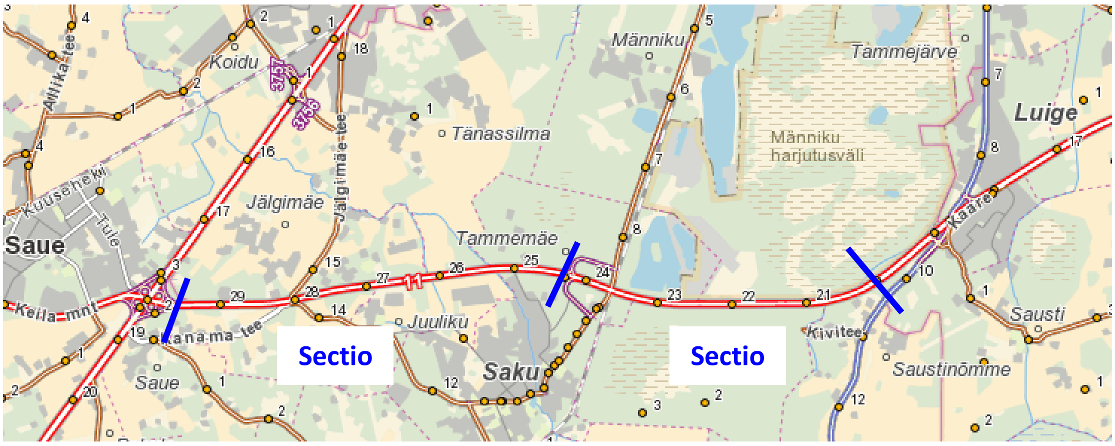

Figure 3.3. Sector 3 – *Luige interchange ... Kanama interchange*

Section No.	Beginning, km	End, km	Name	Current situation	Year of construction/ completion
7	20.2	24.3	Luige–Saku	Project completed (Škepast&Puhkim AS) Project expertise underway (Realprojekt OÜ)	2017 2018
8	24.1	29.6	Juuliku interchange	Project completed (Škepast&Puhkim AS) Construction practically finished (Tallinna Teede AS, Merko Ehitus Eesti AS, Merko Infra AS)	Autumn 2017

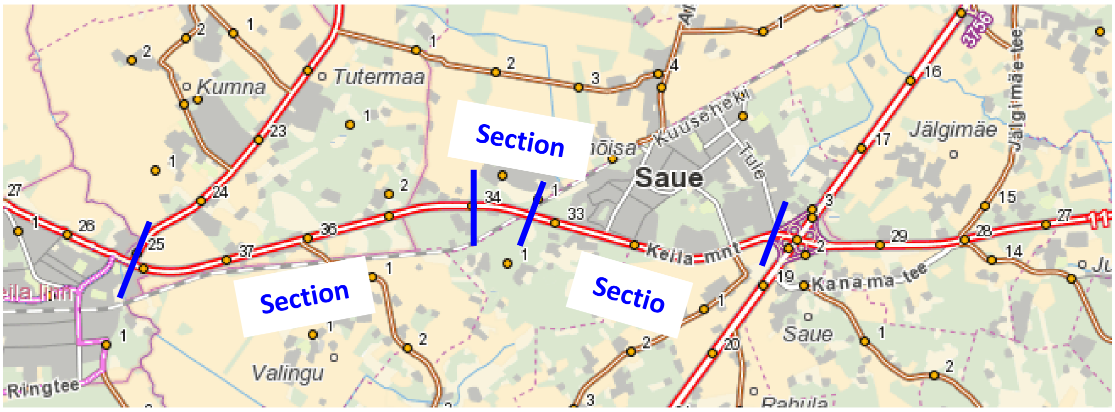

Figure 3.4. Sector 4 – Kanama interchange ... Keila

Section No.	Beginning, km	End, km	Name	Current situation	Year of construction/ completion

Section No.	Beginning, km	End, km	Name	Current situation	Year of construction/ completion
9	30.1	33.5	Saue–Valingu overpass	Considered as a 1+1 highway in this survey	Unknown
10	33.5	34.0	Valingu overpass	Project currently being designed Construction estimated to take place in	2018 2018–2019
11	34.0	38.2	Valingu–Keila	Considered as a 1+1 highway in this survey	Unknown

3.2. Entrance Roads to the City of Tallinn

Tallinn's plans in regard to entrance roads concerning the development of national roads of the Road Administration. Take into consideration the 15-year term (i.e. 2019 (2020)+15≈2035). Does the city have specific plans that should be taken into account and which could affect this project and in what perspective?

The following major road construction plans of Tallinn are worth mentioning:

- reconstruction of Haabersti intersection;
- construction of Reidi road;
- reconstruction of Gonsiori street.

From the aforementioned, the second example, i.e. construction of Reidi road, can be assumed to have an indirect impact on this project in regard to the incorporation of the Old Harbour, especially in relation to heavy traffic routes.

In regard to planned activities, the prospective construction of Väo interchange (Tallinn–Narva highway / Tallinn ring road) is also worth mentioning, as the capacity of the interchange will increase significantly as a result of this, meaning that the capacity for taking on extraordinary traffic flows in emergency situations will increase as well.

A significant opportunity provided by the solution planned would be the prospective construction of a so-called small Tallinn ring road, which could be used as an alternative to the current Takkubba ring road to some extent. However, no actual steps have been taken for the construction of this road, which is why it is highly unlikely to be constructed in the given time period.

A project that is to be carried out with participation of the city of Tallinn is also important in the context of this project, as its aim is to create a waiting car park for heavy vehicles near the city border (Sõjamäe?), where vehicles headed towards the Old Harbour are allowed to leave the car park and enter the route to the city centre at the so-called best point in time in order to avoid their long-term parking in the harbour or city streets. This system, which is currently already in development, should indeed be incorporated into the ITS solution of Tallinn ring road.

4. TRAFFIC VOLUME ON THE RING ROAD AND ANALYSIS OF TRAFFIC FLOWS

4.1. Change in the Traffic Volume of Tallinn Ring Road

The weighted average traffic volume has increased by 36% in the last ten years on Tallinn ring road (2016 vs 2006), whereas the number of road trains has increased an average of two times.

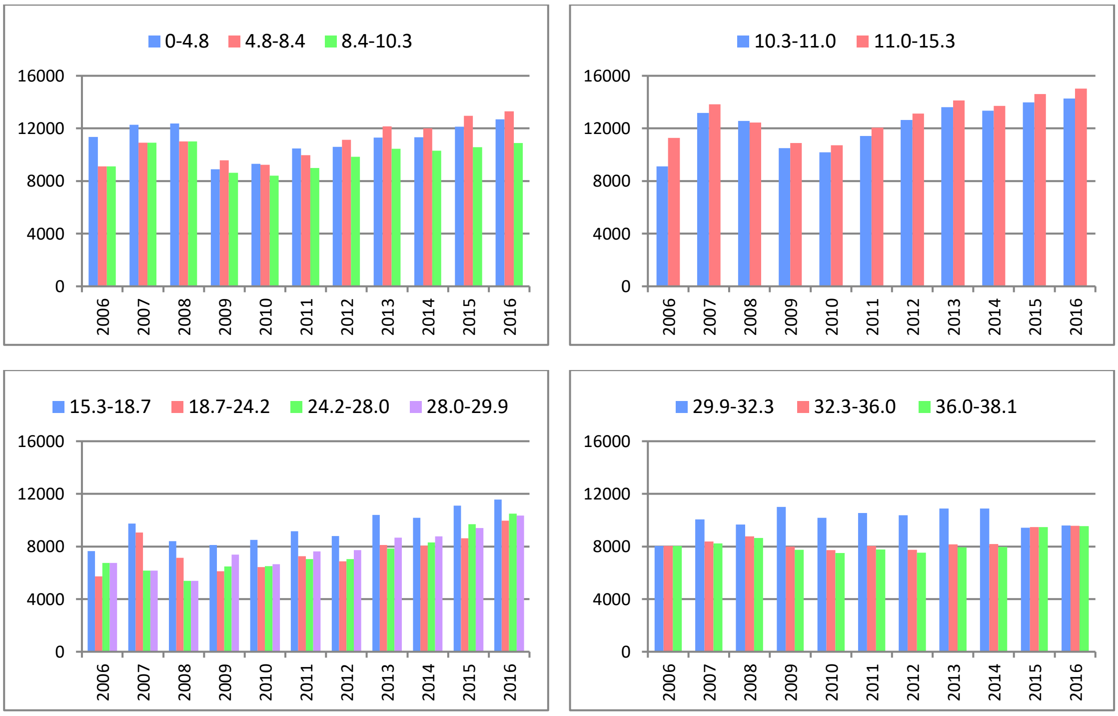

Figure 4.1. Traffic volume on sections of the Tallinn ring road from 2006–2016

Sections with the highest traffic volume values (AADT >12,000 vpd) on Tallinn ring road are km
0–8.4 (Väo–Karla) and km 10.3–15.3 (Jüri–Kurna).

In regard to road trains, the highest traffic volume values (RT > 2,000 vpd) have been recorded on km 11.0–15.3 (Jüri–Kurna) and km 18.7–28.0 (Luige–Jälgimäe). The number of road train decreases onwards from Kanama interchange, the amount of road trains from there up to Keila is 750 vpd on average.

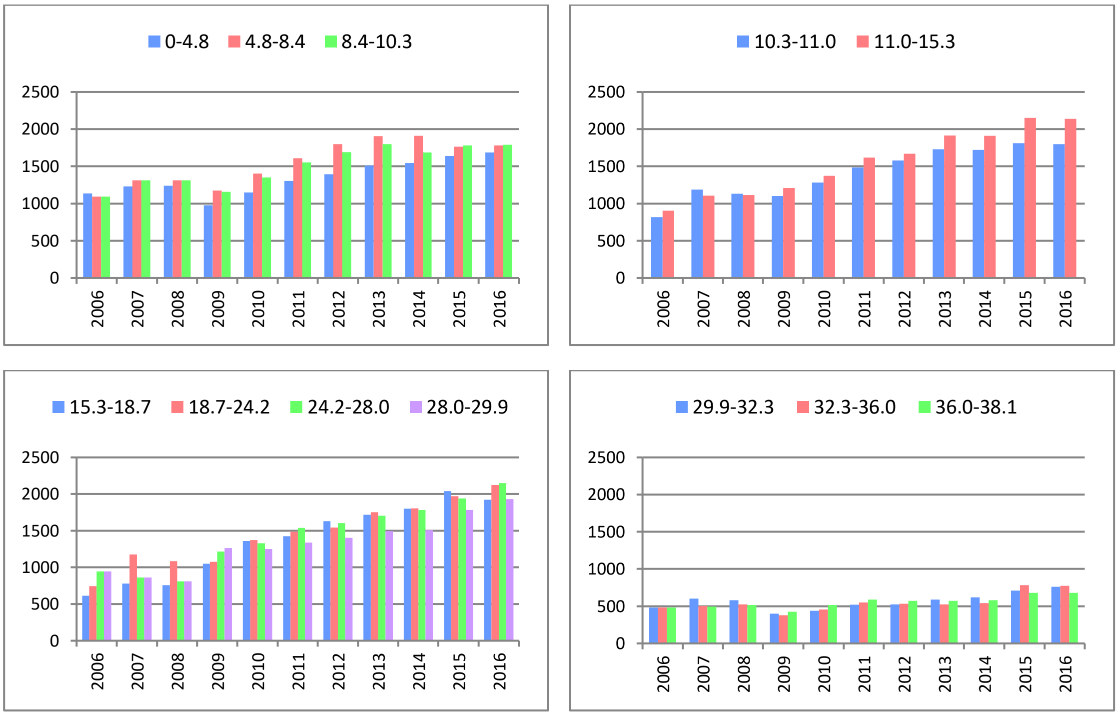

Figure 4.2. Traffic volume of vehicles belonging to the road train class on sections of the Tallinn ring road from 2006–2016

The largest increase in the traffic volume of vehicles belonging to the road train class has been demonstrated on road sections between Jüri ring road and Kanama interchange (100–200%), whereas the increase remains within 40–60% elsewhere.

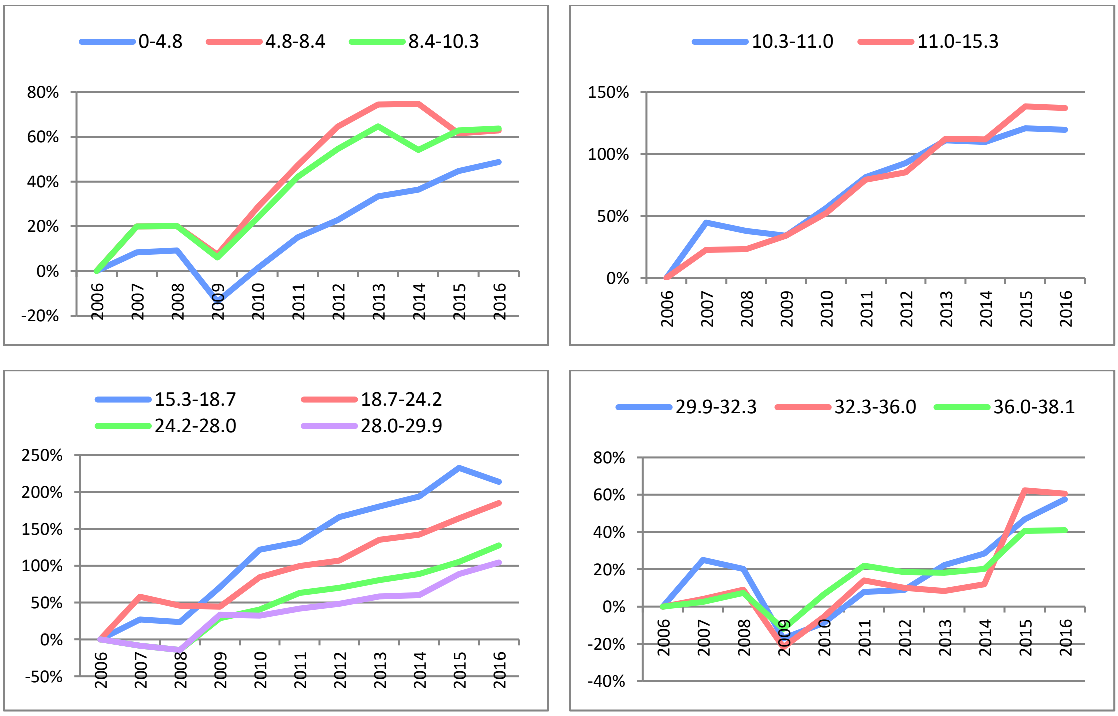

Figure 4.3. Change in the traffic volume of vehicles belonging to class RT on sections of the Tallinn ring road

4.2. Nature of Traffic on Tallinn Ring Road

There are several stationary traffic counting stations on Tallinn ring road, only one of which has, however, been transformed into a permanent traffic counting station (PCS 11–15.7 Vaela). The rest of the stationary counting stations operate periodically – usually from 4 to 8 weeks one or several times per year. Therefore, characteristic traffic distribution across a day, week, year can only be described on the basis of Vaela PCS.

