



Faculty of Civil Engineering
Institute of Transportation Engineering
Department of Geomatics

Rūdolfs Vingris

(Student ID Number: 081RBC102)

Master's thesis

Traffic safety analysis based on geospatial classification of streets

Scientific supervisor: **Prof Dr Eimuntas Kazimieras Paršeliūnas**,
Vilnius Gediminas Technical University

Reviewers:

Prof. Dr. sc. ing. **Juris Smirnovs**

Doc. dr. **Darius Popovas**

Riga 2021

Master's thesis is developed at the Department of Geomatics

Author: Rūdolfs Vingris  05.01.2021.
(name, surname) (signature) (date)

Supervisor: Eimuntas Paršeliūnas  05.01.2021.
(name, surname) (signature) (date)

Master's thesis recommended for defence.

Head of department: Dr.sc.ing. Jānis Kaminskis  08.12.2020
(signature) (date)

Master's thesis defended at the State Examination Commission of the Department of Geomatics on 14-01-2021 and rated _____ (____).
(date, month, year) (rating in words, appropriate mark)

Secretary of the Commission: _____
(name, surname) (signature) (date)

RIGAS TECHNICAL UNIVERSITY
DEPARTMENT OF GEOMATICS
MASTER'S THESIS TASK

Student of the Department of Geomatics: Rūdolfis Vingris 081RBC102
(name, surname) (student ID number)

Master's thesis title: Traffic safety analysis based on geospatial classification of streets
approved by head of department _____ an order No. _____.

Basic data for master's thesis:

- Road accident data from the Information system of road accident and violation scene analysis - Ministry of the Interior data. (*Iekšlietu ministrija – Ceļu satiksmes negadījumu un pārkāpumu notikuma vietu analīzes informācijas sistēma*)
- OpenStreetMap data
- Road accident data and OCTA insurance claims - Motor Insurers' Bureau of Latvia (*Latvijas Transportlīdzekļu apdrošinātāju birojs*)

Content of the Explanatory Memorandum:

The general objective of the Master thesis is to get at least one step closer to the safe roads. To succeed this goal author develops GIS (geographic information system) tool/platform, which analyse input data (from different sources) to display classification of road safety. The GIS tool should take into an account publicly available road and traffic related data to calculate and classify road segments into 5 safety levels. Restricted access and commercially sensitive data are not used in this work, however the target of Master thesis is to provide a platform, where publicly available data are analysed and displayed regularly and are available with everyone. Potential users with restricted access will have already designed platform for further research process and possibility to include restricted access data is available.

Content and date of the graphical part:

Objective is to provide a generic tool and platform suitable for any city and rural territory in Latvia, however for the development process, the dataset of Riga is used as an example. Riga is the capital and the largest city in Latvia, therefore, if the development of the tool will be successful, it can be run on a dataset that covers all territory of Latvia.

Thesis scientific supervisor:

Eimuntas Paršeliūnas
(name, surname)



Student:

Rūdolfis Vingris
(name, surname)





VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF ENVIRONMENTAL ENGINEERING
DEPARTMENT OF GEODESY AND CADASTRE

Rūdolfs Vingris

**TRAFFIC SAFETY ANALYSIS BASED ON GEOSPATIAL
CLASSIFICATION OF STREETS**

Master's degree Thesis

Innovative Solutions in Geomatics study programme, state code 6281EX001

Innovative Solutions in Geomatics specialisation

Measurement Engineering study field

Vilnius, 2021

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF ENVIRONMENTAL ENGINEERING
DEPARTMENT OF GEODESY AND CADASTRE

APPROVED BY
Head of Department



(Signature)

Jūrate Sužiedelytė Visockienė
(Name, Surname)

2020-01-14

(Date)

Rūdolfs Vingris

**TRAFFIC SAFETY ANALYSIS BASED ON GEOSPATIAL
CLASSIFICATION OF STREETS**

Master's degree Thesis

Innovative Solutions in Geomatics study programme, state code 6281EX001

Innovative Solutions in Geomatics specialisation

Measurement Engineering study field

Supervisor Prof. Dr. Eimuntas Kazimieras Paršeliūnas  2020-12-13
(Title, Name, Surname) (Signature) (Date)

Vilnius, 2021

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF ENVIRONMENTAL ENGINEERING
DEPARTMENT OF GEODESY AND CADASTRE

Measurement Engineering field of study
Innovative Solutions in Geomatics study programme, state code 6281EX001
Innovative Solutions in Geomatics specialisation

APPROVED BY
Head of Department



(Signature)

Jūratė Sužiedelytė Visockienė

(Name, Surname)

2020-12-17

(Date)

OBJECTIVES FOR MASTER THESIS

.....No.
Vilnius

For student: Rūdolfs Vingris
(Name, Surname)

Master Thesis title: Traffic safety analysis based on geospatial classification of streets.

Approved on 30 November, 2020 by Dean's decree No 135ap
(day, Month) (year)

The Final work has to be completed by 3 January, 2021
(Day, Month) (Year)

THE OBJECTIVES:

The general objective of the Master thesis is to get at least one step closer to the safe roads. To succeed this goal author develops GIS (geographic information system) tool/platform, which analyse input data (from different sources) to display classification of road safety. The GIS tool should take into an account publicly available road and traffic related data to calculate and classify road segments into 5 safety levels. Restricted access and commercially sensitive data are not used in this work, however the target of Master thesis is to provide a platform, where publicly available data are analysed and displayed regularly and are available with everyone. Potential users with restricted access will have already designed platform for further research process and possibility to include restricted access data is available. Objective is to provide a generic tool and platform suitable for any city and rural territory in Latvia, however for the development process, the dataset of Riga is used as an example. Riga is the capital and the largest city in Latvia, therefore, if the development of the tool will be successful, it can be run on a dataset that covers all territory of Latvia.

Academic Supervisor
(Signature)

Prof. Eimuntas Paršeliūnas.....
(Title, Name, Surname)

Objectives accepted as a guidance for my Master Thesis



(Student's signature)

Rūdolfs Vingris

(Student's Name, Surname)

.....2020-12-12.....

Vilnius Gediminas Technical University
Faculty of environmental engineering
Department of geodesy and cadastre

ISBN ISSN
Copies No.
Date 30-12-2020

Innovative Solutions in Geomatics study programme master thesis.

Title: **Traffic safety analysis based on geospatial classification of streets**

Author **Rūdolfs Vingris** Academic supervisor **Prof Dr Eimuntas Kazimieras Paršeliūnas**

Thesis language

☐ Lithuanian

☒ Foreign (English)

Annotation

“Traffic safety analysis based on geospatial classification of streets” is the solution proposed and developed by the Author to show that it is possible to analyse road and traffic safety by using geospatial and open-source data as well as tools offered by ArcGIS software.

The result of the Master’s thesis is a WEB based application created in the ArcGIS Online platform. The application is available under the link: <https://ej.uz/on69>

The developed application contains a published map of road accidents, which includes and displays the classification of road sections depending on the analysis of road accident points.

Several traffic safety strategies that are implemented in other countries have been studied as well, and some of the points the Author is recommending to consider for Latvian safe roads policy. Authors have developed this work with the vision - Safe Roads, by offering this solution to the authorities responsible for road safety as a daily work tool, therefore supporting decision-making on road safety improvement. The tool is designed to enable the relevant authorities to make decisions by following the principle “value for money”.

Structure: introduction, theory, practical part, results, conclusions and suggestions, references.

Theses consist of: 86 p. text without appendixes, 47 pictures, 6 tables, 39 bibliographical entries.

Appendixes included.

Keywords: GIS, ArcGIS, ArcGIS Online, Traffic, Road safety, Road accident, Crash, Crash mapping, Safe roads, CAIS

Vilnius Gediminas Technical University
Faculty of environmental engineering
Department of geodesy and cadastre

ISBN ISSN
Copies No.
Date 30-12-2020

Innovative Solutions in Geomatics study programme master thesis.

Title: **Traffic safety analysis based on geospatial classification of streets**

Author **Rūdolfs Vingris** Academic supervisor **Prof Dr Eimuntas Kazimieras Paršeliūnas**

Thesis language

☐

Lithuanian

☒

Foreign (English)

Anotācija

“Satiksmes drošības analīze, balstoties uz ielu ģeotelpisku klasifikāciju” jeb angļiski “Traffic safety analysis based on geospatial classification of streets” ir Autora piedāvāts un izstrādāts risinājums, kā, izmantojot ģeotelpiskus un brīvi pieejamus datus kā arī ArcGIS programmatūras platformas piedāvātos tehniskos rīkus, var veikt autoceļu un ielu satiksmes drošības analīzi. Darba rezultāts ir ArcGIS Online vidē izveidota interneta aplikācija. Aplikācija satur nopublicētu ceļu satiksmes negadījumu karti, kurā ietverta un attēlota autoceļu posmu klasifikācija atkarībā no ceļu satiksmes negadījumu punktu analīzes. Interneta aplikācija pieejama šeit: <https://ej.uz/on69>

Autors ir aplūkojis arī citu valstu satiksmes drošības stratēģijas, un atsevišķas tēzes rekomendē īstenot arī Latvijā. Autors šo darbu ir izstrādājis ar vīziju – Droši ceļi, un piedāvā savu risinājumu ceļu satiksmes drošības atbildīgajām instancēm kā ikdienas darbu rīku, kas var palīdzēt satiksmes drošības uzlabošanas lēmumu pieņemšanā. Rīks paredzēts, lai attiecīgās instances spētu pieņemt pamatotus lēmumus, balstoties uz “ieguvums pret izmaksām” principu.

Struktūra: ievads, teorētiskā daļa, praktiskā daļa, rezultāti, secinājumi un ierosinājumi, atsauces.

Darbs sastāv no: 86 lpp. teksta bez pielikumiem, 47 attēli, 6 tabulas, 39 bibliogrāfiskie ieraksti. Iekļauti pielikumi.

Keywords: GIS, ArcGIS, ArcGIS Online, Traffic, Road safety, Road accident, Crash, Crash mapping, Safe roads, CAIS

TABLE OF CONTENTS

Introduction	16
1. Theory - Road traffic safety concept	19
1.1. General vision – safe roads	19
1.2. Road safety strategies.....	21
1.2.1. Vision Zero	23
1.2.2. Dutch version of safe system	25
1.3. GIS and road safety in Latvia.....	26
1.4. Novelty of the Master thesis	31
1.5. Used technologies	32
1.6. Developing WEB map and application – workflow	33
1.7. Star Rating and EuroRAP road classification	34
2. Geospatial tool development – Road traffic and road segment classification	
38	
2.1. Data	39
2.1.1. LVC Data	39
2.1.2. IeM CAIS data	42
2.1.3. LTAB Road traffic accident data	45
2.1.4. OpenStreetMap data.....	46
2.2. Data processing model and workflow.....	47
2.2.1. IeM CAIS road accident data processing.....	48
2.2.2. IeM CAIS data cleaning.....	52
2.2.3. IeM CAIS data relationship classes	55

2.2.4.	OSM data conversion to geodatabase	57
2.2.5.	Road and street data preparation for analysis	60
2.2.6.	Road and street intersection data preparation for analysis.....	61
2.2.7.	Calculation of OCTA expenses in every intersection	64
2.2.8.	Data analysis	65
2.3.	Road safety classification.....	67
2.4.	WEB map and application	69
3.	Results.....	74
3.1.	Road accident WEB application	74
3.2.	Results of road accident analysis	75
	Conclusions, suggestions and proposals	81
	References	83
	APPENDICES	87

LIST OF FIGURES

Figure 1. Road fatalities per million inhabitants (European Commission, 2019).	20
Figure 2. Safe System results hierarchy at EU level.....	24
Figure 3. LVC interactive WEB map (LVC, 2020).....	27
Figure 4. Information system of a road accident and violation scene analysis-CAIS (IeM, 2020)	28
Figure 5. LTAB interactive WEB map (LTAB, 2020).....	29
Figure 6. Example of LTAB mobile application – input data screen	30
Figure 7. Example of LTAB mobile application - completed European Accident Statement	31
Figure 8. Thematic map creation process (J.Štrauhmanis)	33
Figure 9. Countries of EuroRAP programmes and projects. (EuroRAP, 2020) ...	35
Figure 10. LVC provided State road network centreline data.	41
Figure 11. IeM CAIS. Downloading road accident data.....	43
Figure 12. Downloaded IeM CAIS data	44
Figure 13. The downloaded OSM data in SHP files.....	47
Figure 14. Model - 00_CAIS_data_template	49
Figure 15. Model - 01_CSV_to_GDB_CaisVirsnost	49
Figure 16. Model - 02_CSV_to_GDB_Dalibnieki	50
Figure 17. Model - 03_CSV_to_GDB_JuridiskaKvalifikacija.....	51
Figure 18. Model - 04_CSV_to_GDB_NegadijumaDetalas.....	51
Figure 19. Model - 05_CSV_to_GDB_SaistitieRegistri.....	52
Figure 20. CAIS data duplicates	53
Figure 21. Cleaning data duplicates	53
Figure 22. Visualised data errors (duplicates)	54
Figure 23. Results of CAIS data cleaning.....	54
Figure 24. Model - 06_Create_Relationship_Class_AllData	55
Figure 25. Create Relationship class.....	57
Figure 26. Model - 07_OSM_data_processing	58
Figure 27. Example of street buffer with 10m radius	59
Figure 28. Model - 08_Road_Street_Buffers_for_OSM_CSN_Analysis.....	60

Figure 29. Model - 09_AccidentData_Analysis	60
Figure 30. Calculate geometry	62
Figure 31. Road and street intersection buffers	63
Figure 32. Dissolved road and street intersection buffers.....	63
Figure 33. Calculation of OCTA expenses	65
Figure 34. Model - 10_1_Road_Street_Analysis.....	66
Figure 35. Model - 10_2_Intersection_Analysis.....	67
Figure 36. Statistics of the field “Accident rate (per 1km)”	68
Figure 37. Accident rate intervals and road segment safety class	69
Figure 38. Map design in ArcGIS Pro	69
Figure 39. WEB map configuration in ArcGIS Online	71
Figure 40. Configuration of WEB application in ArcGIS Web AppBuilder.....	72
Figure 41. Configure Filter widget	73
Figure 42. Road and street accident WEB application	74
Figure 43. IeM CAIS data - Counts of Accident points by Months over Years...	75
Figure 44. LTAB data - Counts of Accident points by Months over Years	76
Figure 45. Relationship between road intersection accidents and total costs	78
Figure 46. Vienības gatve / Ozolciema iela - Higher accident count, lower costs	79
Figure 47. Brīvības gatve un Gustava Zemgala gatve - Lower accident count, higher costs	80

LIST OF TABLES

Table 1. Road safety strategies in reference countries (I.A.Tisca, N.Istrat, C.D.Dumitrescu, G.Cornua)	22
Table 2. Road safety classification levels	36
Table 3. LVC provided Annual average traffic intensity data.	41
Table 4. Road accident data in CSV file, provided by LTAB	46
Table 5. Sum of accident points into the buffers	59
Table 6. Road and Street Buffers (10m)	77

ABBREVIATIONS AND ACRONYMS

AGOL	ArcGIS Online – WEB based GIS application solution. Developed by Esri and part of ArcGIS platform
App	Application
ArcGIS	GIS software platform developed and maintained by Esri
ArcGIS Pro	Esri developed GIS desktop application
CAD	Computer Aided Design
CAIS	Information system of road accident and violation scene analysis (CAIS – Ceļu satiksmes negadījumu un pārkāpumu notikuma vietu analīzes informācijas sistēma)
CSDD	Road Safety Directorate (CSDD - Ceļu satiksmes drošības direkcija)
CSV (.csv)	Comma Separated Value file format
DBSchema	Data base schema – attribute field structure and field properties of the database feature class or table
Desktop	Environment for software and applications which requires to use personal computer
Esri	Environmental Systems Research Institute - international supplier of GIS software, WEB GIS and geodatabase management applications
EUR	Euro (currency)
EuroRAP	The European Road Assessment Programme - an international not-for-profit organisation dedicated to saving lives through safer roads
GDB (.gdb)	Geodatabase
GIS	Geographic information system
GPS	NAVSTAR (NAVigation Satellite Time And Ranging) Global Positioning System, United States of America
IeM	Ministry of the Interior (IeM – Iekšlietu ministrija)
IeM IC	The Information Centre of the Ministry of the Interior (IeM IC - Iekšlietu ministrijas Informācijas centrs)
KASKO	Voluntary land vehicle insurance, which provides for indemnification in case of vehicle damage, robbery or theft
km	Kilometre
LKS-92	Latvian Coordinate system 1992 (LKS-92 – Latvijas koordinātu sistēma 1992)
LRS	Linear reference system
LTAB	Motor Insurers' Bureau of Latvia (LTAB – Latvijas Transportlīdzekļu apdrošinātāju birojs)
LVC	The Latvian State Roads (LVC – Latvijas Valsts ceļi)
m	Meters
OCTA	Compulsory motor third party liability insurance

OSM	OpenStreetMap
RGB	Red, Green, Blue - colour palette
RTU	Riga Technical University
SHP (.shp)	Geospatial vector data format for GIS software
SQL	Structured query language
TXT (.txt)	Text file
VGTU	Vilnius Gediminas Technical University
WEB	World Wide Web (WWW); internet.
WGS-84	World Geodetic System 1984
ZIP (.zip)	Archive file format

INTRODUCTION

For many years' Latvian road users (vehicle drivers, bicycle riders, pedestrians, etc.) are not satisfied with the road infrastructure and they are complaining about the quality of Latvian road pavements and the quality of their maintenance. Social surveys and comments on social media like news portals, Twitter and Facebook, etc. show that society is not satisfied with how income from taxes is spent and the government has been blamed for not taking appropriate actions to solve issues and find proper solutions for road budget spending. According to the Author's point of view lack of forceful road budget policy and road user dissatisfaction with current shared infrastructure leads to a psychologically negative environment in society. It causes unnecessary intolerance between traffic participants and might result in aggressive habits and actions while using road infrastructure. There are several researches that show correlation between road accidents or crashes and aggression of the traffic members. Obviously, not all accidents are caused by traffic member aggression. There can be several reasons related to both human factors and physical infrastructure, for example, some of them is ignorant of the traffic rules, tiredness, lack of skills or unfortunate coincidence, insufficient visibility of traffic signs, quality of road surface, etc.