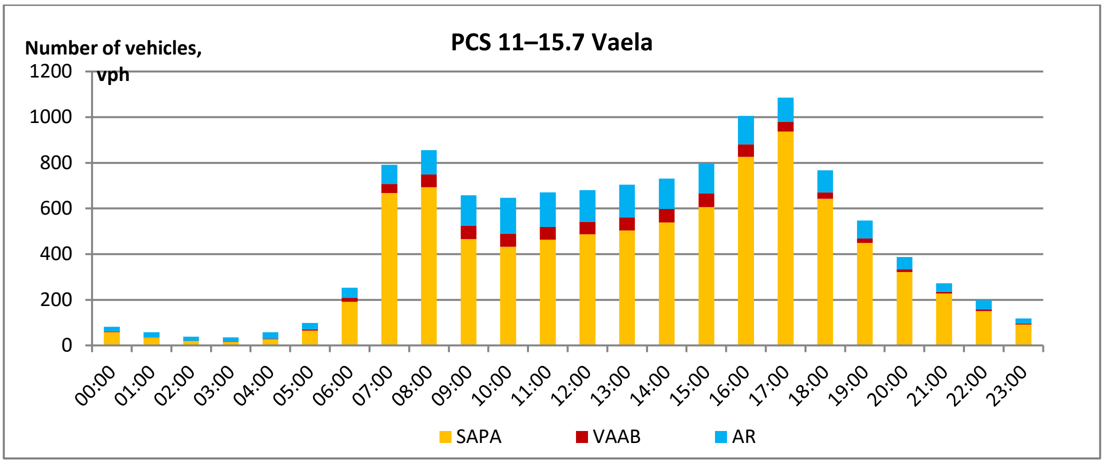

Figure 4.4. Distribution of traffic volume across vehicle classes in one day

The peak period for passenger cars and vans (PCV), as well as the overall peak period, is from 7.00–9.00 in the morning and from 16.00–18.00 in the evening, whereas the situation is completely different when it comes to heavy traffic (vehicles of classes TB, RT), for which traffic volume is higher during daytime from 8.00–17.00 (an average of 6.5–8.2% per hour out of the entire traffic volume per day). The maximum peak period in the evening from 17.00–18.00 constitutes 9.4% of the entire traffic volume per day. In case of Vaela PCS, the annual average traffic volume during this time is 1,085 vph. No specific period can be distinguished in regard to national holidays. Peak periods during the first 200 hours of the year largely coincide with the period from 17.00–18.00 (also from 16.00–17.00 on Fridays) and some with the period from 8.00–9.00 on workdays.

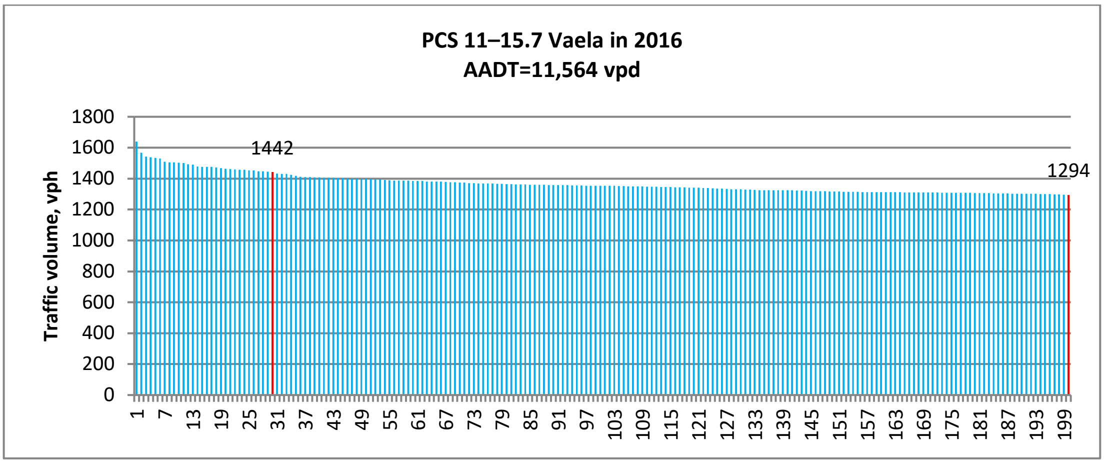

Figure 4.5. The first 200 hours of the year on the basis of data from Vaela PCS

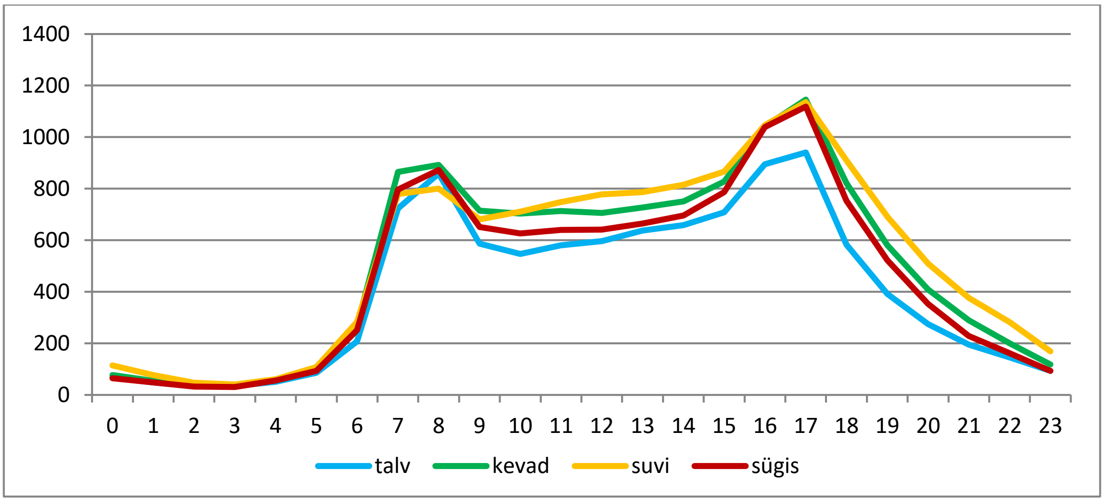

Figure 4.6. Seasonal distribution of traffic volume

No remarkable seasonal differences can be distinguished in traffic volume. Traffic volume is lower during wintertime, while daytime and evening traffic volume is somewhat higher during summertime than during other seasons. However, the evening peak period remains of the same magnitude as in spring and autumn.

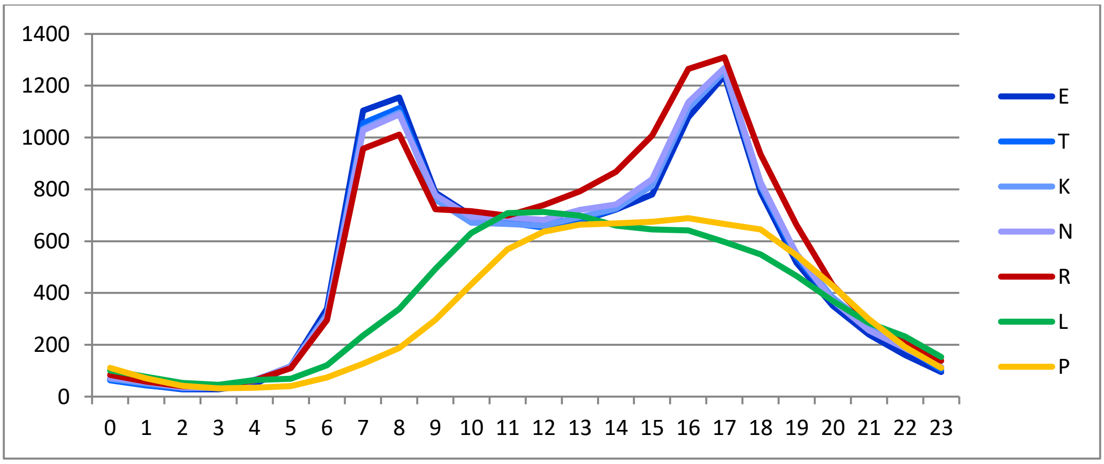

Figure 4.7. Distribution of traffic volume in the course of the day across different weekdays

The bulk of the traffic volume on Tallinn ring road is distributed on workdays, during which there is ca 28% more vehicles on the road than on weekends. Maximum peak time in the evening on workdays was from 17.00–18.00 and it was 1,268 vph according to Vaela PCS. The proportion of peak period traffic volume constitutes 10.0% of the entire traffic volume of the day on workdays.

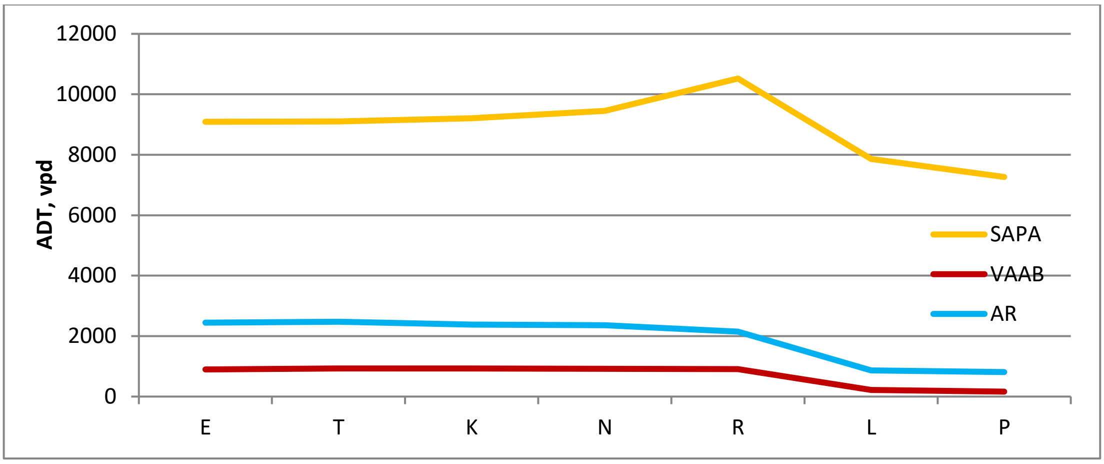

Figure 4.8. Distribution of traffic volume on the basis of vehicle classes across days of the week

If one were to look at the distribution of traffic volume across vehicle classes, it can be seen that vehicles of the car/van class constitute a relatively even flow from Monday to Thursday, whereas traffic volume is the highest on Fridays and decreases somewhat during the weekend. However, in case of heavy traffic, the volume of traffic remains similar across all workdays but there are ca 79% less trucks/buses and ca 65% less road trains on the roads during weekends than there are on workdays.

5. EFFECTS OF THE DEVELOPMENT OF TALLINN RING ROAD

5.1. The Effect of Tallinn Ring Road on the Establishment of Traffic Flows in Tallinn and Nearby Areas

It can already be said that Tallinn ring road is used by inhabitants of nearby local municipalities as well as the citizens of the city of Tallinn for travelling from one place in Tallinn (or nearby areas) to another, since it is not necessarily a shorter route in some cases, but is still a faster alternative in comparison with routes going through the city. It can therefore be assumed that when the Tallinn ring road is completed to its entire extent as a 2+2 highway, its usage by vehicle drivers of nearby areas will increase even more.

However, traffic volume on Tallinn ring road is still most affected by development activities (construction of industrial areas, shopping centres, etc.) in nearby areas. The sustainable urban mobility plan for the area of Tallinn is in development (estimated completion in spring 2019) and it can result in different changes on the basis of how actively development activities/functions are directed. In regard to developments, the most important estimation is the time of completion of a certain object. Some planning projects, which should have been completed by today, have only been partly realised by now, at best (e.g. shopping centre Gate Tallinn should have been completed to the extent of 60% by now, however, this is not the case in reality). The same goes for the development of Ameerikanurga by the Tallinn ring road.

The most important change in regard to Tallinn ring road is definitely the construction of the small Tallinn ring road, but the time of realisation is unknown for this as well. A draft(?) project has been prepared for the interchange of highway No. 2 Tallinn–Tartu–Võru–Luhamaa, in which a multi-level solution has been used for the crossing of highway No. 2 and small Tallinn ring road and the allocation of land for the construction of the interchange has been confirmed. However, the extension of small Tallinn ring road to basic road 15 Tallinn–Rapla–Türi constitutes an even more important impact on the traffic of the city of Tallinn.

6. MODELLING OF INCIDENTS

6.1. Accident Scenarios

Traffic obstruction is a situation during which regular traffic flow is disrupted. There can be various reasons. The most common reason for this is the occurrence of a traffic accident or slower than average travel speed due to bad weather conditions (slipperiness, visibility/fog). It can, of course, also be a combination of several different factors.

Since the 2+2 road sections of Tallinn ring road are relatively new, there is not much reason to analyse traffic accidents that have occurred on the ring road as of now. On the basis of data received from the information system of the Traffic Information Center[6], the average time for eliminating the traffic obstruction (generally a traffic accident) or the restoration of regular traffic flow is 2.5–3 h.