The Author understands that granted road budget is a result of different economic factors and, of course, is limited and never will be enough to cover all expenses that road maintenance and traffic safety improvement needs as there should be non-stop improvements. Also, the Author believes, that even with a limited budget it is possible to achieve better results in road traffic safety if there are a well-considered road budget policy and right priorities which can be set based on a well-argued analysis of the real situation. If road safety depends on the quality of the infrastructure, which is one of the key elements, then the quality of the infrastructure depends on budget and available resources.

The aim of the Master's thesis is to create a generic GIS tool by using open-source data and commercial software in order to provide a platform for society and road and traffic responsible authorities for road safety policy decision making. The Author seeks to develop and provide a platform that would indicate the most critical hot spots in road infrastructure and provide a platform for analysing and understanding the reasons for hot spot critical origins.

In order to reach the aim, the Author has set several tasks:

- Define the vision and describe the concept of road safety;
- Review most common road traffic strategies and safety systems;
- To examine the current GIS and road safety-related tools in Latvia;
- Propose and create the methodology used for GIS tool development;
- Based on GIS developed tool – create and design the WEB map and application for data reviewing and analysing.

The **Hypotheses** defined for the Master's theses – it is possible to create a GIS tool based on WEB and desktop technologies, which allows to analyse and classify roads into safety levels.

The Author realizes the complexity of road traffic safety and management system in Latvia which can lead to restrictions of gathering essential and required data or information from involved authorities. Taking into account those risks, the Author provides a geospatial model based on a combination of a real and artificially designed data.

The Author of the Master thesis has experience in the GIS field for more than 8 years and is interested in road and traffic safety-related topics and articles. The Author believes that the task would be successful in a long-term if the road and traffic safety authorities would implement the Author's suggested platform into their daily workflow and would use that as a tool for solving traffic safety issues and making decisions and actions.

For the novelty of this work, the Author proposes the methodology of open-source data procession and integration into WEB-based application. The innovative part of the thesis is a base of the platform where each traffic member can find useful information and data according to their access and role in the industry. As the part of possible future development tasks and research, the work at the stage of Master thesis is a solid base for further research (Doctoral thesis), developing a new project – “Contribution of State road and traffic safety organisations, to improve road and traffic safety, implementing Vision zero and Safe road system”, adding real time data and workflow integration between several state organisations (LVC, CSDD, IeM, LTAB, etc.) and adding real-time measurements to GIS WEB map and application, etc. For an even more advanced solution Author suggests deploying and adding the concept of “Latvian road and street budget

management with GIS tools” to ensure a connection between road safety and road budget management systems, helping professionals to make better decisions and act accordingly to the best “value for the money”. Author provided a conceptual idea of “Latvian road and street budget management with GIS tools” at the conference “23-osios Lietuvos jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis“ teminė konferencija” on 15 May 2020, in Vilnius, Lithuania. The article of that conference is available in Annex 2.

The Master thesis contains 4 main chapters:

- Theoretical part – the comprehensive review of road and traffic visions and strategies, as well as using GIS technologies.
- Practical part – description of the workflow and most important tasks for developing GIS tools, WEB map, and application.
- Results of the data processing.
- Conclusions, suggestions, and future works if the research on this topic will continue.

The WEB map and application is available here: <https://ej.uz/on69>

1. THEORY - ROAD TRAFFIC SAFETY CONCEPT

1.1. General vision – safe roads

The general vision of this Master thesis is to get one step closer to the safe roads. This statement might sound generic however it is very precise – safe roads for all traffic members and participants. The Author believes that Latvian State authorities can develop and implement such a road and traffic management policy where road and traffic safety risks are decreased to a minimum and all the factors which could cause fatal accidents and accidents with serious injuries would be mitigated or eliminated at all.

The concept of road safety is changing through time, depending on human philosophy, mentality, country, availabilities, and technologies. According to the topic “*Issues concerning the road safety concept*” at 3rd Global Conference on Business, Economics, Management and Tourism, 26-28 November 2015, Rome, Italy there were stated several phases of road safety management approach during previous decades:

Phase 1: thinking and practice in the 1950s focused on the role of driver and on the approach “the victim is to blame”. The management of the road safety during this period can be characterized by dispersed, uncoordinated and insufficiently documented units, which fulfilled single isolated functions;

Phase 2: thinking and practice in the 1960s and 1970s focused on interventions at the infrastructure – driver – vehicle system, before, during and after the accident, without establishing the responsibilities of an institutional management;

Phase 3: thinking and practice in the 1980s and 1990s focused on interventions in the entire system, on clearly outlined objectives and on creating a base at the institutional level, so as to make plans and action programs which eventually had reduced considerably the road accidents during these decades;

Phase 4: From 1990, thinking and practice focused on holistic approaches known as Safety system, which aimed mainly at eliminating long-term adverse effects and serious injuries from traffic accidents. (Ionela Adriana Tisca, Nicolae Istrat, Constantin Dan Dumitrescu, Georgica Cornu, 2016)

Starting from 1990 we are still at Phase 4. Of course, the Author understands that traffic safety management and road infrastructure is improving and today in 2020 the

situation is much better. According to the latest statistical data, the total number of road fatalities per year in the EU since 2001 has decreased significantly from 51,400 fatal incidents to 22,700 fatal incidents in 2019 and forecasted 14,800 fatal incidents in 2020. These data show a very good decreasing trend but numbers still have to be considered and treated.

Looking at road fatalities per million inhabitants in 2019, data shows that in the EU average number is 51 fatal incidents, but in Latvia, the number is above average and reach 69 fatal incidents per million inhabitants (*Figure 1. Road fatalities per million inhabitants (European Commission, 2019)*). Among Baltics countries it is the highest number, therefore clearly is giving signals that road safety management policy requires some attention.

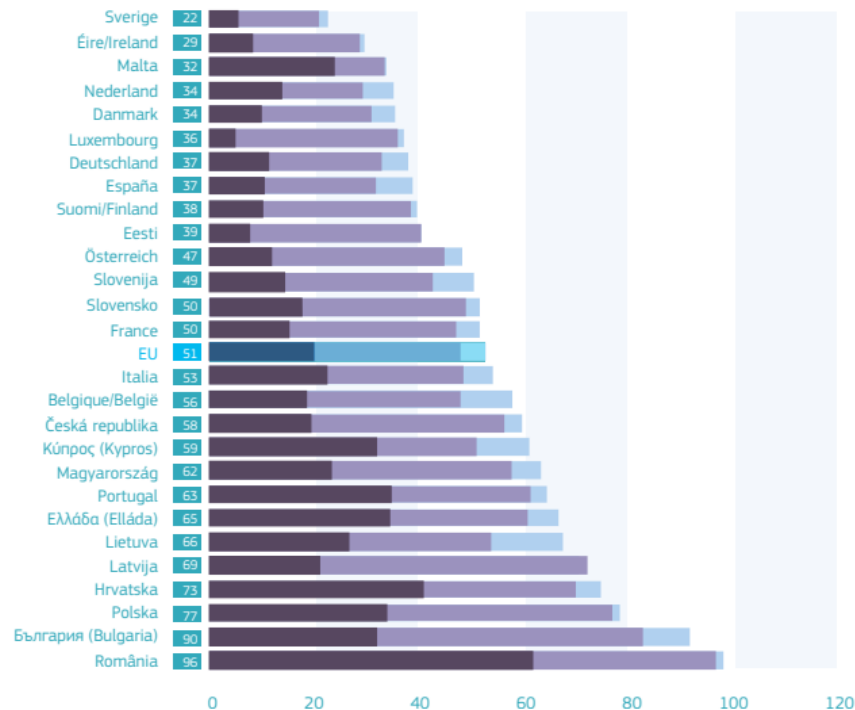


Figure 1. Road fatalities per million inhabitants (European Commission, 2019)

Although the trend for 2020 is looking better, even with the best knowledge, highest road funding, and budget it is almost impossible to make the environment 100% safe from any accident. The same article “*Issues concerning the road safety concept*” states that *Since the risk of being involved in a road accident can be reduced through various measures, one could state that road accidents as well can be prevented through legislative*

measures, preventive education, or technical and corrective measures, which would reduce the number of such accidents and implicitly of casualties. (Ionela Adriana Tisca, Nicolae Istrat, Constantin Dan Dumitrescu, Georgica Cornu, 2016). The Author agrees that road accident risks can be reduced by taking appropriate actions and measures and it is possible to reduce road accidents with fatal or severe injuries, making the environment safe as much as it is possible. This aim can be reached by following the principle – “value for money”. In terms of this Master thesis “value for money” would be a possibility for road safety responsible authorities to make the most advantageous decisions and act accordingly to the situation. The term “value for money” in terms of road safety has been used in many analyses when it comes to road safety measures and policymaking. For example, a report called “Traffic Safety Synthesis on Cost-Benefit Analysis” produced by the National Technical University of Athens (NTUA), the Austrian Road Safety Board (KFV), and the European Union Road Federation very well describes this correlation between road accidents and “cost-benefit” or “value for money” ratio, of course, In practice, it will never be possible to base road safety policy fully on cost-benefit analyses, but it is crucial to define and give priority to those measures that provide the largest reductions of the number of road traffic fatalities, however, measures may not always be the most cost-effective.