Table 5.1. Number of events related to traffic obstructions in 2017 as shown in the database of the Traffic Information Centre

Description in the information system of the Traffic Information Centre	Number of TAs	Time spent on eliminating the traffic obstruction, h		
		Medium	Min.	Max.
Traffic flow disrupted	39	2.8	0.1	12
Road partly closed	4	1.8	0.7	4
Road closed	3	3.0	0.5	11

There have been 4 incidents on two-carriageway roads in 2017, as a result of which traffic flow has been disrupted[7]:

- accident – short-term rerouting of traffic in one direction; road closed for 44 min;
- traffic accident – both directions of road closed; road closed for 1h 29 min;
- fire in a vehicle – one direction closed for traffic for a short-term period, one lane reopened within ca 1 hour; road closed for 1 h 17 min;
- truck loaded with rubble turned sideways on the road, one lane – one lane closed for 3 h 26 min.

Traffic accidents, resulting in closing traffic in one direction, have also occurred before[8], but these have been unique incidents:

[6] Email, 27 November 2017, Kristjan Duubas, Road Administration
[7] Email, 27 November 2017, Siim Jaksi, Road Administration
[8] Email, 20 November 2017, Jaan Saia, Road Administration

- highway No. 1 km 21.95 Jõelähtme – vehicle which was performing a U-turn collided with a truck, rear-end collisions with vehicles that had stopped before the site of the accident and roadway departures; road closed for ~5 h;
- highway No. 2 km 33 – tanker truck turned sideways on the road, road closed for cleaning for a couple of hours;
- highway No. 4 km 16.3 – motor vehicle drifted over the dividing strip to the oncoming lane and collided with another vehicle, road closed for ~4 h;
- highway No. 4 km 18.8 – collision with a vehicle that was performing a U-turn, road closed for ~3 h;
- highway No. 11 km 12.8 – control lost over vehicle on slippery road, vehicle collided with the road barrier, causing several other vehicles to collide with it, road closed for ~4 h;
- highway No. 11 km 15.1 – driving into the formwork of a road formation by vehicle with high-rise cargo, road closed for ~12 h, rerouting of vehicles via other roads;
- highway No. 11 km 6–8 – traffic accidents involving vehicles drifting to the oncoming lane have occurred on a long gentle curve on a 1+1 road section, during which the road has been closed and traffic rerouted via other roads for 2–4 hours.

Since no specific traffic obstructions can be used as a basis in this survey, we can draw on the following in estimating the likelihood of such incidents:

- the most likely traffic obstruction to occur on roads is apparently one where traffic is disrupted or closed on only one lane. The likelihood of the occurrence of such an event can be related to the occurrence of a minor traffic accident (or other similar incident) without human damages;
- the occurrence of an incident where both lanes in one direction are closed for traffic is less likely. From a traffic safety point of view, such an event could be regarded as a more serious traffic accident or similar situation that involves human damages (e.g. injuries).
- the least likely event to occur is one where traffic is disrupted on both lanes in both directions as a result of the incident. If such events are connected to the occurrence of a traffic accident, such events can provisionally be regarded as a very serious accident involving several injured persons or fatalities.

Table 5.2. Description of accident scenarios

Type of TA	Injured persons	Disruption of traffic flow	Time for eliminating the disruption, h
Minor	No	No significant disruption	0
Medium	No or minor injuries	On one lane	1.5
Serious	Yes, minor or serious injury *	On both lanes	3.0
Very serious	Yes, serious injury or death *	On both lanes	8.0

* Remark – in the context of disruption of traffic flow, an accident could be considered serious or very serious even if it does not involve human injuries (e.g. road train transporting fuel is overturned in the middle of the road, the driver is going around the vehicle and extinguishing the petrol tank until emergency rescue arrives).

7. TRAFFIC MODEL OF TALLINN AND ITS NEARBY AREA

7.1. Traffic Modelling

Traffic modelling has been conducted on the basis of the traffic model of Tallinn during evening peak period (hereinafter referred to as “EPP”). The transport planning package of the common traffic modelling software Citilabs Cube Voyager has been used during the process. The traffic model of Tallinn includes the entire Tallinn and its nearby areas, incl. Tallinn ring road. The development of the traffic model of Tallinn began in 1996 and the base model has been annually updated and calibrated in accordance with information received from surveys and traffic counting results. In 2008, the traffic models of the city of Tallinn and Tallinn ring road were merged.

Figure 7.1. Road network in the traffic model of Tallinn and its nearby area.

The traffic model comprises two parts: road network and correspondence matrix. In regard to the road network, the model includes data on each road section and intersection:

- road section (length, travel speed, capacity, etc.);
- intersection (type, number of lanes, traffic light programme, etc.).

Correspondence matrix is a matrix that characterises the connections between places of departure and arrival and constitutes the so-called connections between unit and transport zones. Transport zone is the generalised unit of the area modelled and the amount of units is selected on the basis of the task at hand, however, it must be enough to enable to distribute traffic flows on the network at an appropriate level of accuracy. There are 400 transport zones that are either places of departure or arrival in the traffic model of Tallinn and its nearby area. Transport zones are related to land use and they include a description of what type of a zone it is and its background. During the preparation of the forecast model, it is also necessary to consider future changes in land use, therefore also taking into account possible new or changing correspondences arising from new plans. Thus, transport zones that are related to land use also involve notes on plans. During the preparation of the forecast model, the intention has been to consider all known datasets of plans related to the land use of Tallinn and nearby areas, including small designs with little traffic impact.

Since changes and impacts of land use are in constant development, the correspondence matrix does require corrections from time to time. The last more serious correction of the correspondence matrix was conducted in 2016 via the use of the data of the Tax and Customs Board regarding the home and workplace of citizens.

A forecast matrix has been prepared in the context of this survey, showing that the overall growth of the correspondence matrix (i.e. comprehensive traffic demand) of Tallinn is 19.5% in the period of 2019–2034. Therefore, the model of 2019 shows 79,492 travels in the course of the evening peak period and the model of 2034 shows 94,990 travels. It is important to point out that the growth is calculated in accordance with changes in land use and by incorporating traffic-political objectives of Tallinn. For instance, traffic growth in the city centre of Tallinn is not foreseen and some places where there is currently no traffic will be open for traffic then (e.g. realisation of Veskimöldre or Koru zoning plans).

7.2. Traffic Model 2019

7.2.1. Road Network

The street network of the 2017 base model has been adjusted with objects that have been completed or will most likely be completed by 2019:

- highway No. 11 Tallinn ring road sections km 0–20 and 24–30 have 2+2 lanes, incl. completed reconstruction of Väo interchange.
  P.S. The section of km 20–24 has 1+1 lanes in the 2019 traffic model, however, it does not change the traffic volume of Tallinn ring road as there are no intersections on this section and the capacity of the road section is adequate.

Objects in the city of Tallinn:

- Reidi road (Russalka–Ahtri tn);
- Traffic solution for Gonsiori tn, involving public transport lanes and reversible lanes (reversible lane leading out of the city in the evening);
- Haabersti interchange (construction of an overpass, reconstruction of Rannamõisa road);
- Tallinn main street project has been realised (sections of Narva and Pärnu highway have been limited to facilitate alternative types of travel and restrict car traffic).

7.2.2. Land Use

It has been assumed in regard to land use that constructions that are still ongoing in 2016–2017 shall be finished by 2019.

7.3. Traffic Model 2034

7.3.1. Road Network

The following objects that are likely to be completed by 2034 have been included in traffic model 2034:

- highway No. 11 section km 0–30 (from Väo interchange to Kanama interchange) has 2+2 lanes and multi-level interchanges.
- Objects in the city of Tallinn:
- breakthrough of Tervise tn (connects Viljandi highway to Rahumäe road);
- Rannamõisa road has 2+2 lanes up until the ring road of Vahepere road;
- reconstruction of Paldiski highway into a major road with 2+2 lanes (from Haabersti up to the Harku–Rannamõisa intersection of road 11191).

7.3.2. Land Use

- Zoning plans regarding Tallinn and nearby areas have been realised to the extent of around 90%.
- In the context of major plans nearby the Tallinn ring road, it is assumed that Ameerikanurga and Kanadanurga (both located near the interchange of highway No. 2 and highway No. 11) have not been realised or have been realised to a small extent, i.e. so that the intended network of distributor roads has not yet been completed.

7.4. Aggregated Data on Traffic Modelling

In the context of this survey, traffic modelling has been conducted for two primary purposes:

- provide an input for profitability calculations concerning time expenditure;
- assess the capacity and bottlenecks of bypass roads.

The analysis of bypass routes along with recommendations for alleviating problems has been set out in Annex 2 (Problem areas of Bypass Routes in 2019 and 2034).

Aggregated data on traffic modelling are set out in tables 7.1 and 7.2. The model includes two scenarios: one where the relevant road section of highway No. 11 is open (regular traffic) and one where the relevant road section is closed and traffic is rerouted via alternative routes. The only road section on highway No. 11 that does not have any alternative routes is road section 5 (highway No. 2 – Vaela), for which the model displays a situation where all traffic on highway No. 11 is distributed onto the street network of Tallinn (the main alternative is Järvevana road).

If only one direction (one thread) is closed, the calculation of time expenditure takes the decrease of travel speed (connections) into consideration and distribution of traffic to other routes is not taken into account.

Data on traffic volume of Tallinn ring road (AADT) for 2019 and 2034 are set out in **Annex 5**.

Table 7.1. Aggregated data on traffic modelling (2019)

		TALLINN KOKKU		T11 TALLINNA RINGTEE			ÜMBERSÕIDUD						
							1. alterntiiv (väljaspool T11 Tallinna ringteed)			2. alterntiiv (üldjuhul seespool T11 Tallinna ringteed)			
		summaarne läbisõit	summaarne ajakulu	teedevõrgu pikkus*	summaarne läbisõit	summaarne ajakulu	teedevõrgu pikkus*	summaarne läbisõit	summaarne ajakulu	teedevõrgu pikkus*	summaarne läbisõit	summaarne ajakulu	Joonise nr
	lõik	a-km	ajakulu	km	a-km	tundi	km	a-km	tundi	km	a-km	tundi	
2019	1	669346	19665	7,8	6059	73	18,7	6834	108		ei ole		STR-01
	1 niit kinni				6059	202							
	T11 kinni	668679	20051	7,8	0	869,5	18,7	11185	248		ei ole		STR-02
2019	2	669346	19665	3,3	2777	31	33	4327	69		ei ole		STR-03
	1 niit kinni				2777	93							
	T11 kinni	671006	20447	3,3	0	806,5	33	8002	117		ei ole		STR-04
2019	3	669346	19665	7,4	6050	68	31,3	4163	66	10,8	188	4	STR-05
	1 niit kinni				6050	202							
	T11 kinni	669172	19936	7,4	0	882	31,3	4803	74	10,8	6174	169	STR-06
2019	4	669346	19665	4,4	3389	44	30,9	13223	191	14	2783	56	STR-07
	1 niit kinni				3389	113							
	T11 kinni	669608	20414	4,4	0	754,5	30,9	15409	285	14	4821	191	STR-08
2019	5	669346	19665	8,1	7330	86		ei ole			ei ole		STR-09
	1 niit kinni				7330	244							
	T11 kinni	675324	21620	8,1	0	936		ei ole			ei ole		STR-10
2019	6	669346	19665	8,9	6986	78	17,4	1275	20	16	4820	75	STR-11
	1 niit kinni				6986	233							
	T11 kinni	671056	20078	8,9	0	806	17,4	5356	94	16	10298	197	STR-12
2019	7	669346	19665	10,4	6617	74	35	9285	130	30,8	15068	256	STR-13
	1 niit kinni				6617	221							
	T11 kinni	670466	20259	10,4	0	636	35	15102	219	30,8	18481	342	STR-14
2019	8	669346	19665	4,3	3079	34	15,1	4817	91		ei ole		STR-15
	1 niit kinni				3079	103							
	T11 kinni	669634	20092	4,3	0	744	15,1	9418	233		ei ole		STR-16
2019	9	669346	19665	7,1	5153	60	10,9	1649	25	14,3	9760	123	STR-17
	1 niit kinni				5153	172							
	T11 kinni	670096	19847	7,1	0	726	10,9	4160	101	14,3	12801	198	STR-18
2019	10	669346	19665	11,7	6177	77	19,9	4042	60		ei ole		STR-19
	1 niit kinni				6177	206							
	T11 kinni	672032	20092	11,7	0	532	19,9	12271	257		ei ole		STR-20

*) mudel arvestab teedevõrgu pikkust suuna kaupa ehk 2 km pikkune kahesuunaline teelõik on selles tulbas 4 km.

Table 7.2. Aggregated data on traffic modelling (2034)

		TALLINN KOKKU		T11 TALLINNA RINGTEE			ÜMBERSÕIDUD						
						0,5	1. alterntiiv (väljaspool T11 Tallinna ringteed)			2. alterntiiv (üldjuhul seespool T11 Tallinna ringteed)			
		summaarne läbisõit	summaarne ajakulu	teedevõrgu pikkus*	summaarne läbisõit	summaarne ajakulu	teedevõrgu pikkus*	summaarne läbisõit	summaarne ajakulu	teedevõrgu pikkus*	summaarne läbisõit	summaarne ajakulu	Joonise nr
	lõik	a-km	ajakulu	km	a-km	tundi	km	a-km	tundi	km	a-km	tundi	
2034	1	859883	33312	7,8	9677	120	18,7	8480	136		ei ole		STR-21
	1 niit kinni				9677	323							
	T11 kinni	861129	34955	7,8	0	1411,5	18,7	14161	501		ei ole		STR-22
2034	2	859883	33312	2,1	2819	32	32,8	6724	110		ei ole		STR-23
	1 niit kinni				2819	94							
	T11 kinni	868706	35378	2,1	0	1321,5	32,8	16758	285		ei ole		STR-24
2034	3	859883	33312	6,1	8721	99	31,3	6333	102	10,8	678	14	STR-25
	1 niit kinni				8721	291							
	T11 kinni	863100	34803	6,1	0	1423,5	31,3	10468	159	10,8	7991	391	STR-26
2034	4	859883	33312	4,4	5549	132	30,9	17660	258	14	4550	116	STR-27
	1 niit kinni				5549	185							
	T11 kinni	867849	35383	4,4	0	1427,5	30,9	21789	419	14	9157	320	STR-28
2034	5	859883	33312	8,1	13348	231		ei ole			ei ole		STR-29
	1 niit kinni				13348	445							
	T11 kinni	871587	42354	8,1	0	1715,5		ei ole			ei ole		STR-30
2034	6	859883	33312	8,9	12450	143	17,4	2240	37	16	6976	112	STR-31
	1 niit kinni				12450	415							
	T11 kinni	862387	36179	8,9	0	1447	17,4	10865	338	16	13147	621	STR-32
2034	7	859883	33312	10,4	12006	146	35	13731	199	30,8	20037	364	STR-33
	1 niit kinni				12006	400							
	T11 kinni	865064	35713	10,4	0	1154,5	35	24043	454	30,8	27812	665	STR-34
2034	8	859883	33312	4,3	5942	69	15,1	6333	123		ei ole		STR-35
	1 niit kinni				5942	198							
	T11 kinni	863841	36741	4,3	0	1462,5	15,1	12517	713		ei ole		STR-36
2034	9	859883	33312	7,1	8677	118	10,9	2159	36	14,3	12311	171	STR-37
	1 niit kinni				8677	289							
	T11 kinni	862062	34882	7,1	0	1222	10,9	5411	192	14,3	18197	518	STR-38
2034	10	859883	33312	11,7	8823	113	19,9	5677	98		ei ole		STR-39
	1 niit kinni				8823	294							
	T11 kinni	867241	34605	11,7	0	765	19,9	14123	385		ei ole		STR-40

*) mudel arvestab teedevõrgu pikkust suuna kaupa ehk 2 km pikkune kahesuunaline teelõik on selles tulbas 4 km.