1.2. Road safety strategies

Safe roads and minimised number of accidents should be one of the state’s priorities. Most of the developed countries have initiated various actions and programs aimed at improving road safety. Each country has its own targets and activities, but the framework of the policy for most countries are the same. Some of the used strategies/visions are presented below in *Table 1. Road safety strategies in reference countries (I.A.Tisca, N.Istrat, C.D.Dumitrescu, G.Cornua).*

Country	Adopted vision
Sweden	Zero vision
Norway	Zero vision
United Kingdom	Zero vision
Austria	Level of road safety compared with the first three countries in the Europe
Netherlands	Sustainable road safety
Denmark	Even one accident is too much
Canada	To have the safest roads in the world
Australia	Vision zero/ roads safer for the whole community
New Zealand	A road safety culture

Table 1. Road safety strategies in reference countries (I.A.Tisca, N.Istrat, C.D.Dumitrescu, G.Cornua)

According to the article “*Issues concerning the road safety concept*”, the adopted vision on road safety represents a description of a future desirable situation, which is based on a well-established theory on how different components of the road system are desired to interact to ensure the maximum possible level of safety. The vision is adopted on a long-term, without mentioning a deadline, but providing guidance on road safety and offering the possibility to reflect on the necessary improvements to achieve the situation referred to in the vision. If there is commitment and funding, a road safety vision directs the actions and constitutes a foundation for road safety plans and programs.

Vision Zero on road safety is based on the idea of minimizing the number of road accidents during a calendar year.

Sustainable Safety in the Netherlands and the Swedish Vision Zero are the best-known examples of road safety visions, which were adopted by other countries. In both visions, the basic idea is to transform the road system so as to eliminate all known human-error possibilities, and to reduce physical damages due to accidents. (Ionela Adriana Tisca, Nicolae Istrat, Constantin Dan Dumitrescu, Georgica Cornu, 2016)

In order to have a stronger safe roads policy, In June 2019, the European Commission adopted the EU Road Safety Policy Framework 2021-2030, outlining specific policy measures planned for 2021-2030. The European Commission has come forward with a new and ambitious long-term road safety programme. *The new EU 10-year action programme should be guided by the long-term Vision Zero and embody the Safe System approach. It should enshrine the targets adopted in the Valletta Declaration to reduce both deaths and serious injuries by 50% between 2020 and 2030 (European Transport Safety Council, 2018).*

The Author agrees that Safe road approach is necessary to develop and apply to each of the countries, of course, also Latvia follows the same European Commission guidelines, but there are still place for improvements and possible tools to use in order to reach the aim and fulfil the vision. In the Authors point of view, the key to this achievement would be targeting the weakest or critical points at infrastructure or traffic and road safety-related actions and despite limited financial resources it is possible to achieve this goal if the best value for money is considered, analyses performed, and decisions and actions are taken accordingly.

To achieve this goal Author provides a geospatial tool (platform), which allows users to analyse road traffic safety and find the hot spots where infrastructure or traffic safety improvements are needed. This platform could be a working tool in order to implement a safe road strategy by helping to display and understand the real and designed situation of the safety levels according to publicly available data, leaving space for tool development if some restricted data has been considered.

1.2.1. Vision Zero

Vision Zero or Safe System approach is commonly used and widely supported long-term ideal and has been adopted as a safe road strategy. According to European Commission reports, this strategy states that the long-term solution to the problem of road accidents is to create a road transport system in which nobody is killed or seriously injured as a result of road accidents (*Figure 2. Safe System results hierarchy at EU level*). Clearly explains the safe road system result hierarchy at the EU level by 2050.

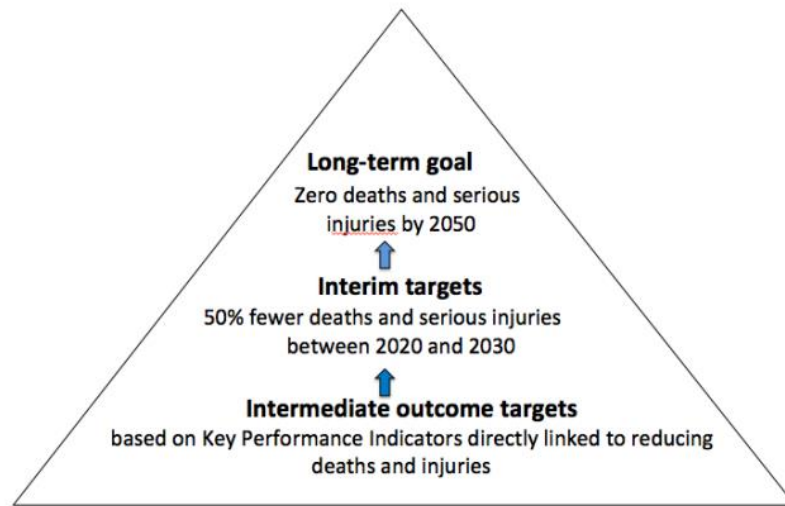


Figure 2. Safe System results hierarchy at EU level

Vision Zero is based on ethics and shared responsibility principles, as follows (OECD, 2008):

- *Human life and health are paramount ethical considerations which are not be allowed to be traded-off against the benefits of the road transport system, such as mobility.*
- *Rather than placing responsibility for accidents and injuries on the individual road users, it is shared between the providers of the system and the road users. The road user remains responsible for following basic rules, e.g. obeying speed limits; the system designers and enforcers are responsible for the functioning of the system. In the event that road users make errors or even fail to follow the rules, the responsibility reverts to the system's designers to ensure that such failings do not result in death or serious injuries (European Commission, Directorate General for Transport, 2018).*

EU Road Safety Policy Framework 2021-2030 has defined Next steps towards "Vision Zero", thus this should be part of the Latvian safe roads policy and Author supposes that this strategy in Latvia is possible in terms of appropriate road safety planning, management, and successful corporation between national and regional road safety authorities. Moreover, *Vision Zero aims to stimulate technological innovation that may result in the development of new and more cost-effective road safety measures than those*

that are currently used (European Commission, Directorate General for Transport, 2018). This statement shows the need for new innovations on measures and therefore also analyses which are need in order to define them. At this point, Author has developed such a tool (platform) that could be used for decision making and foster the process.

1.2.2. Dutch version of safe system

Another good approach for safe road policy has been implemented in the Netherlands. They have developed their version of the Safe System approach, but the main idea is to eliminate or significantly reduce serious injuries through the use of safe system architecture in designing new parts of our road network system or retrofitting the existing system. The main points of this system are:

- *It is ethical, as we do not want to hand over a traffic system to subsequent generations (in environmental policies, what we call “sustainable development”) at the current casualty levels but rather at considerably lower levels, with zero being ultimate aim;*
- *It is a pro-active approach, which means that it is not necessary to wait for crashes before acting; instead, we use the knowledge we have and adapt our knowledge to local conditions;*
- *It emphasizes the idea that “People are the measure of all things” in such a way that the vulnerability of the human body, as well as human capacities and limitations, are the guiding factors when designing a safe system;*
- *It is an integral/holistic approach that designs system components integrally and deals with the whole system, not just “spikes in distributions.” “Integral” also means that other policy areas (infrastructure investments, environmental policies, urban planning, etc.) should meet certain safety levels;*
- *The safe system approach aims at eliminating and/or reducing so-called “system gaps”. These are “latent gaps,” or individual weaknesses in components of the system;*
- *It embodies a preventable injuries approach to identify priorities in actions 1) based on a good understanding of crash causes, 2) based on the expected effects*

of remedies and cures, and 3) starting with the most cost-beneficial interventions. (Wegman, 2017)

In 2017 F.Wegman refers to the United Nations' decision to reduce halve the number of global deaths and injuries from road traffic accidents by 2020 and by 2030 to provide access to safe, accessible, affordable, and sustainable transport systems for everyone. It includes improving road safety, by expanding public transport, spending special attention on the needs of those in vulnerable situations, women, and children, persons with disabilities, and older persons.

The Author of those thesis agrees with F.Wegman at all six points of sustainable safety system mentioned above – especially about identified priorities.

1.3. GIS and road safety in Latvia

There are several publicly available road and traffic safety-related GIS products provided by different companies and organisations. Each of them is useful and represents information regarding business tasks those companies deliver. However, there is not any similar product which would combine all the information that product contains.