8. BYPASS ROUTES

8.1. Homogeneous Road Sections

Tallinn ring road has been divided into homogeneous road sections by separate driving directions. Homogeneous section is a road section between two points, from where it is possible to redirect traffic; it usually includes ramps, intersections, places where the dividing strip is interrupted.

Locations of existing ramps, intersections and maintenance gates in the median barrier are mapped out during appointment of homogeneous road sections. Development projects regarding Tallinn ring road have also been reviewed and additional locations, which will be realised in the upcoming years, have been added.

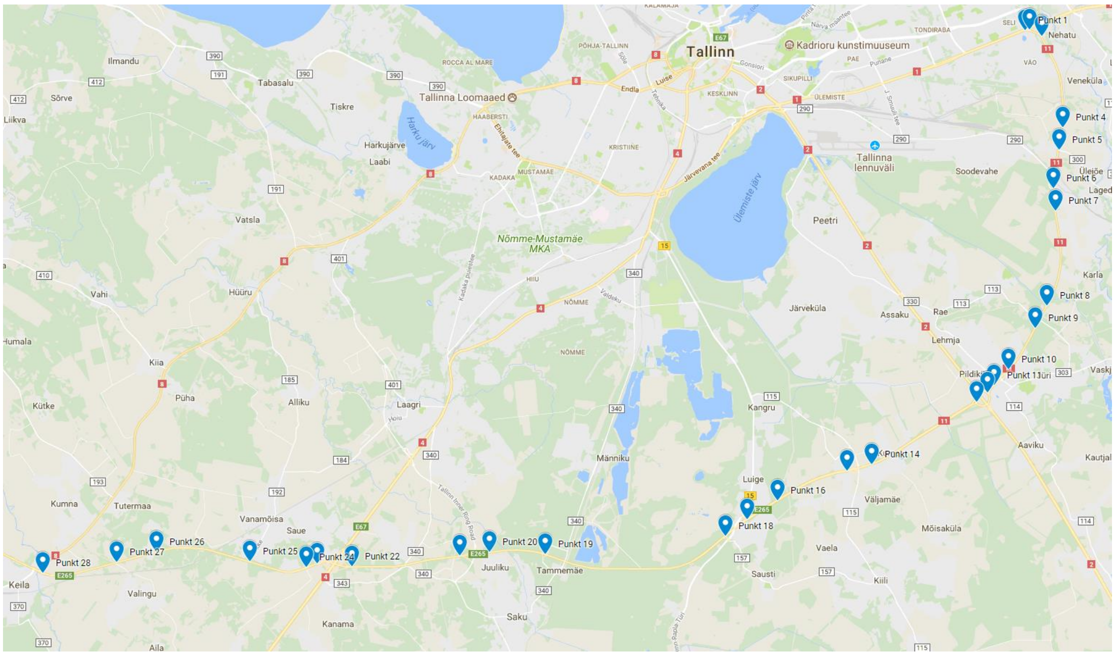

Figure 8.1. Map of homogeneous road sections

Google Maps provides a better overview of the road sections set out in the map (relevant link shared with the contracting entity).

8.2. Problem Areas of Bypass Routes in 2019 and 2034

Modelling has been carried out for evening peak period situations for 2019 and 2034.

The modelling has resulted in determining the intersections (interchanges) where implementation of additional measures is necessary in case of complete rerouting of traffic – temporary traffic management, authorised official, etc.

Capacity coefficients of performance (i.e. ratio of traffic volume and capacity) are set out in extract schemes of intersections by traffic directions. For instance, coefficient 1.123 means that capacity is implemented to the extent of 112.3%, i.e. all that exceeds 1.0 (over 100%) signifies complete exhaustion of capacity. In case of unchannellised (lanes with shared manoeuvres) intersections, coefficients of performance shall be added together. For instance, if coefficients displayed by traffic directions 0.543 and 0.345 actually originate from one lane, the capacity coefficient of performance is 0.543 + 0.345 = 0.888, i.e. 88.8% of capacity has been used.

NB: Circles marking the capacity coefficient of performance in figures STR-01–STR-40 also consider the existence/absence of turning lanes and have therefore already been added up.

Some schemes also display demand, which stands for the amount of cars that would like to perform the relevant manoeuvre (cph). This provides the executor of rerouting with information regarding the traffic volume which should be taken into account during rerouting.

It has been estimated that the ITS solution is applicable in case of closure, i.e. part of the traffic volume has already chosen a better route and the place of rerouting will serve less than the regular traffic flow.

Overview of problem areas of bypass routes is set out in **Annex 2**.

8.3. Bypass Schemes

Bypass schemes have been prepared separately for each homogeneous road section. Three different scenarios have been taken into account:

- traffic direction 1, i.e. STEE 1, (both lanes of the carriageway) is closed;
- traffic direction 2, i.e. STEE 2, (both lanes of the carriageway) is closed;
- traffic direction 1 and 2 (all lanes of carriageways) are closed.

If the traffic obstruction only occurs on one lane in one direction, traffic shall be redirected to the other lane in the same direction and time expenditure of road users will be slightly higher (intertwining one direction onto one lane and temporary speed restriction).

If the traffic obstruction only occurs on both lanes in one direction, traffic shall be redirected to the other direction (1+1) and time expenditure of road users will be slightly higher (intertwining two directions onto one lane and temporary speed restriction).

Road conditions and effects of additional traffic volume on bypass roads have been taken into account during the preparation of bypass routes.

Bypass routes are presented to their full extent in **Annex 3**.

9. SURVEILLANCE AND TRAFFIC MANAGEMENT SYSTEMS

9.1. Existing Equipment on Tallinn Ring Road

In 2009, 7 stationary traffic counting stations were installed at Tallinn ring road, which began operating as periodic counting stations. As of now, one of these stations (Vaela) has been converted into a permanent traffic counting station, whereas several other periodic traffic counting stations are currently out of order, since reconstruction work is being carried out on the highway.

Table 9.1. Locations of various existing equipment on Tallinn ring road

Road address					Name of location	Type of equipment	Year of instalment
Highway No.	STEE	TO	Distance	Km			
11	1	2	134	3.0	Väo	Periodic traffic counting station	2009
11	1	4	2,997	12.7	Kurna	Periodic traffic counting station	2009/renov. 2015
11	1	5	1,332	16.3	Vaela	Permanent traffic counting station	2009/2016
11	1	5	1,332	16.3	Vaela	Road weather information station and camera	
11	1	5	4,332	19.3	Luige	Road camera	2013
11	1	6	1,767	22.0	Tammemäe	Periodic traffic counting station	2009
11	1	7	1,974	26.3	Juuliku	Periodic traffic counting station	2009
11	1	7	4,574	28.9	Jälgimäe	Periodic traffic counting station	2009
11	1	9	2,225	35.6	Valingu	Periodic traffic counting station	2009

Figure 9.1. Locations of existing equipment

Legend:

	Permanent traffic counting station (Vaela)
	Periodic traffic counting station
	Road weather information station
	Road camera

9.2. Description of ITS Equipment

One of the objectives of ITS equipment is to provide road users with up-to-date information on what is happening on the road, whether notifying of various traffic disruptions (e.g. closing of a lane or slowing of traffic flow due to road construction or traffic accidents) or changes in road conditions due to weather (e.g. sudden slipperiness, decreased visibility (fog), etc.).

The world of ITS equipment is in constant development and since the objective of this survey was not to describe all existing equipment[9], but rather to point out appropriate surveillance and traffic management systems for managing the Tallinn ring road, the following only includes descriptions of equipment that consultants deemed practical to apply in regard to the Tallinn ring road.

9.2.1. Surveillance Systems

The condition of the road surface (dry/wet/slippery, etc.) and visibility (fog, heavy rain, etc.) are important parameters that affect the behaviour of road users and the likelihood of accidents. In Finland, road weather information systems are recommended to be installed after every 40–50 km on main and basic roads. Road sections where variable-message signs are used should be equipped with road weather information stations more frequently (after every 5–10 km)[10]. 16 road weather information systems have been installed on Helsinki Kehä III ring road, which is 45 km long. In order to get up-to-date information on road conditions and notify road users as quickly as possible, it would be reasonable to install additional road weather information stations (and/or road cameras) in addition to the existing one on Tallinn ring road as well as other sectors of the ring road (cf. Figure 9.4).

There are several different traffic cameras for monitoring traffic. Starting with simpler cameras that enable to monitor traffic conditions and ending with cameras that automatically identify various traffic events.

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[9] The topic of VMS has been addressed in a previous survey ordered by the Road Administration – “Muutuvteabega liikluskorraldusvahendite kasutamine” Ramboll Eesti AS, 2013

[10] Lähesmaa, J.; Levo, J. Tiesääseurannan tavoitetila. Tiehallinnon selvityksiä 6/2003.

AID, automatic incident detection, is appropriate for detecting disruptions in traffic flow. Traffic events that the system is capable of detecting[11]:

- stopped vehicle;
- car driving in the wrong direction;
- pedestrian on the road;
- unauthorised items on road;
- significantly decreased visibility;
- fire (does not, however, replace a fire alarm system);
- decrease in the average speed of car flow (does not apply to an individual car).

9.2.2. Warning Systems

If there is information about a disruption of traffic flow on the road, said information can also be provided to road users. There are several different options for this:

- VWS, i.e. variable warning sign, enables to display various warning signs;
- VSL, i.e. variable speed limit sign, enables to display various speed limits;
- combination of the aforementioned signs (VWS+VSL).

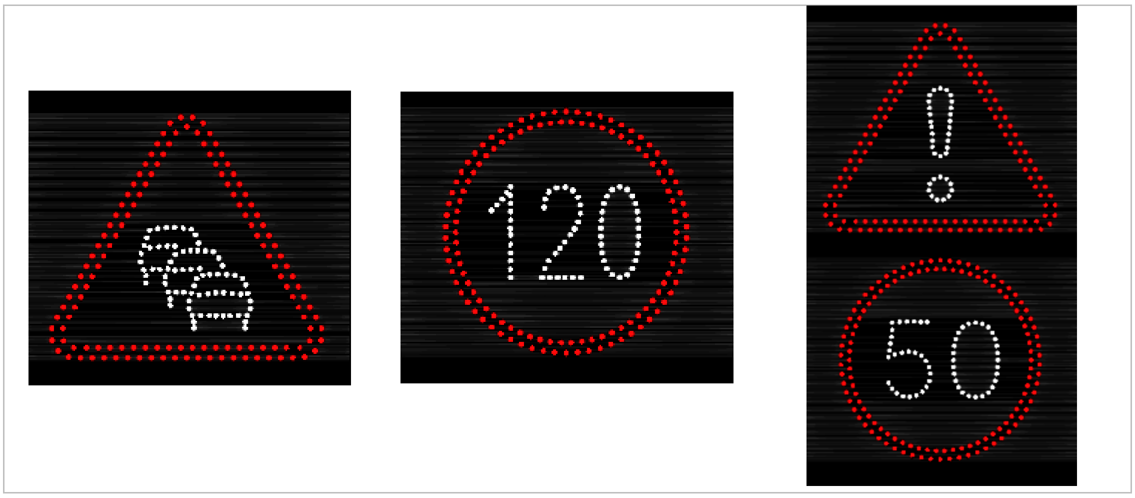

Figure 9.2. Example of various variable-message warning signs

9.2.3. Systems That Affect Traffic Flow

Systems that affect traffic flow enable to provide information on upcoming traffic disruptions and offer possible bypass options for rerouting traffic.

Variable-message sign, i.e. VMS, enables to display various messages.

[11] Homepage of IB Foor OÜ www.foor.ee

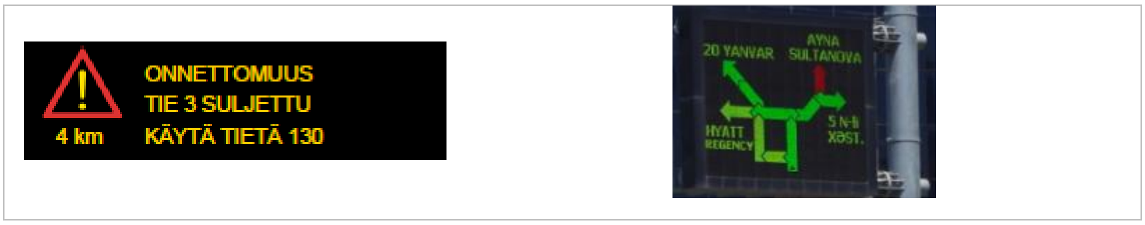

Figure 9.3. Example of different various-message signs

9.3. Locations of ITS Equipment

There is currently only one road weather information station and one road camera on Tallinn ring road. In order to gain a better overview of weather conditions, it would be reasonable to install road weather information stations in other sectors of the ring road as well; plans for 4 additional road weather information stations have currently been made. Provided that existing stationary traffic counting stations remain at their current location, consultants have proposed 2 additional traffic counting stations, which would enable to display, in addition traffic counting data, also traffic volume and speed over a selected period of time, which would provide information regarding possible traffic disruptions (traffic volume, average speed and percentage of heavy traffic over the last 15 minutes is currently displayed in the Tarktee application). Locations of possible new road weather information stations and traffic counting stations are brought out in Figure 9.4 and Table 9.2.