LVC interactive WEB map is a very good and useful resource, to review the situation on Latvian roads, however, this WEB map is not practical for data analysis and data is not available for downloads. At least not in the public version. LVC provides few data files through Latvia's Open Data portal (<https://data.gov.lv/eng>).

Figure 3. LVC interactive WEB map (LVC, 2020) shows LVC provided WEB map and data including road condition, severe road accidents, traffic intensity in several places, and LVC road infrastructure.

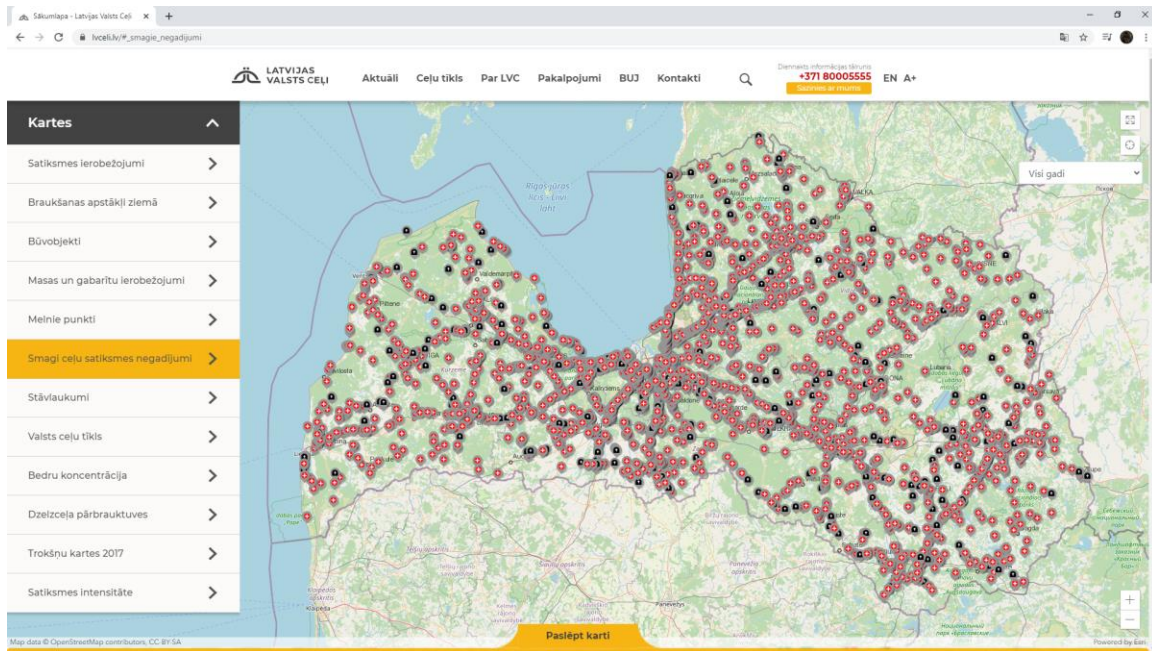


Figure 3. LVC interactive WEB map (LVC, 2020)

Ministry of the Interior – Information system of a road accident and violation scene analysis (CAIS), provides road accident data. This source provides accident hotspots and allows users to filter data in many ways and combinations. As you can see in *Figure 4. Information system of a road accident and violation scene analysis-CAIS (IeM, 2020)*, CAIS provides road accident WEB map, where accidents are symbolised as heat-map. CAIS allows users to review, filter, and download the road accident data.

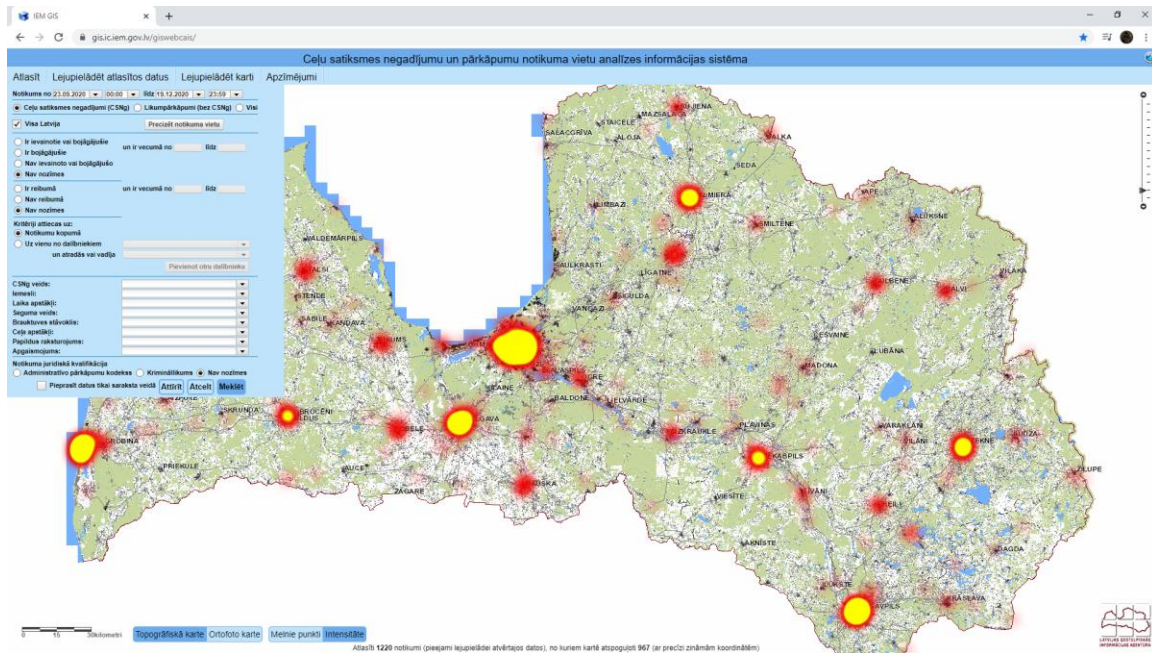


Figure 4. Information system of a road accident and violation scene analysis-CAIS (IeM, 2020)

LTAB has published road accident data with the value of OCTA insurance claims. This data is probably the best source for calculating expenses of road accidents and refers to a specific place in a road network. There might be other sources, but they are not publicly available. In Figure 5. *LTAB interactive WEB map (LTAB, 2020)* Author shows LTAB provide WEB map with road accident data, reported by road police, and collected by European Accident Statement paper form. The WEB map is for the data review and it is not possible to filter and download data from the LTAB webpage.

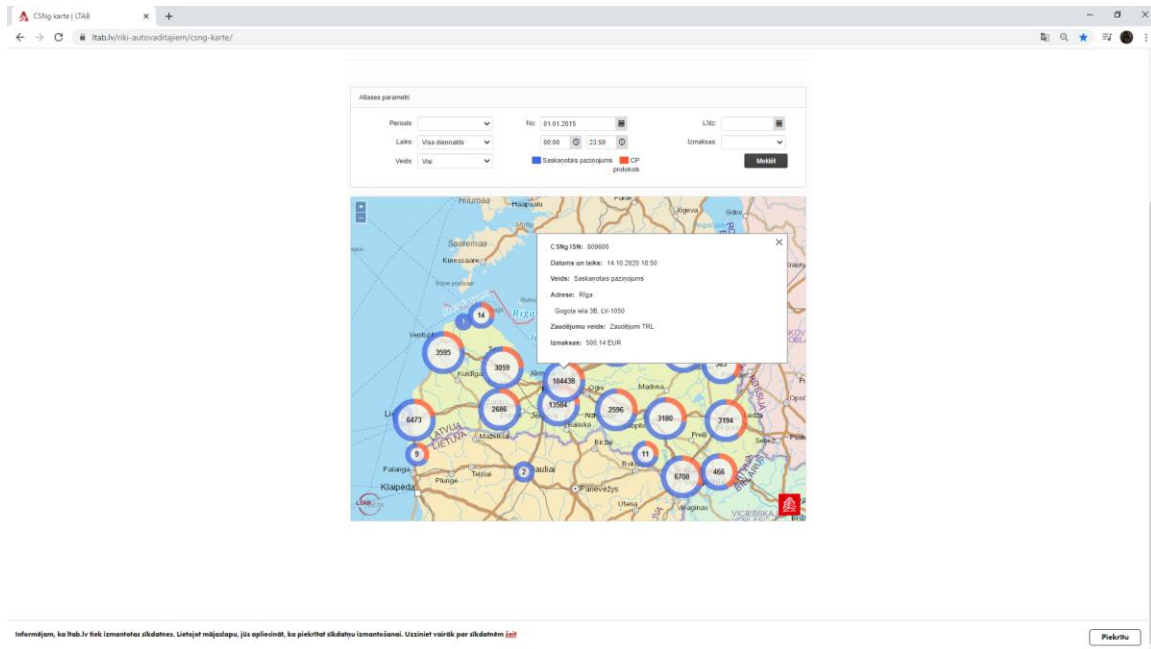


Figure 5. LTAB interactive WEB map (LTAB, 2020)

In Latvia, there is already developed and available mobile application for minor road accidents. It is a useful application that is a good alternative for physical paper reports – “European Accident Statement”. Both types of reports are useful in case of minor accidents, however, reports reported in the mobile applications are stored into a database directly, excluding unnecessary manual data entry into a database. This process is faster, and data can be sent to insurance companies and displayed on the map much faster, than if the report is submitted in paper form.