Figure 9.4. Locations of new road weather information stations and traffic counting stations

Legend:

	New traffic counting station
	New road weather information station

Table 9.2. Address data of the locations of new road weather information stations and traffic counting stations

Order No.	Name	Road address*					LAT	LON
		Highway No.	STEE	TO	Distance	Km		
New traffic counting station								
1	New LP-1	11	1	3	2,261	8.339	59.37274	24.91011
2	New LP-2	11	1	8	2,088	31.656	59.31186	24.54723
New road weather information station								
1	New TIJ-1	11	1	2	1,864	4.730	59.40394	24.91604
2	New TIJ-2	11	1	4	3,265	12.968	59.34465	24.85467
3	New TIJ-3	11	1	7	1,145	25.471	59.31628	24.65383
4	New TIJ-4	11	1	9	1,355	34.730	59.31654	24.49487

* - road address has hereinafter been determined on the basis of the status set out in the Road Register as at 1 December 2017. Road addresses are about to undergo significant changes in the upcoming years due to ongoing reconstruction works on objects on Tallinn ring road.

Locations of traffic cameras to be installed in the context of getting a better overview of traffic conditions are set out in Figure 9.5 and Table 9.3. As a rule, such cameras are installed onto overpasses or portals located at an interchange.

Figure 9.5. Locations of traffic cameras

Table 9.3. Address data of the locations of new traffic cameras

Order No.	Name	Road address					LAT	LON
		Highway No.	STEE	TO	Distance	Km		
1	ITS1 - LK-1	11	1	1	1,818	1.818	59.42980	24.91973
2	ITS1 - LK-2	11	1	2	2,208	5.074	59.40086	24.91626
3	ITS1 - LK-3	11	1	3	2,337	8.415	59.37212	24.90956
4	ITS1 - LK-4	11	1	4	611	10.314	59.35813	24.89098
5	ITS1 - LK-5	11	1	4	5,230	14.933	59.33642	24.82429
6	ITS1 - LK-6	11	1	5	3,733	18.701	59.32198	24.76524
7	ITS1 - LK-7	11	1	6	4,012	24.245	59.31556	24.67512
8	ITS1 - LK-8	11	1	7	1,856	26.182	59.31549	24.64147
9	ITS1 - LK-9	11	1	8	431	29.999	59.31322	24.57521
10	ITS1 - LK-10	11	1	9	10	33.385	59.31615	24.51813
11	ITS1 - LK-11	11	1	9	2,288	35.663	59.31449	24.47899

Locations of boards that combine variable-message warning signs and variable speed limit signs (VWS+VSL) are set out in Figure 9.6 and Table 9.4.

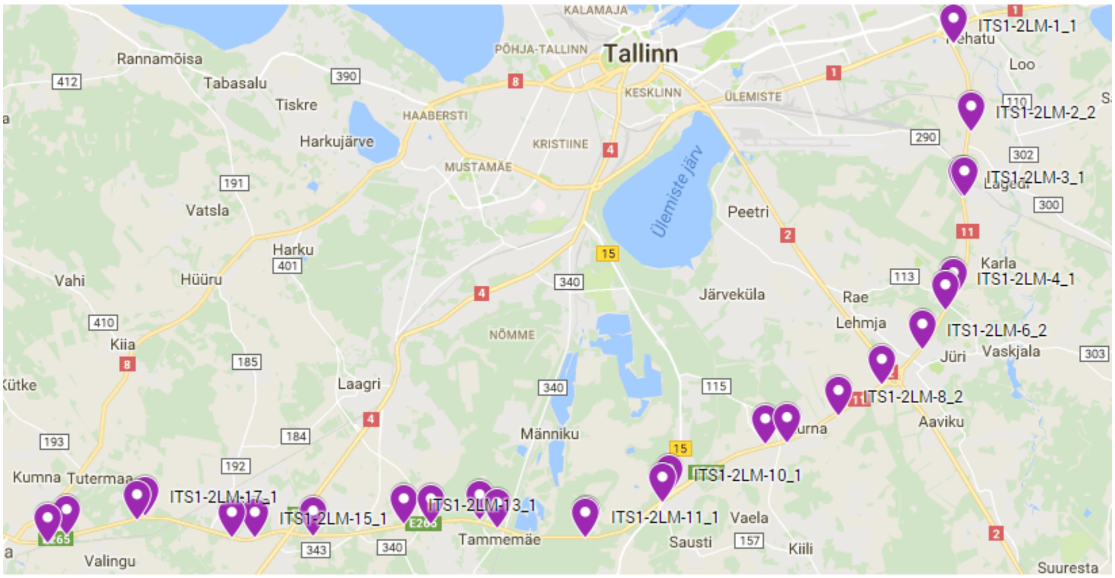

Figure 9.6. Locations of VWS+VSL

Table 9.4. Address data regarding locations of new VWS+VSL signs

Order No.	Name	Road address					LAT	LON
		Highway No.	STEE	TO	Distance	Km		
1	ITS1-2LM-1_1	11	1	1	679	0.679	59.4391	24.9116
2	ITS1-2LM-1_2	11	1	1	637	0.637	59.4395	24.9117
3	ITS1-2LM-2_2	11	1	2	414	3.280	59.4168	24.9201
4	ITS1-2LM-3_1	11	1	2	2,282	5.148	59.4001	24.9158
5	ITS1-2LM-3_2	11	1	2	2,301	5.167	59.4001	24.9170
6	ITS1-2LM-4_1	11	1	3	2,129	8.207	59.3738	24.9110
7	ITS1-2LM-4_2	11	1	3	2,126	8.204	59.3737	24.9116
8	ITS1-2LM-5_1	11	1	3	2,552	8.630	59.3705	24.9074
9	ITS1-2LM-6_2	11	2	4	244	9.947	59.3604	24.8958
10	ITS1-2LM-7_1	11	1	4	1,899	11.602	59.3514	24.8748
11	ITS1-2LM-8_2	11	2	4	3,556	13.259	59.3435	24.8530
12	ITS1-2LM-9_1	11	1	5	437	15.405	59.3359	24.8161
13	ITS1-2LM-9_2	11	2	4	5,229	14.932	59.3365	24.8270
14	ITS1-2LM-10_1	11	1	5	3,551	18.519	59.3231	24.7676
15	ITS1-2LM-10_2	11	2	5	4,017	18.985	59.3208	24.7638
16	ITS1-2LM-11_1	11	1	6	1,089	21.322	59.3120	24.7254
17	ITS1-2LM-11_2	11	1	6	1,117	21.350	59.3118	24.7249
18	ITS1-2LM-12_1	11	1	7	168	24.494	59.3164	24.6710
19	ITS1-2LM-12_2	11	1	6	3,685	23.918	59.3143	24.6803
20	ITS1-2LM-13_1	11	1	7	2,345	26.671	59.3152	24.6329
21	ITS1-2LM-13_2	11	1	7	1,560	25.886	59.3155	24.6467
22	ITS1-2LM-14_2	11	1	7	4,996	29.322	59.3120	24.5869
23	ITS1-2LM-15_1	11	1	8	1,514	31.082	59.3118	24.5569
24	ITS1-2LM-16_2	11	1	8	2,191	31.759	59.3118	24.5453
25	ITS1-2LM-17_1	11	1	9	958	34.333	59.3174	24.5017
26	ITS1-2LM-17_2	11	1	9	1,225	34.600	59.3164	24.4972
27	ITS1-2LM-18_1	11	1	9	3,289	36.664	59.3124	24.4619
28	ITS1-2LM-18_2	11	1	9	3,902	37.277	59.3104	24.4518

Since automatic incident detection systems (AIDs) are relatively expensive, the first approach is to install these in each sector of Tallinn ring road (in accordance with the completion of road sections). It would be reasonable to monitor the situation on the ring road for a few years in advance (if and where the risk for traffic accidents is highest) and only then make a decision on the necessity of installation.

Figure 9.7. Locations of AIDs

Table 9.5. Address data regarding locations of new AIDs

Order No.	Name	Road address					LAT	LON
		Highway No.	STEE	TO	Distance	Km		
1	ITS2-AID-1	11	1	3	3,418	9.496	59.3636	24.9005
2	ITS2-AID-2	11	1	4	2,718	12.421	59.3472	24.8629
3	ITS2-AID-3	11	1	7	3,630	27.956	59.3132	24.6107
4	ITS2-AID-4	11	1	8	3,538	33.106	59.3156	24.5229

In order to inform of events (traffic disruption) and improving traffic flow, it is reasonable to install VMSs (cf. Figure 9.3 and Table 9.6) on the ring road as well as intersecting radial roads (i.e. highway No. 1, highway No. 2, highway No. 15, highway No. 4 and highway No. 8), which would enable drivers who are travelling on these roads to choose an alternative route instead of Tallinn ring road in advance in case that an incident has occurred there.

Figure 9.8. Locations of large boards (VMS)

Table 9.6. Address data of the locations of large boards (VMS)

Order No.	Name	Road address					LAT	LON
		Highway No.	STEE	TO	Distance	Km		
1	ITS2-ST-1	1	1	1	8,339	8.339	59.4376	24.8819
2	ITS2-ST-2	1	2	2	3,028	12.268	59.4488	24.9477
3	ITS2-ST-3	11	1	3	353	6.431	59.3888	24.9185
4	ITS2-ST-4	11	1	3	414	6.492	59.3883	24.9214
5	ITS2-ST-5	2	1	2	4,745	10.250	59.3670	24.8597
6	ITS2-ST-6	2	2	3	2,258	14.321	59.3387	24.9050
7	ITS2-ST-7	15	1	1	4,410	4.410	59.3608	24.7658
8	ITS2-ST-8	15	1	4	2,505	11.508	59.3031	24.7440
9	ITS2-ST-9	11	1	7	383	24.709	59.3171	24.6673
10	ITS2-ST-10	11	1	7	4,107	28.433	59.3119	24.6025
11	ITS2-ST-11	4	1	2	3,384	16.424	59.3271	24.5944
12	ITS2-ST-12	4	2	3	2,335	20.653	59.2960	24.5522
13	ITS2-ST-13	11	1	8	3,748	33.316	59.3155	24.5190
14	ITS2-ST-14	8	1	3	4,577	23.022	59.3243	24.4626
15	ITS2-ST-15	8	1	4	1,320	26.445	59.3157	24.4165

Locations of ITS solutions can be viewed in more detail via the Google Maps application (link sent to the contracting entity).

9.4. Stepwise Realisation Plan for ITS Solutions

In the context of the first approach, it would be practical to install ITS equipment on road sections where traffic volume is the highest and there are no bypass options.

Stepwise establishment of the ITS system can be carried out in two ways:

- by sections of Tallinn ring road;
- by the level (notification level) of ITS equipment.

Traffic volume and risk level must, first and foremost, be considered when establishing the ITS system by sections of highway No. 11 Tallinn ring road. According to consultants, it would be reasonable to begin with 2+2 lanes and multi-level road sections that have already been completed, whereas the recommendation for other sections is to include the establishment of the ITS system into the technical specifications of the plan.

Priority sections of Tallinn ring road (ranking prepared by consultants) are:

1. Karla interchange – Luige interchange (incl. an especially important section of highway No. 2 – Vaela interchange where weather conditions can change very fast);
2. Väo interchange–Karla interchange;
3. Juuliku interchange – Saue;
4. Luige interchange – Juuliku interchange (included in the ITS project);
5. Saue–Keila (included in the ITS project).

There are two principal stages for realising the system by the level (notification level) of ITS equipment:

- Stage I – informing of possible risks and reducing situations where one accident causes another on Tallinn ring road – road weather information stations, AID and VWS+VSL. Primarily affects traffic flow and reduces accident costs.
- Stage II – stage I + rerouting notifications on Tallinn ring road and radial roads (highway No. 1, highway No. 2, highway No. 15, highway No.4, highway No. 8) – option to reroute traffic further from the place of the accident, making it possible to lose less time.

The two methods of establishing the ITS system may also be combined (section and ITS level).

10. COST-EFFECTIVENESS ANALYSIS

The objective of the cost-effectiveness analysis is to calculate the ratio of costs and benefits regarding investments made and find the economically best and cheapest solution from the society's point of view for implementing ITS solutions on Tallinn ring road. The start year of all scenarios addressed in the context of the cost-effectiveness analysis is 2019 and the end year is 2034. Therefore, the period of analysis is 15 years which can also be regarded as the life span of ITS equipment. The residual value of the investment by the end of the analysis period is set at 10%. The discount rate used in the cost-effectiveness analysis[12] is 4.0%.

Due to the terms of reference, the need for changing technical conditions of highways (e.g. 2+2 cross-section instead 1+1 cross-section of SEC_10) and the need for implementing road surface repair methods have not been addressed in the cost-effectiveness analysis.

Compliance with efficiency criteria is evaluated by comparing the amount of savings accrued by the society as a result of the realisation of investments with the expenditure. Therefore, the cost-effectiveness analysis criteria includes the following requirements:

- net present value, NPV > 0
- benefit/cost ratio, B/C ratio > 1.0;
- economic internal rate of return, EIRR > 4.0%.

A rating scale for the benefit/cost ratio has been proposed in the ROSEBUD WP5 (2005)[13] analysis for evaluating the results of the cost-effectiveness analysis. This benefit/cost ratio rating scale has been developed with the intention of simplifying the evaluation of economic efficiency of traffic safety improvement measures. Limit values and corresponding grades of the benefit/cost ratio have been set out in Table 10.1.