This application is provided by LTAB and both reports (digital and paper form) are valid and can be submitted after the accident. Reports are submitted by both drivers involved in an accident, however, there are few restrictions when the report can be submitted without road police involvement:

- Only 2 vehicles are involved and damaged;
- No injured persons (not even slightly);
- There is no damage made to other third party property;
- There is no serious damage to vehicles (does not need an evacuation, both involved cars are permitted by regulations to continue driving);
- Involved drivers agree on the relevant circumstances of the accident.

In all other cases, police must be contacted. (*European Accident Statement, 2020*)

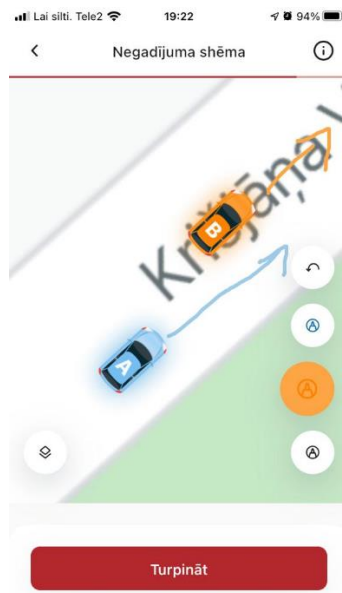


Figure 6. Example of LTAB mobile application – input data screen

Figure 6. Example of LTAB mobile application – input data screen is an example of how minor road accidents can be reported without road police involvement. The persons who are involved in a road accident can report about an accident by using a mobile phone and mobile application, that allows to collect all accident details and allows to draw accident schema.

Figure 7. Example of LTAB mobile application - completed European Accident Statement shows an example of completed European Accident Statement form. This form is identical to the paper form.

Figure 7. Example of LTAB mobile application - completed European Accident Statement

According to the Author's point of view, a similar application would be necessary for the police to record and report about accidents, which cannot be reported by LTAB mobile application or European Accident Statement paper form.

1.4. Novelty of the Master thesis

There have been a lot of research published by the Road Safety Directorate (CSDD) about road and traffic-related issues and solutions in Latvia. There is also an available road accident WEB map on IeM CAIS and LTAB homepage. There are some television shows for road traffic-related topics and even an internet blog. However, there are not any platforms available for road and traffic safety issues, which combine multiple data sources and perform specific analytics, at least not publicly available.

The novelty of the thesis is the combination of multiple open-source data, which is analysed, visualised in one common environment, and made publicly available. It is designed as a good platform for further developments like:

1. Include restricted access, online and real-time data from the road, traffic, and safety responsible authorities:
 - a. LVC – state road centre lines,

- b. online and real-time traffic information on state roads,
 - c. online and real-time road conditions (including maintenance and construction works),
 - d. online and real-time road surveillance cameras,
 - e. traffic count data,
 - f. etc.
2. Create multiple WEB based environments for each authority to help them perform and to their daily tasks in one platform (CSDD; LVC; Local government traffic departments etc.).
 3. Include crowdsource data, where road traffic members can report road traffic-related issues and suggestions. This would give authorities a better vision of public needs according to the road network maintenance works and tasks – for example, road safety audits. (*Puķītis, 2013*)

1.5. Used technologies

To develop the road accident WEB map and WEB application Esri technologies are being used. There are several reasons why the Author has chosen Esri developed ArcGIS software instead of some other, for example, open-source technologies. Firstly, Esri is the largest GIS software provider in the world, according to “*businesswire.com*”. The Esri GIS market share is over 45% that makes them leaders in the industry. (*Pruchniewski, 2019*) Author’s opinion – Master thesis practical work should be made in a common environment, where most of the GIS users would find it easy to use and practical for daily work.

Secondly – Esri provided ArcGIS software and the application suite contains a wide range of applications. Each of them is made and designed for different kinds of tasks and business fields, but all of them are compatible and data, as well as processes, can communicate between each other.

Thirdly – this software is available for students at VGTU and RTU where the Master thesis is developed.

ArcGIS Pro is a GIS desktop application and is a useful tool for preparing data and data processing. As ArcGIS Pro use desktop hardware, it performs all procedures faster than WEB based technologies. Due to a large number of data records, some of geoprocessing tasks could be difficult to perform manually, therefore ArcGIS Pro Modelbuilder was used to design automatic data processing models.

For processed data results, visualisation, and further analytical tasks, the Author use ArcGIS Online and ArcGIS Online WEB Appbuilder. Those applications ensure data storage (ArcGIS Online) and platform for the WEB application. Those technologies allow the developer (Author) to design WEB map and application for the end-user, including all the functions end-user need, to use WEB map, and perform analytical work in the WEB environment.

1.6. Developing WEB map and application – workflow

Jānis Štrauhmanis in his book “*Tematiskā kartogrāfija*” (Thematic cartography) offers a scheme of suggested steps for creating a thematic map. Author considers this workflow as appropriate for the Master thesis.

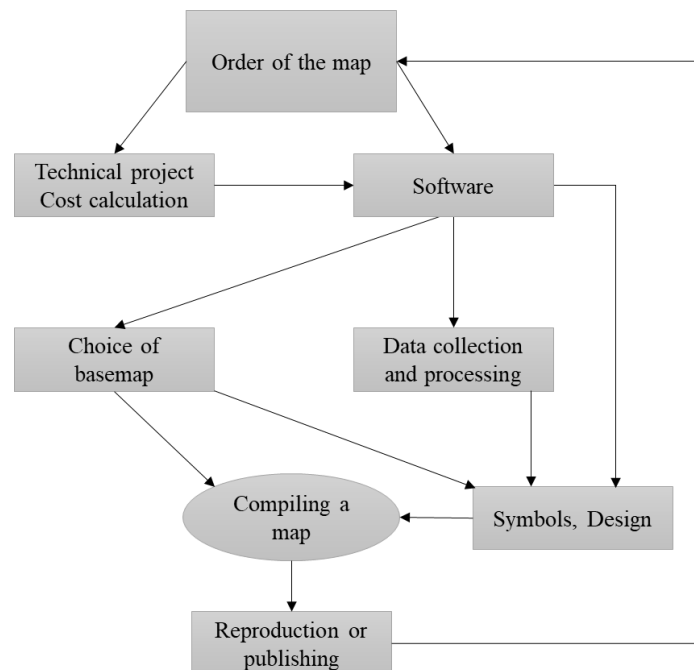


Figure 8. Thematic map creation process (J.Štrauhmanis)

Figure 8. Thematic map creation process (J.Štrauhmanis) schema shows the main phases of the process:

1. Objective or order of the map from a customer.
2. Technical project and potential Cost calculation, which leads to the choice of software and used technologies.
3. When software and technologies are chosen, the next phase is to collect and process data, and accordingly, choose the basemap that highlights and supplements data.
4. When data is collected and processed, the next steps are referred to the compilation of the map and its' design. In the term of those theses, "Compiling a map" also includes a compilation of the WEB application. Despite the differences between map and application, in this case process involves both products – map and application.

The last phase is map publishing, which ends into a cycle from the very beginning, by overviewing the product and working on revision and the update of the product. This schema is a visualisation of how the life cycle of the product is provided. In terms of those theses, every phase includes WEB application as well as WEB map.

1.7. Star Rating and EuroRAP road classification

EuroRAP which works in 29 European countries, has rated 105,297 thousand km, mapped 1,2 million Crash rates and made 24 billion investments in all countries, also talks about a safe system approach. (EuroRAP, 2020) For this Master thesis, some of their ideas are used – like road star rating and road classification into 5 levels.

The EuroRAP approach to Safe system and road star rating conceptually is similar to the ideas of those theses:

The RAP approach includes an objective, evidence-based measure of the safety performance of the road for all road users that can guide policy, standards, and performance tracking. The RAP assessments also include fatality and serious injury predictions and high-level Safer Road Investment Plans that optimise lives saved per unit of investment. iRAP results are often used to deliver broad network level outcomes that

provide road authorities and others with risk assessment data and programme costs for high level planning, budgeting and the setting of road safety policy targets. (EuroRAP, 2020)



Figure 9. Countries of EuroRAP programmes and projects. (EuroRAP, 2020)

Blue pin drops on the map in *Figure 9. Countries of EuroRAP programmes and projects. (EuroRAP, 2020)* represents countries, that takes part in EuroRAP programmes and projects.

EuroRAP uses a complicated system of methodology to classify roads and grants the rating. However, in those Master thesis road classification is set by accident count per one road unit (km). The Author proposes to calculate accident rate (per 1km), which is the basic value for road safety star rating and safety classification. The formula is created and based on available data. The formula can be modified, if additional data is available and are related to road safety issues:

$$S_a = \frac{\sum n \times 1000}{l}$$

Where:

S_a – Accident rate (per 1km) – the sum of accidents per 1 km,

$\sum n$ – the sum of accidents along the road segment,

l – length of the segment (m).

This formula calculates the density of the accidents per 1 km. It gives precise density value but for visualisation and road classification it is not the best value to use due to the high number of possible values. Therefore, the Safety rating coefficient should be sorted into five classes using the formula:

$$R = \frac{\max S_a}{5}$$

Where:

R – safety rating interval;

max S_a – the highest value of safety rating coefficient.

The final road safety rating is set based on the safety rating coefficient which fits in specific safety rating interval:

Star rating	Classification value (risk)	Interval	Colour	Colour palette (R;G;B)
5 Star	Low	$S_a \leq R$	Green	148;194;96
4 Star	Low – Medium	$R < S_a \leq 2R$	Yellow	255;241;92
3 Star	Medium	$2R < S_a \leq 3R$	Orange	238;164;7
2 Star	Medium – High	$3R < S_a \leq 4R$	Red	232;82;54
1 Star	High	$4R < S_a$	Black	0;0;0

Table 2. Road safety classification levels

Values used in *Table 2. Road safety classification levels*:

- Star rating – name the rating value, set for the road segment. The number of stars are used to describe road safety reading in an easy understandable way.
- Classification value – describes road segment accident risk value.
- Interval – value which describes accident risk at the road segment.
- Colour – used for road segment visualisation.
- Colour palette (R;G;B) – Colour codes for visualisation.

Those colours and colour schemes are used in WEB map to classify road segment buffers accordingly to the road star rating and road classification value (risks). This colour schema makes a better visual understanding of the road segment safety and statistical data of the road accident amount in the road segment.

2. GEOSPATIAL TOOL DEVELOPMENT – ROAD TRAFFIC AND ROAD SEGMENT CLASSIFICATION

It is already stated earlier that the target of the Master thesis is to develop a GIS tool and a platform, which analyses input data (from different sources) to display a classification of road safety. The GIS tool takes into account publicly available road and traffic-related data to calculate and classify road segments into 5 safety levels. Because of the potential risks of data collection (restricted access and commercially sensitive data), the target of the Master thesis is to provide just a platform, where publicly available data are shown normally, but potential users with restricted access will have already designed platform for the further research process. Target is to provide a generic tool and platform suitable for any city and rural territory in Latvia, however, for the development process, the datasets of Riga as the capital and the largest city in Latvia are used as an example. During the development of the tool, the results were successful. Therefore, data that covers the whole country is included in the WEB map and application. However, for example only Riga, the few of largest cities and rural areas are used.

The practical part of the Master thesis is based on the theory of the thematic map creation process described in “*Tematiskā kartogrāfija*” (Štrauhmanis, 2002). The Author of the Master thesis chose to follow those guidelines as much it is possible. The Author mentions the most general phases of the development process of the GIS road accident analysis tool:

- Review of the road traffic safety literature.
- Data gathering from different sources.
- Data reviewing, sorting, and pre-processing.
- Road accident data processing and analytic tool development in ArcGIS Model builder.
- Data visualisation, WEB map design, data, and WEB map publishing to ArcGIS online.
- WEB application development, design, and configuration in ArcGIS Web AppBuilder.

All those phases are intended to be part of a circular process and can be reviewed, analysed, modified, and repeated.

2.1. Data

For the Master thesis, Author uses open source and freely available data and data that is provided by companies without any charge. The Author has chosen to use open-source data to provide society, road and traffic responsible authorities, and other interested parties with GIS and geospatial data capabilities. In case of the successful development of the GIS tool and further research, the Author considers using subscribed data or bought data from third parties (companies).

2.1.1. LVC Data

The Latvian State Roads (LVC) is the only organisation (company) whose responsibilities are to maintain and manage the Latvian State road network and infrastructure. *The Latvian State Roads (LVC) performs the management of the state road network, administration of the State Road Fund and organisation of public procurement in order to provide the public with profitable, durable, safe and environmentally friendly state road network. Maintenance and development of parish, company and household roads is supervised, as well. (LVC, 2020)* LVC offers a State road network centreline data at Latvia's Open Data portal. This centreline dataset as well as State road network traffic intensity data is freely available for downloads. *(Latvia's Open Data portal, 2020)*

For the tool development at least two LVC data sets should be used:

- *satiksmes-intensitate-2008-2018-1.xls* – which contains Annual average traffic intensity data.
- *LVC_CENTERLINES.gdb* – file geodatabase with State road network centreline data.

Those two datasets would ensure some of the basic requirements for GIS tool development - road network, which is essential for road accident analysis per road segment and traffic intensity data, which would allow identifying most intense roads and road segments.

These data sets have some advantages and disadvantages. As an advantages Author mentions:

- Reliability – data is provided by an official source;
- Quality – data is sorted, without errors and contains official names of the roads;

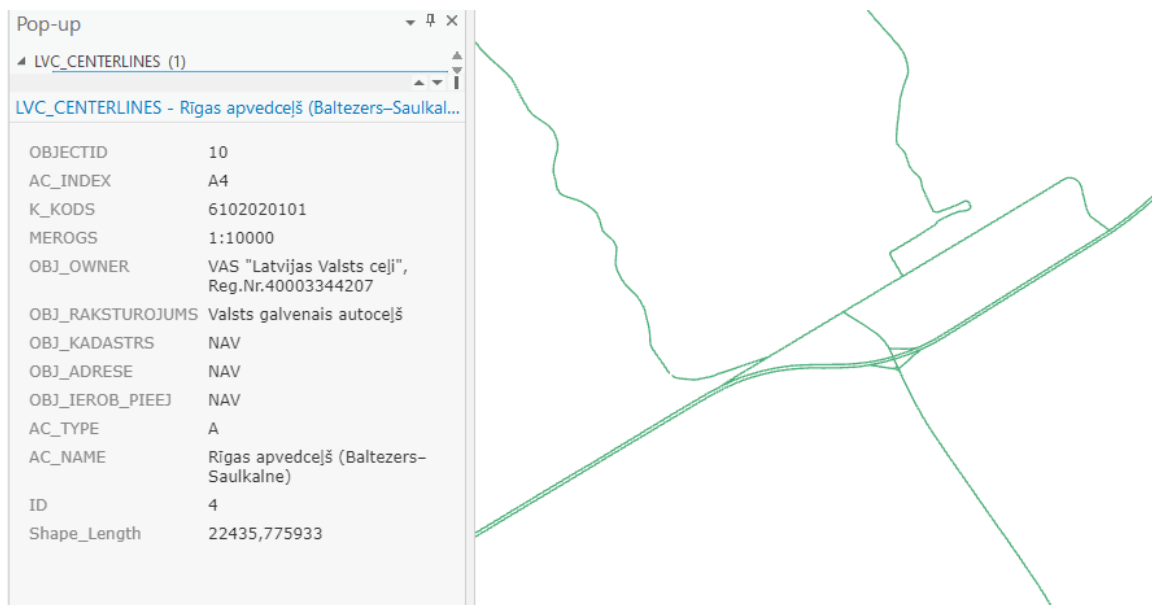
and disadvantages:

- Update frequency – irregular, depending on LVC;
- Cities – Data set does not include street centreline data of cities;
- Compatibility - State road centreline data does match the corresponding records from the traffic intensity data files.

Comparing advantages and disadvantages of LVC provided data, the Author decided to not use LVC data for developing the GIS tool, for the main reason referring to excluded city street data and incompatible State road centreline and traffic intensity data. *Figure 10. LVC provided State road network centreline data.* and *Table 3. LVC provided Annual average traffic intensity data.* show that State road centrelines do not have a corresponding attribute value in the traffic intensity table. At the intensity data table, road segment records (that have traffic intensity values) have been identified by the start and endpoint value, measured in km, while in geospatial data, road segments are called in a name (Attribute: “AC_NAME”). This difference does not allow to join these data sets automatically, therefore these datasets are reviewed and suggested for further research.

For future tasks, Author suggests – LVC publish and provide mutually compatible datasets at Latvia's Open Data portal. Second suggestion – develop a linear reference system.

Linear Referencing (LR) is the specification of a location by means of a distance measurement along a sequence of road sections (a “traversal”) from a known reference point (the “traversal reference point”). (Val Noronha, Richard L. Church, 2002) LRS is the system that should be developed on the basis of State road centrelines, and the data from traffic intensity table records can be used, located, and joined with the objects from the State road network.