Table 10.1. Grades of benefit/cost ratio and corresponding limit values (ROSEBUD WP5, 2005)

Grade	Benefit/cost ratio (B/C ratio)
Poor	< 1.0
Acceptable	1.0…3.0
Very good	> 3.0

10.1. Description of the Methodology of the Cost-effectiveness Analysis

The methodology for the cost-effectiveness analysis carried out in this survey has been coordinated with the contracting entity and similar methodology has also been previously

[12] Commission delegated Regulation (EU) No 480/2014, Article 19 Discounting of cash flows http://eur-lex.europa.eu/legal-content/ET/TXT/HTML/?uri=CELEX:32014R0480&from=ET
[13] ROSEBUD, Deliverable WP5, Recommendations, Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making. 2005

used in other projects and surveys carried out by the Road Administration in regard to evaluating traffic safety and traffic flow.[14] [15]

Different cost-effectiveness analyses on maximum speed permitted are based on the possibilities of HDM-4 (Highway Development and Management Tool) software. This software is used in various countries in regard to making decisions and plans concerning road and street management and evaluating investment alternatives. The concept of the analytical framework of HDM-4 is based on analysing the lifecycle of various highways and various related assets. The concept is implemented by modelling the deterioration of road surfaces, effects of repair works, fees of road users, effects of the society and environment throughout the lifecycle of a highway, which is generally estimated at 15–40 years in similar analyses.

The analytical concept of HDM-4 has been developed in order to compare the cost and benefits of various investment opportunities and conducting an economic analysis. It helps to assess the cost and benefits of various investment alternatives across the analysed years over the analysis period determined by the user of the software. All costs incurred over the reference period shall be discounted to the determined start year. To compare different alternatives, it is necessary to be familiar with detailed descriptions of investment programmes, design norms and various maintenance opportunities and solutions, as well as with the cost of investments and various costs (maintenance, repair works, etc.) related to the activities concerning these investments, estimated traffic capacity and environmental conditions during the exploitation period.

Economic benefits received by society from the investments is determined by comparing the costs and benefits regarding the realisation of these investments with the costs and benefits of the so-called baseline option (option 0). A baseline option (option 0) is a situation where the project is not carried out or carried out as little as possible in order to maintain the current situation. As a rule, the situation referred to only involves the implementation of necessary works and costs.

The efficiency of road-related investments is significantly affected by the overall condition of the surface of roads as well as the number and composition of vehicles travelling on those roads. In the long-term, the condition of road surface and its changing is, in turn, directly dependent on maintenance and repair methods. The impact of the condition of road surfaces and level of road planning on road users is measured by the costs incurred by the road user and other external effects on the society and environment. Costs incurred by road users include maintenance costs of a vehicle (fuel, tyres, lubricants, spare parts, amortisation, etc.), travel time of passengers as well as goods, and cost of traffic accidents to the society (incl. loss of life, human injuries, damages to vehicles and roadside objects, etc.).

[14] Differentiation of maximum speed allowed on Estonian roads outside built-up areas, stage II; ERC Konsultatsiooni OÜ, 2014

[15] Survey on measuring the use of automatic traffic supervision , which is based on measuring average speed; ERC Konsultatsiooni OÜ, 2013

Effects on the society and environment can be expressed through exhaust gases emitted by vehicles, energy consumption, traffic noise and benefits that society receives by use of roads. Even though effects on society and environment are at times difficult to express, HDM-4 enables to implement them as so-called external factors.

10.2. Analysed Options

The cost-effectiveness analysis is carried out by comparing various options with the baseline option, i.e. with a situation where investments are not made (do nothing). It is, in some sense, theoretical, because something is generally always done in the event of problems, however, this is a globally used methodology and it must be followed.

Baseline alternative (OPT_0)

In the context of this survey, the baseline alternative represents a situation where the Tallinn ring road has been completed up until Kanama overpass as a 2+2 cross-section highway, while remaining a 1+1 cross-section highway from there on to Keila (intersection with national main road No. 8 Tallinn–Keila–Paldiski). During summertime (ca 6 months per year), permitted travel speed on the road sections of the ring road with 2+2 cross-section is generally 110 km/h and 90 km/h during wintertime. The same 90 km/h limit is also applicable all-year round on the road sections with 1+1 cross-section. There are no traffic schemes or traffic management solutions to be applied in the event of a traffic or other accident, in case of more serious accidents, traffic will basically stop at the location of the accident on Tallinn ring road until the consequences of the accident have been eliminated and the road is reopened for traffic. There is no notification system for informing road users.

Alternative option 1 (OPT_1)

Basically entails the continuation of the current situation, i.e. traffic schemes are implemented and traffic is managed in case of a traffic or other accident, but ITS solutions and dynamic traffic management solutions are nonexistent. This means that traffic will stop for a certain period after a traffic or other accident, as it will take some time for traffic schemes to be implemented, road users to be notified of possible bypass routes and for traffic to move smoothly again. General travel speed regime (summertime/wintertime) and frequency and number of traffic accident is similar to the baseline alternative.

Alternative option 2 (OPT_2)

Traffic schemes have been set in place for resolving traffic or other accidents in the event that they occur and in addition to this, traffic flow is managed and road users are warned via variable-message warning and speed limit signs (VWS+VSL), which have been installed on Tallinn ring road. Additional road weather information stations have been installed on Tallinn ring road for receiving operational information on the condition of the road surface and traffic counting stations have been installed on road sections in order to receive information on traffic flow. This means that in case of an accident, information regarding the accident and its possible location will reach road supervisors, maintenance providers as well as road users quicker than in OPT_1. Road users can therefore avoid the situation and will not necessarily drive to the traffic jam at the location of the accident, rerouting of traffic will be initiated quicker and operatively, because information regarding the accident will reach road managers and maintenance providers quicker. Arising from the use of variable-message speed limit signs, permitted speed limit can be changed according to actual road conditions, therefore the overall average travel speed is higher than in OPT_0 and OPT_1 (cf. Point 10.5). Due to the use of ITS equipment, the frequency and number of traffic accidents is also lower in this option than in OPT_0 and OPT_1 (cf. Table 10.6).

Alternative option 3 (OPT_3)

Conditions are similar to option 2 with the difference that in addition to variable-message warning and speed limit signs, Tallinn ring road and intersecting major roads have also been equipped with (VMS+VWS) variable-message traffic control devices. Road users are also additionally informed via other existing applications and information sources. In the event of an accident on Tallinn ring road, notification and behaviour of road users is similar to OPT_2, however, traffic accidents are somewhat less frequent, since various information on the condition of road surface, changing of weather conditions, traffic situation, etc. is shared with road users in a more operative manner and to a larger extent. General travel speed regime (summertime/wintertime) is similar to OPT_2.

10.3. Primary Data of the Cost-effectiveness Analysis

Conduct of the cost-effectiveness analysis requires the determination and collection of necessary primary data. The following includes descriptions on various primary data, calculation principles and primary sources of the data that has been used in the cost-effectiveness analysis conducted in the context of this survey. In case it is impossible to find a value in regard to certain data, an expert evaluation has been used as an alternative.

10.3.1. Traffic Accidents

Occurrence of traffic accidents on highways is, as a rule, random, yet there are a number of factors that increase the likelihood of accidents, i.e. certain measures can be taken to manage the occurrence of traffic accidents. On the basis of the prerequisite set out in the starting task of this survey, the analysis will consider the Tallinn ring road up to Kanama overpass as a completed highway with a 2+2 cross-section and as a main road with a 1+1 cross-section up to Keila thereafter.

Key figures on various types of traffic accidents that have occurred on Estonian roads have been set out in Table 10.2. This data is based on the data of the Road Register (1 September 2017) and is therefore, as a rule, characteristic of traffic accidents that involved human injuries.

Table 10.2. Key figures of traffic accidents on main roads with various cross-sections

Road Network	Key figures of traffic accidents per mileage of 100 million car kilometres		
	fatalities	injured persons	Number of TAs

Main roads 2+2 roads	1.06	9.41	20.4
Main roads 1+1 roads	2.37	21.34	28.6
Tallinn Ring Road	0.88	11.87	17.0

According to international surveys[16], around 7–11 traffic accidents, which involve human injuries, occur on highways with divided carriageways (2+2 cross-section) per mileage of 100 million car kilometres per year. The ratio of traffic accidents is lower on roads that have been constructed to a further extent.

Estonia has a relatively high (practically twice as high) frequency and number of traffic accidents on highways with a 2+2 cross-section, which is partly due to the relatively low level of construction of such highways (especially regarding older road sections). Same level intersections, U-turns, exits are allowed, traffic of pedestrians and vulnerable road users is not divided from the main road, etc.

Tallinn ring road will be constructed as a class I highway and the level of construction is significantly different from other highways with 2+2 cross-section that have been in exploitation for some time. According to consultants, it is not right or justified to utilise the traffic accident data of other older highways with 2+2 cross-section to describe the traffic accident level of the newly constructed Tallinn ring road. A clear downward trend can be seen on national roads in regard to the occurrence of traffic accidents.

Therefore, in this cost-effectiveness analysis, the traffic accident level of the newly constructed Tallinn ring road with a 2+2 cross-section is regarded at 9.0 traffic accidents per 100 million car kilometres per year on the basis of the value set out in international surveys. The Tallinn ring road that is to be constructed does not directly comply with the requirements of a motorway (TA level 7.0), however, its construction level is clearly of a higher level than a regular 2+2 highway (TA level 11.0).

Table 10.3. Road sections analysed and values of traffic accident levels in baseline alternative (OPT_0)

Order No.	**Road section**	**Length, km**	**Annual mileage, million km**	**Number of traffic accidents and human damages per year**		
				Accidents	**Injured persons**	**Fatalities**
1	Highway No. 11_SEC_1	3.700	17.15	1.54	0.15	0.02
2	Highway No. 11_SEC_2	1.143	5.30	0.48	0.05	0.01
3	Highway No. 11_SEC_3	3.574	17.35	1.56	0.16	0.02
4	Highway No. 11_SEC_4	2.983	13.27	1.19	0.12	0.02

[16] Elvik, R., Hoye, A., Vaa, T., Sorensen, M. The Handbook of road safety measures, second edition 2009

5	Highway No. 11_SEC_5	3.930	21.57	1.94	0.19	0.03
6	Highway No. 11_SEC_6	3.380	14.27	1.28	0.13	0.02
7	Highway No. 11_SEC_7	5.540	20.16	1.81	0.18	0.03
8	Highway No. 11_SEC_8	1.950	7.46	0.67	0.07	0.01
9	Highway No. 11_SEC_9	6.190	22.81	2.05	0.21	0.03
10	Highway No. 11_SEC_10	5.770	20.13	3.62	0.36	0.05
	TOTAL:	**38.160**	**159.460**	**16.16**	**1.62**	**0.24**

10.3.2. Impact of Variable-message Signs on Traffic Accidents

The primary objective of VMSs is to warn road users of various exceptional situations, as well as provide feedback to road users on their behaviour.

The impact of variable-message signs (VMSs) has been addressed in various international surveys. A research published in 2009[17] includes an in-depth overview of various surveys and Table 10.4 includes a summary of this survey.

Table 10.4. Impact of variable-message signs (VMSs) on traffic accidents

Type of VMS	Type of TA affected	Type of traffic accident affected	Percentage of change in the number of TAs	
			Estimated impact	**Limits of 95% probability**
Warning regarding a traffic accident	TAs involving human damages	Traffic accidents on motorways	-44%	-59%...-22%
Warning about fog	Undetermined TAs	Accidents in the fog	-84%	-93%...-63%
Changeable speed limits	TAs involving human damages	TAs in summer TAs in winter	-13% -2%	– –
Warning regarding a traffic jam	TAs involving human damages TAs involving property damages	Rear-end collision Rear-end collision	-16% +16	-26%...-4% +1%...+34%
Travel speed boards	Undetermined TAs	All TAs	-46%	-62%...-24%

At the same time, it must be acknowledged that these surveys are quite old and the development that technology has undergone in the mean time has decreased the cost of variable-message signs on the one hand and expanded the uses of such signs on the other hand. The operability and speed of information exchange has significantly changed as well in the last 10 years.

[17] Elvik, R., Hoye, A., Vaa, T., Sorensen, M. The Handbook of road safety measures, second edition 2009

Arising from the aforementioned data and estimates of consultants, the impact of variable-message signs on traffic accidents in comparison with OPT_0 is regarded as follows in this survey:

- no changes in the number of traffic accidents in regard to option 1 (OPT_1)
- implementation of option 2 (OPT_2) decreases the number of traffic accidents by 40%
- implementation of option 3 (OPT_3) decreases the number of traffic accidents by 60%

10.3.3. Cost of Traffic Accidents

Conclusions set out in the research carried out by the Department of Logistics of Tallinn University of Technology[18] have been used as a basis during the assessment of the cost of traffic accidents to the society. The costs of traffic accidents by type, which have been used in the cost-effectiveness analysis, have been set out in Table 10.5.

Table 10.5. Damages arising from traffic accidents in the cost-effectiveness analysis

Indicator	Unit of measurement	Unit cost of traffic accident (2016 forecast), euro	Unit cost of traffic accident in HDM-4 software, euro
Fatality in traffic accident	euros/fatality	2,052,572	2,052,572
Person left disabled in traffic accident	euros/disabled person	698,160	60,351*
Person injured in traffic accident	euros/injured person	26,782	
Property damage in traffic accident	euros/accident	9,883	9,883
Moderate traffic accident	euros/accident	45,850	45,850

* - HDM-4 software does not have a directly available option for entering the costs to society regarding persons left disabled in a traffic accident and the number of persons left disabled in a traffic accident is also not registered in the Road Register. Therefore, damages of disabled and injured persons in traffic accidents is merged on the basis of the principle that the damages of disabled persons constitute 5% and the damages of injured persons constitute 95% of the damages of injured persons in traffic accidents.

10.3.4. Traffic Accident Scenarios

Eliminating the consequences of accidents with different levels of severity, i.e. the period of impact to other road users, is different. There are many possibilities regarding how and for how long an accident may disrupt traffic and it is probably not possible to model all of them. The situation has been simplified in the context of this analysis and accidents have been divided into three groups on the basis of the level of severity (taking into consideration their impact on other road users, i.e. how much the accident disrupts traffic):

- very serious traffic or other accident, due to which Tallinn ring road is closed for traffic in both directions. The probability of such accidents is considered 1% of all traffic accidents;
- serious traffic or other accident, due to which one direction of Tallinn ring road is closed for traffic. The probability of such accidents is considered 10% of all traffic accidents;
- moderately severe traffic or other accident, due to which one lane in one direction of Tallinn ring road is closed for traffic (the other is open). The probability of such accidents is considered 89% of all traffic accidents;

[18] Koppel, O., Liiklusõnnetustest ühiskonnale põhjustatud kahjude määramise metoodika täiustamine, kahjude suuruse hindamine ja prognoosimine. Research 12054. 2012

The impact of other types of traffic accidents has not been considered in the cost-effectiveness analysis, as it has relatively no impact on time expenditure of other road users.

Table 10.6 sets out the estimated number of accidents across analysed sections of Tallinn ring road on the basis of their level of severity.

Table 10.6. Number of traffic and other accidents for alternatives analysed on the basis of their level of severity

Order No.	Road section	Length, km	Analysis alternative	Estimated number of accidents per year, qty		
				Very serious	Serious	Moderate
1	Highway No. 11_SEC_1	3.700	OPT_1	0.015	0.154	1.374
			OPT_2	0.009	0.086	0.769
			OPT_3	0.006	0.062	0.549
2	Highway No. 11_SEC_2	1.143	OPT_1	0.005	0.048	0.424
			OPT_2	0.003	0.027	0.238
			OPT_3	0.002	0.019	0.170
3	Highway No. 11_SEC_3	3.574	OPT_1	0.016	0.156	1.390
			OPT_2	0.009	0.087	0.778
			OPT_3	0.006	0.062	0.556
4	Highway No. 11_SEC_4	2.983	OPT_1	0.012	0.119	1.063
			OPT_2	0.007	0.067	0.595
			OPT_3	0.005	0.048	0.425
5	Highway No. 11_SEC_5	3.930	OPT_1	0.019	0.194	1.728
			OPT_2	0.011	0.109	0.967
			OPT_3	0.008	0.078	0.691
6	Highway No. 11_SEC_6	3.380	OPT_1	0.013	0.128	1.143
			OPT_2	0.007	0.072	0.640
			OPT_3	0.005	0.051	0.457
7	Highway No. 11_SEC_7	5.540	OPT_1	0.018	0.181	1.615
			OPT_2	0.010	0.102	0.904
			OPT_3	0.007	0.073	0.646
8	Highway No. 11_SEC_8	1.950	OPT_1	0.007	0.067	0.598
			OPT_2	0.004	0.038	0.335
			OPT_3	0.003	0.027	0.239
9	Highway No. 11_SEC_9	6.190	OPT_1	0.021	0.205	1.827
			OPT_2	0.011	0.115	1.023
			OPT_3	0.008	0.082	0.731
10	Highway No. 11_SEC_10	5.770	OPT_1	0.036	0.362	3.225
			OPT_2	0.020	0.203	1.806
			OPT_3	0.014	0.145	1.290
TOTAL:		**38.160**	**OPT_1**	**0.16**	**1.62**	**14.39**
			OPT_2	**0.09**	**0.91**	**8.06**
			OPT_3	**0.06**	**0.65**	**5.75**

10.4. Time expenditure

10.4.1. Travel Time and Costs of Vehicles

Baseline data on vehicles and travel time included in the cost-effectiveness analysis are based on the dataset brought out in the research by the Department of Roads of the Tallinn University of Technology[19]. This data has been updated in subsequent years in accordance with economic changes. The latest correction and updating of baseline data was carried out in 2011 in regard to the conduct of the strategic analysis of Estonian national roads[20]. Costs related to vehicles have a relatively small impact on the results of the cost-effectiveness analysis, since alternatives compared affect vehicle-related costs in a rather similar manner. However, costs related to travel time differ in alternatives analysed, because the average travel speed is different.

Calculations concerning time expenditure of road users is based on the average gross wage in Estonia. According to the data of Statistics Estonia[21], the average gross wage in Estonia in 2016 was 1,146 euros per month. Provided that there are 160 working hours in one month, the hourly rate is 7.16 euros.

The time expenditure methodology (used in Europe)[22] provides that time expenditure in case of work-related travels is the sum of 1.3 times the salary rate and the cost of the employer (33.5%). In case of commutes to work and back (estimated at a third of all travels), the cost of time is considered 35% of an average gross wage and 20% of an average gross wage in the case of travels during leisure time. On the basis of a research completed by the Department of Roads of the Tallinn University of Technology in 2003[23], 45.8% of travels on highways (incl. all vehicle types) are related to work, whereas leisure time travels constitute 54.2%. On the basis of the calculation method described, the primary parameters of time expenditure used in this analysis are as follows:

- average cost of working time (with time expenditure of the commute) 5.02 euros/h;
- average cost of non-working time 1.43 euros/h;
- delay of goods and cargo 0.26 euros/h.

The data on the number of passengers in a vehicle and the objective of the travel used in the analysis are based on the data set out in the research completed by the Department of

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[19] Koppel, M., HDM-4 evitamiseks vajalike liikluskulude arvutamise lähteandmete panga koostamine. Lõpparuanne. Department of Roads at Tallinn University of Technology 2003
[20] Kaal, T., Truu, M., Jentson, M., Kaal, L., Jusi, P., Riigimaanteede strateegiline analüüs 2011 aastal. Lõpparuanne. AS Teede Tehnokeskus, 2011
[21] www.stat.ee
[22] „Tieliikenteen ajokustannusten yksikköarvot 2010“, Liikennevirasto, Helsinki 2010
[23] “HDM-4 evitamiseks vajalike liikluskulude arvutamise lähteandmete panga koostamine. Lõpparuanne”, Department of Roads of Tallinn University of Technology, Tallinn 2003

Roads of Tallinn University of technology in 2003[24]. This data has been updated in subsequent years in accordance with economic changes.

Table 10.7. Division of the number of passengers in a vehicle and the objective of travels

Type of data	Type of vehicle*		
	PCV	TB	RT
Passengers per vehicle in the city of Tallinn	1.4	20.0	1.2
Passengers per vehicle on Tallinn ring road	1.5	4.0	1.2
Proportion of travels regarding the commute to work	25%	80%	100%
Proportion of leisure time travels	75%	20%	0%

* - type of vehicle in accordance with the types set out in the Road Register

10.4.2. Increased Time Expenditure due to an Accident

Traffic obstructions arising from an accident create an additional time expenditure for other road users, the size of which is largely dependent on the severity level of the accident, how fast alternative traffic schemes are implemented and how operatively additional notification of road users is carried out. In order to analyse accidents that occur on Tallinn ring road, an additional time expenditure depending on the severity of the accident has been calculated for each alternative and it has been compared with the additional time expenditure of the baseline alternative. Since traffic volume, i.e. number of road users, changes annually, the additional time expenditure arising from an accident also differs every year.

Table 10.8. Additional time expenditure arising from an accident and its decline compared to the baseline alternative

Order No.	Road section	Length, km	Analysis alternative	Cost of additional time arising from an accident, euro		The decline of additional time expenditure arising from an accident compared to the baseline alternative, euro	
				In 2019	In 2034	In 2019	In 2034
1	Highway No. 11 SEC_1	3.700	OPT_0	2,947	9,131	–	–
			OPT_1	2,573	8,572	374	560
			OPT_2	1,224	4,458	1,724	4,674
			OPT_3	776	3,027	2,172	6,105
2	Highway No. 11 SEC_2	1.143	OPT_0	1,362	3,208	–	–
			OPT_1	1,239	3,031	122	177
			OPT_2	652	1,648	710	1,561
			OPT_3	450	1,161	912	2,047
3	Highway	3.574	OPT_0	2,694	8,862	–	–

[24] Koppel, M., HDM-4 evitamiseks vajalike liikluskulude arvutamise lähteandmete panga koostamine. Lõpparuanne. Department of Roads at Tallinn University of Technology 2003

Order No.	Road section	Length, km	Analysis alternative	Cost of additional time arising from an accident, euro		The decline of additional time expenditure arising from an accident compared to the baseline alternative, euro	
				In 2019	In 2034	In 2019	In 2034
	No. 11 SEC_3		OPT_1	2,282	8,293	412	570
			OPT_2	1,043	4,308	1,651	4,554
			OPT_3	639	2,925	2,055	5,938
4	Highway No. 11 SEC_4	2.983	OPT_0	3,235	8,212	–	–
			OPT_1	3,083	7,847	152	365
			OPT_2	1,663	4,187	1,572	4,026
			OPT_3	1,157	2,928	2,078	5,285
5	Highway No. 11 SEC_5	3.930	OPT_0	12,999	53,611	–	–
			OPT_1	12,850	53,340	149	272
			OPT_2	6,885	29,278	6,114	24,333
			OPT_3	4,748	20,723	8,251	32,888
6	Highway No. 11 SEC_6	3.380	OPT_0	2,959	13,013	–	–
			OPT_1	2,629	12,619	330	394
			OPT_2	1,239	6,677	1,720	6,336
			OPT_3	774	4,572	2,185	8,441
7	Highway No. 11 SEC_7	5.540	OPT_0	4,963	15,490	–	–
			OPT_1	4,780	15,224	183	266
			OPT_2	2,391	8,017	2,572	7,473
			OPT_3	1,555	5,450	3,408	10,040
8	Highway No. 11 SEC_8	1.950	OPT_0	1,295	7,464	–	–
			OPT_1	1,144	7,232	151	232
			OPT_2	575	3,931	720	3,533
			OPT_3	384	2,756	911	4,708
9	Highway No. 11 SEC_9	6.190	OPT_0	2,684	11,386	–	–
			OPT_1	2,290	10,863	394	523
			OPT_2	1,023	5,665	1,661	5,722
			OPT_3	667	3,940	2,017	7,447
10	Highway No. 11 SEC_10	5.770	OPT_0	6,685	16,479	–	–
			OPT_1	6,212	15,816	473	663
			OPT_2	3,039	8,231	3,647	8,248
			OPT_3	2,055	5,715	4,630	10,764
	TOTAL:	**38.160**	**OPT_0**	**41,823**	**146,858**	–	–
			OPT_1	**39,083**	**142,837**	**2,740**	**4,021**
			OPT_2	**19,734**	**76,399**	**22,089**	**70,459**
			OPT_3	**13,206**	**53,196**	**28,617**	**93,662**

10.5. Travel Speed

Changes in travel speed have a direct impact on the costs of road users. With the increase in speed, operational costs of vehicles increase, whereas time expenditure decreases. The permitted speed limit regimes on Tallinn ring road concerning the options analysed are set out in Table 10.9.

It has been estimated that the current situation will be maintained in alternative options OPT_0 and OPT_1, under which the permitted speed limit is generally at 90 km/h for one half of the year and 110 km/h for the other half. In case of alternative options OPT_2 and OPT_3, the overall permitted speed limit is somewhat higher, since variable-message speed limit signs have been implemented, allowing to also permit a higher speed limit during wintertime if the weather conditions are favourable and do not impact the level of traffic safety. The exception is the road section from Saue entrance up to Keila where the differences in speed limits in regard to various alternatives are less significant on the road section with a 1+1 cross-section.

Table 10.9. Average annual permitted speed limit on Tallinn ring road for alternatives analysed

Road section	Average annual permitted speed limit for alternative analysed, km/h			
	OPT_0	OPT_1	OPT_2	OPT_3
Highway No. 11 SEC_1 – Highway No. 11 SEC_9	95	95	105	105
Highway No. 11 SEC_10	85	85	90	90

Actual travel speed, which HDM-4 takes into account in the analysis, is different from these numbers and dependent on the type of vehicle, width of the carriageway, traffic density on a certain road section, etc. Figure 10.1 includes an example of travel speeds of various types of vehicles on road section SEC_1 in the case of alternative options OPT_0 and OPT_2.

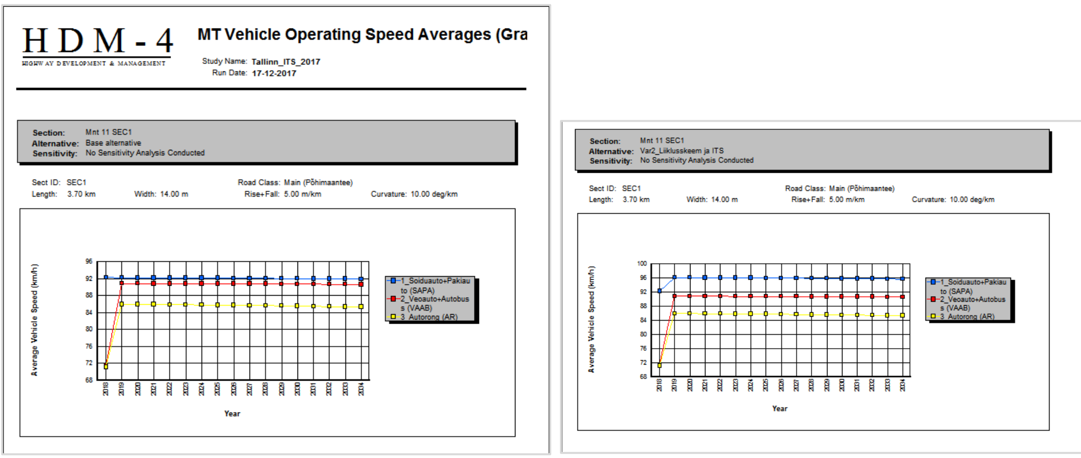

Figure 10.1. Travel speeds of different types of vehicles on road section SEC_1 in case of alternative options OPT_0 and OPT_2

10.6. Exhaust Gases

The movement of vehicles generates exhaust gas which, in turn, gives rise to various expenditure and health damages to the society, damages to building materials, damages to agriculture and the natural environment in general. Health-related costs are considered as the largest expenditure category.

Changes in the travel speed of vehicles affect the amount of exhaust gases emitted into the air by vehicles. Increase in the average travel speed also increases the amount of exhaust gases and vice versa. The vehicle description module of HDM-4 software also includes parameters related to exhaust gases and one of the outputs of the software is changes in the amount of exhaust gas emitted by vehicles. Therefore, changes in the amount and cost of exhaust gases emitted by vehicles have been included in the cost-effectiveness analysis.

Unit costs of different components of exhaust gases are based on the results brought out in the IMPACT (2008) survey. Data set out in the survey report by Jüssi et al. (2008)[25] has been taken into account as well. Table 10.10 has set out different components of exhaust gases included in this survey and their unit costs.

Table 10.10. Components of exhaust gases emitted by vehicles and their unit costs calculated in the HDM-4 software.

Exhaust gas component	Chemical symbol	Unit cost, euro/t	Comments
Hydrocarbon	HC	543	
Carbon monoxide	CO	–	According to literature, emitted quantity is considered so low that it is not calculated
Nitrogen oxides	NO_X	1,956	
Sulphur dioxide	SO_2	1,086	
Carbon dioxide	CO_2	11	
Particulates	PM	4,129	
Tin	Pb	–	The unit cost of this component was unavailable in literature

Travel speed is of similar character in analysed alternatives OPT_0 and OPT_1 as well as in OPT_2 and OPT_3, therefore the amount of exhaust gas emitted is also similar for these alternatives. The costs generated by exhaust gas and their differences in alternatives compared has been set out in Table 10.11. Since travel speed is higher in analysed alternatives OPT_2 and OPT_3, the costs arising from exhaust gases of vehicles in these alternatives are, in conclusion, approximately 1.17 million euros higher during the period analysed. Variable-message signs and other ITS solutions do principally make traffic smoother and reduce the risk of traffic jams, however, current and estimated traffic volume on Tallinn ring road is so low and, at the same time, the cross-section of the road is so wide that the risk of traffic jams is virtually non-existent (according to models of HDM-4). This means that traffic flow is smooth in every alternative analysed and changes made do not affect the amount of exhaust gas.

Table 10.11. Total cost of exhaust gases emitted by vehicles during the analysis period (2018–2034) calculated in the HDM-4 software

Road section	Total costs arising from exhaust gases during analysis period, million euros	Differences in costs arising from exhaust gases,

[25] Jüssi, M., Anspal, S., Kallaste, E., Transpordi väliskulude hindamine: hindamismetoodika ja sisendandmete kaardistus. 2008

	OPT_0 and OPT_1	OPT_2 and OPT_3	thousand euros
Highway No. 11 SEC_1	7.05	7.18	130.1
Highway No. 11 SEC_2	2.18	2.22	40.1
Highway No. 11 SEC_3	6.93	7.06	133.6
Highway No. 11 SEC_4	5.64	5.74	99.4
Highway No. 11 SEC_5	9.25	9.41	160.1
Highway No. 11 SEC_6	6.53	6.63	102.7
Highway No. 11 SEC_7	10.10	10.24	138.5
Highway No. 11 SEC_8	3.77	3.82	50.7
Highway No. 11 SEC_9	9.61	9.78	171.7
Highway No. 11 SEC_10	5.83	5.97	142.5
TOTAL	**66.88**	**68.05**	**1,169.4**

10.7. Cost of ITS Equipment

A substantial component of the cost of the cost-effectiveness analysis is the cost of ITS equipment as well as the cost of its instalment, maintenance and operation. The data used in the analysis regarding said costs is based on information received from the Road Administration and suppliers of such equipment. The cost of equipment has been generalised in this survey, since specific cost of equipment as well as the cost of maintenance shall be determined during public procurements.

Unit costs of ITS equipment and its maintenance used in the cost-effectiveness analysis have been set out in Table 10.12.

Table 10.12. Unit cost of ITS equipment and its cost in the cost-effectiveness analysis

Type of ITS equipment	Cost of equipment* along with instalment costs, euro	Annual maintenance and operation cost of the equipment**, euros per year	Need for ITS equipment, qty		Cost of ITS equipment, euro	
			OPT_2	OPT_3	OPT_2	OPT_3
Traffic camera, surveillance	6,000	300	11	11	66,000	66,000
Traffic camera, automatic incident detection station (AID)	60,000	3,000	–	4	–	240,000
Variable-message warning and speed limit sign (VWS+VSL)	12,000	600	56	56	672,000	672,000
Variable-message sign (VMS)	45,000	2,250	–	15	–	675,000
Road traffic information station, full set	25,000	1,250	4	4	100,000	100,000
Traffic counting station	7,000	350	2	2	14,000	14,000
TOTAL COST OF ITS EQUIPMENT:					**852,000**	**1,767,000**
OTHER COSTS (design, unexpected, etc.) 20%:					**170,400**	**353,400**
TOTAL INVESTMENT:					**1,022,400**	**2,120,400**
INVESTMENT WITH VAT:					**1,226,880**	**2,544,480**
ANNUAL MAINTENANCE COST OF ITS EQUIPMENT (along with other costs) without VAT:					**53,250**	**110,438**
ANNUAL MAINTENANCE COST OF ITS EQUIPMENT (along with other costs) with VAT:					**63,900**	**132,525**

* the cost displayed is without VAT and is an estimate, the exact price of the equipment will be determined as a result of a public procurement and can therefore differ from figures cited herein

** the annual maintenance cost is regarded at 5.0% of the cost of the equipment

10.8. Results of the Cost-effectiveness Analysis

The objective of the cost-effectiveness analysis is to compare alternatives analysed with the current situation and determine the economic impact of investments to be made on society in order to find the most cost-effective option. Compliance with efficiency criteria is evaluated by comparing the impact of ITS solutions on the traffic safety and traffic flow on Tallinn ring road and the amount of savings accrued by society as a result of this with the expenditure. This cost-effectiveness analysis consists of the comparison of three alternative scenarios with the baseline alternative. HDM-4 output reports of cost-effectiveness analyses have been set out in **Annex 4**.

The analysed options have undergone sensitivity analysis with the aim of monitoring the impact of input variables on the socio-economic profitability of the alternatives. The selection of variables for the analysis was based on the results of the specific cost-effectiveness analysis and the experience of consultants and the analysis includes the following scenarios:

- **Scenario 1** – changes in investment costs are relatively normal and therefore it is important to analyse its impact on the results of the cost-effectiveness analysis. This analysis has addressed a possibility where the investment made becomes 50% more expensive;
- **Scenario 2** – the forecast of the change in traffic volume is an important input parameter in the cost-effectiveness analysis, however, it is difficult to predict. This analysis has addressed a possibility where the increase of traffic volume is 40% lower than expected;
- **Scenario 3** – changes in traffic safety have a significant impact on the end-results of the cost-effectiveness analysis, however, it is difficult to predict since there is not enough statistics on the topic and relevant models have not yet been developed. This analysis has addressed a possibility where the benefit from the decrease of traffic accidents is 30% lower than expected.

The summary of the results of analysed alternatives in the cost-effectiveness and sensitivity analyses are set out in Table 10.13. The following can be concluded from the results of the analyses conducted:

- implementation of both analysed alternatives OPT_2 and OPT_3 on Tallinn ring road is economically beneficial. OPT_2 displays a better cost/benefit ratio (2.8) of the alternatives analysed, difference with OPT_3 is remarkable (cost/benefit ratio 2.0);
- the number of traffic accidents and its change in the period analysed has the greatest, i.e. the most significant, impact on the results of different alternatives in the cost-effectiveness analysis. The result of analysed alternative OPT_2 will turn negative in case the benefit from the decrease of traffic accidents decreases over 55%. The result of analysed alternative OPT_3 will turn negative in case the benefit from the decrease of traffic accidents decreases over 47%;
- appreciation of investments has a far less significant (moderate) impact on the results of the analysis, in the case that investment costs increase by 2.5 times (HDM-

4 software does not permit to analyse a greater increase), the result of both analysed alternatives OPT_2 and OPT_3 will still remain positive, i.e. benefit/cost ratio will remain over 1.0;

- change in traffic volume has little impact on the results of the analysis. It would have virtually no impact on the results if the estimated change in traffic volume were to be smaller than predicted, even in case there is no growth in traffic (growth is 0% over analysis period), the benefit/cost ratio of both analysed alternatives OPT_2 and OPT_3 would still remain over 1.0.

Table 10.13. Results of alternatives analysed in cost-effectiveness and sensitivity analyses

Alternative analysed and its description	Analysis period, years	present value, million euros						Total net present value of costs (NPV of costs), million euros	Total net present value of benefits (NPV of benefits), million euros	Total net present value (NPV), million euros	Economic internal rate of return (EIRR), %	Benefit/cost ratio	Benefit/cost grade (ROSEBUD WP5, 2005)
		ITS equipment		Benefit/cost of vehicles and road users									
		Investment	Maintenance costs	Road user	Travel time	Traffic accidents	Time of TA and exhaust gases*						
BASELINE SCENARIO													
OPT_1 – only traffic schemes are used	15	0.04	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	3.7%	1.00	Acceptable
OPT_2 – use of ITS equipment on a smaller scale	15	0.97	0.62	-3.88	3.35	5.35	-0.30	1.59	4.52	2.93	26.0%	2.84	
OPT_3 – full use of ITS equipment	15	2.01	1.29	-3.88	3.35	7.45	-0.12	3.30	6.80	3.50	18.2%	2.06	
SCENARIO 1 IN SENSITIVITY ANALYSIS – appreciation of investment costs by 50%													
OPT_1 – only traffic schemes are used	15	0.06	0.00	0.00	0.00	0.00	0.04	0.06	0.04	-0.02	-0.6%	0.67	Poor
OPT_2 – use of ITS equipment on a smaller scale	15	1.45	0.62	-3.88	3.35	5.35	-0.30	2.07	4.52	2.45	17.7%	2.18	Acceptable
OPT_3 – full use of ITS equipment	15	3.01	1.29	-3.88	3.35	7.45	-0.12	4.30	6.80	2.50	11.6%	1.58	
SCENARIO 2 IN SENSITIVITY ANALYSIS – growth after traffic forecast is 40% lower than expected													
OPT_1 – only traffic schemes are used	15	0.04	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	3.7%	1.00	Acceptable
OPT_2 – use of ITS equipment on a smaller scale	15	0.97	0.62	-3.50	3.00	4.83	-0.30	1.59	4.03	2.44	23.8%	2.53	
OPT_3 – full use of ITS equipment	15	2.01	1.29	-3.50	3.00	6.73	-0.12	3.30	6.11	2.81	16.3%	1.85	
SCENARIO 3 IN SENSITIVITY ANALYSIS – benefit arising from the decline in traffic accidents decreases by 30%													
OPT_1 – only traffic schemes are used	15	0.04	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	3.7%	1.00	Acceptable
OPT_2 – use of ITS equipment on a smaller scale	15	0.97	0.62	-3.88	3.35	3.74	-0.30	1.59	2.91	1.32	14.9%	1.83	
OPT_3 – full use of ITS	15	2.01	1.29	-3.88	3.35	5.21	-0.12	3.30	4.56	1.26	9.7%	1.38	

equipment													

* – the value displayed includes the additional time expenditure due to traffic accidents as well as the cost of exhaust gas emitted by vehicles (values have been used in the analysis as other external benefits/costs)

11. SUMMARY

The objective of this survey is the development of the traffic management solution for Tallinn ring road on national main road No. 11 (E265).

The survey provided an overview and assessment on continuous operation plans, described possible accident scenarios and utilised the traffic model to determine the probability of traffic jams and its possible locations. The content of continuous operation plans must comply with the requirements set out in the regulation, however, it is recommended to also prepare a short specific code of conduct for resolving crisis situations.

As of now, several sections of Tallinn ring road have been constructed into a two-carriageway highway, whereas other road sections are still being designed or are under construction. This survey has considered a situation where the ring road has been constructed into a two-carriageway highway by 2019, starting from Väo interchange and ending with Kanama interchange (Valingu overpass is likely to be added). The section from Kanama interchange to Keila is regarded to have 1+1 lanes.

Traffic volume on Tallinn ring road has grown 36% in the last 10 years, whereas the number of road trains has doubled on average (there is a similar situation on highway No. 4 Tallinn–Pärnu–Ikla). The most critical period in the sense of traffic volume is on working days between 16.00 and 18.00.

Traffic volume on Tallinn ring road is most affected by possible development activities in nearby areas. It is clear that such developments are mostly affected by the economic situation and various plans will be put to work/continued as the economic environment improves. The construction of the so-called small Tallinn ring road is sure to have a significant impact on the traffic volume on Tallinn ring road, however, its time of realisation is still unknown.

Possible bypass routes were prepared for the possible occurrence of traffic obstructions, involving three different levels (one lane closed, one direction closed, both directions closed). In case of several bypass routes, it must be taken into consideration that they have to be suitable for heavy traffic as well, which entails prior reconstruction. Bypass schemes form a basis for preparing detailed traffic management projects for temporary rerouting of traffic in the future.

Probability of possible traffic jams and impact on the traffic flow of other highways in case of rerouting has been analysed via modelling software Citilabs Cube Voyager and the traffic modelling has been conducted on the basis of the traffic model of an evening peak period. The model has been used to create maps that show the capacity and bottlenecks of bypass routes.

The part of surveillance and traffic management systems has mainly addressed equipment that is essential in regard to the traffic management of Tallinn ring road (and nearby areas in the future). It is firstly recommended to install surveillance and warning systems and thereafter also variable-message information boards for dynamic management of traffic flows.

Three different scenarios have been prepared for the cost-effectiveness analysis regarding feasibility of dynamic traffic management, which are compared with the baseline alternative (continuation of current situation where investments are not made):

- alternative option 1 (OPT_1) – traffic schemes and management is implemented in case of a traffic or other accident, but ITS solutions and dynamic traffic management solutions are nonexistent;
- alternative option 2 (OPT_2) – traffic schemes have been set in place for resolving traffic or other accidents in the event that they occur and in addition to this, traffic flow is managed and road users are warned via variable-message warning and speed limit signs (VWS+VSL), which have been installed on Tallinn ring road;
- alternative option 3 (OPT_3) – in addition to variable-message warning and speed limit signs, Tallinn ring road and intersecting major roads have also been equipped with (VMS+VWS) variable-message traffic control devices.

The objective of the cost-effectiveness analysis is to compare alternatives analysed with the current situation and determine the economic impact of investments to be made on society in order to find the most cost-effective option. The summary of the results of the analysis conducted is brought out in chapter 10.8.

During preparation of a dynamic traffic management system, it is recommended to, first and foremost, consider traffic volume and risk level, which enables to receive the greatest benefits form implementing ITS equipment. In the context of the first approach, it is reasonable to install necessary ITS equipment on the two-carriageway road sections that are already completed and continue this in stages in accordance with the completion of reconstruction works on road sections of Tallinn ring road.

Other recommendations

In regard to road sections that have yet to be designed (from Kanama interchange to Keila), the contracting entity is recommended to include the requirement regarding readiness for installing ITS equipment into the terms and conditions of the design procurement (i.e. the plan has to include the possibility of installing necessary ITS equipment in the future).