CeĶa Nr.	posms	no km	līdz km	2008											2018	2008 KT%	2009 KT%	2010 KT%	2011 KT%	2012 KT%	2013 KT%	2014 KT%	2015 KT%	2016 KT%	2017 KT%	2018 KT%
A-1	A2 - Draudzības iela Ādaži	0,000	6,940	18535											26856	14	10	10	10	15	13	13	17	14	14	14
	Draudzības iela Ādažos - V	6,940	13,030	11791											14802	14	13	12	14	14	15	15	14	19	19	19
	V45 - V101	13,030	21,300	10787											13035	17	14	17	15	14	19	22	19	19	21	20
	V101 - V39	21,300	31,620	5039											9404	22	14	21	26	22	21	21	22	25	25	25
	V39 - V135	31,620	40,410	5056											8097	25	20	25	27	28	26	31	29	27	31	29
	V135 - P 11	40,410	57,677	4898											6670	28	27	31	33	34	33	34	33	34	34	34
	P11 - Salacgrīva	57,677	83,875	3099											5555	34	32	40	32	41	40	41	41	40	41	44
	Salacgrīva - LV robeža	83,875	101,737	3339											4573	36	27	23	20	24	24	24	45	40	45	43
A-2	Rīga - A1	12,405	14,129	27699											40660	11	9	9	11	11	11	11	11	10	10	11
	A1 - Garkalne	14,129	21,520	21769											29834	14	12	14	14	14	16	17	13	14	14	13
	Garkalne - Inčukalns	21,520	37,709	16248											21586	15	9	16	15	18	17	26	21	19	19	19
	Inčukalns - Sigulda	37,709	51,459	12286											12984	14	10	16	16	16	17	17	14	13	13	13
	Sigulda - Līgatne	51,459	63,309	8286											10250	17	15	18	18	17	19	19	16	17	16	16
	Līgatne - P20	63,309	77,766	8123											8650	17	16	18	20	19	19	18	17	17	17	17
	P20 - P30	77,766	94,176	5020											3595	17	13	21	20	25	21	21	20	19	20	24
	Bērzkrogs - P27	94,176	126,498	3684											3975	20	21	20	21	25	21	25	24	24	24	20
	P27 - P39	126,498	176,421	1262											1657	26	24	25	26	27	29	28	26	25	27	27
	P39 - LV robeža	176,421	195,567	537											782	28	22	22	21	24	26	32	26	25	25	25

Therefore, if LVC data would be available with LRS capability, this dataset would be excellent for road accident analysis and development of GIS WEB map and application. Another approach – State road centreline data must be supplemented with a new attribute column (“*posms*” – segment name), which would contain identical values from the traffic intensity table. In that case, Excel data would be adjusted to GIS table principles and would be imported into the GIS database and joined together with State road centrelines, ensuring geospatial data with additional traffic intensity information.

2.1.2. IeM CAIS data

For the road accident analysis and GIS tool development road accident data is required. According to Authors idea and objectives, this data set is the most important. It is also the largest containing data of approximately 1.3 million accident points. The data is provided by the Information Centre of the Ministry of the Interior. During the development process, several data sets have been downloaded. The latest version of data has been downloaded from IeM CAIS on 03.12.2020. (Link to the data source: <https://gis.ic.iem.gov.lv/giswebcais/>)

The Information Centre of the Ministry of the Interior is a direct administration authority subordinate to the Ministry of the Interior. The purpose of the activities of the Centre is to facilitate the prevention and combating of crime and the protection of public order and safety by utilising the means of information processing and analysis, as well as to provide the Ministry of the Interior and its subordinate institutions with effective radio communication and private electronic network systems, which comply with the requirements set by the European Union. (Information Centre of the Ministry of the Interior, 2020)

IeM CAIS offers road accident data in CSV file format and records are dated from 2010. Therefore, for those Master theses and the final WEB map and application the full road accident data set is been used. Data is available for downloads in IeM CAIS and CAIS user must set the desired filters. The Author has set filters, to get all available data (*Figure 11. IeM CAIS. Downloading road accident data.*):

- Accident from 02.12.2010. 00:00 till 29.11.2020. 23:59
- Territory – Latvia;
- Casualties – not applicable;
- Drink driving – not applicable;
- Criteria refer to – whole accident;
- The legal qualification of the accident - not applicable.

← → ↻ gis.ic.iem.gov.lv/giswebcais/ ☆ ☰

Ceļu satiksmes negadījumu un pārkāpumu notikuma vietu analīzes informācijas sistēma

Atlasīt | Lejupielādēt atlasītos datus | Lejupielādēt karti | Apzīmējumi

Notikums no līdz

☒ Ceļu satiksmes negadījumi (CSNg) ☐ Likumpārkāpumi (bez CSNg) ☐ Visi

☒ Visa Latvija

☐ Ir ievainotie vai bojāgājušie un ir vecumā no līdz

☐ Ir bojāgājušie

☐ Nav ievainoto vai bojāgājušo

☒ Nav nozīmes

☐ Ir reibumā un ir vecumā no līdz

☐ Nav reibumā

☒ Nav nozīmes

Kritēriji attiecas uz:

☒ Notikumu kopumā

☐ Uz vienu no dalībniekiem un atradās vai vadīja

CSNg veids:

Iemesli:

Laika apstākļi:

Seguma veids:

Brauktuves stāvoklis:

Ceļa apstākļi:

Papildus raksturojums:

Apgaismojums:

Notikuma juridiskā kvalifikācija

☐ Administratīvo pārkāpumu kodekss ☐ Krimināllikums ☒ Nav nozīmes

☐ Pieprasīt datus tikai saraksta veidā

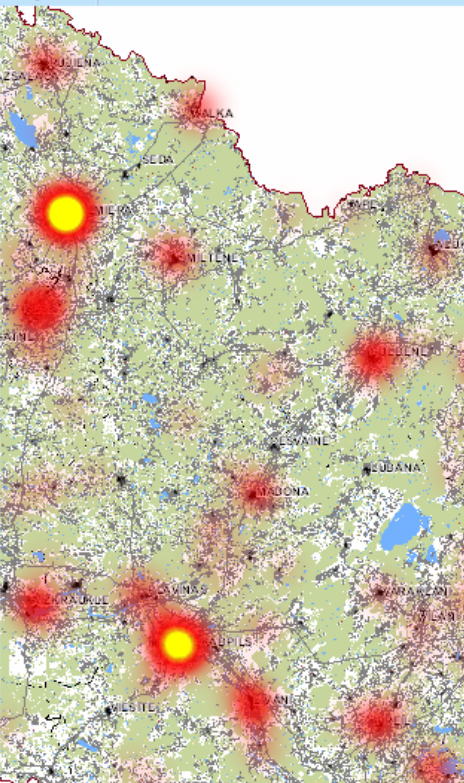


Figure 11. IeM CAIS. Downloading road accident data.

CSV files with the data from IeM CAIS is downloaded in compressed ZIP format. After uncompressing the ZIP file, 5 CSV data files and 1 description TXT file is available. Those files are shown in *Figure 12. Downloaded IeM CAIS data* and they refer to:

- YYYYMMDDhhmm_Apraksts.txt – description file;
- YYYYMMDDhhmm_CaisVirsnos.csv – road accident point data;
- YYYYMMDDhhmm_Dalibnieki.csv – involved persons (participants);
- YYYYMMDDhhmm_JuridiskaKvalifikacija.csv – the legal qualification of the accident;
- YYYYMMDDhhmm_NegadijumaDetalas.csv – accident details;
- YYYYMMDDhhmm_SaistitieRegistri.csv – related registers;

where YYYYMMDDhhmm represents the date, when data has been downloaded:

- YYYY – year;

- MM – month;
- DD – day;
- hh – time (hours);
- mm – time (minutes).

Name	Date modified	Type	Size
 202012021830_Apraksts.txt	02.12.2020 18:31	Text Document	1 KB
 202012021830_CaisVirsnok.csv	02.12.2020 18:31	Microsoft Excel C...	258 523 KB
 202012021830_Dalibnieki.csv	02.12.2020 18:31	Microsoft Excel C...	83 395 KB
 202012021830_JuridiskaKvalifikacija.csv	02.12.2020 18:31	Microsoft Excel C...	261 824 KB
 202012021830_NegadijumaDetalas.csv	02.12.2020 18:31	Microsoft Excel C...	39 114 KB
 202012021830_SaistitieRegistri.csv	02.12.2020 18:31	Microsoft Excel C...	36 762 KB
 rezultati.zip	02.12.2020 18:32	Compressed (zipp...	94 470 KB

Figure 12. Downloaded IeM CAIS data

During the data download process, an unexpected error occurred, and data download was unsuccessful. The Author considers a few possibilities, like data and data server protection from large data requests, loss of internet connection during a download or other issue. Therefore, the Author made an eleven (11) independent data download requests per each year, starting from 2010 data till 2020. It led to changes in data processing model in GIS tool and turned into an additional feature – after those changes in the GIS tool, user can make different download requests from IeM CAIS, download several files and process all of them at the same time.

Despite process automatization and GIS tool capabilities to process the input data files automatically, some manual changes had to be made. One of the tasks GIS tool performs is the input file conversation to GDB table. The restrictions of GDB requires specific file name requirement – the output file name, which is converted and stored into a GDB, cannot start with a numeric character. Therefore, all input file names should be manually fixed, that they do not start with the number. Author fixed the file names, replacing date and time values from the beginning to the end of a file name (Example: CaisVirsnok_202012031143.csv).

Esri provides a solution at ArcGIS Pro Tool Reference site:

Description. *Any database may have naming restrictions for table and field names. For instance, a table in a file geodatabase cannot start with a number or a special character such as an asterisk (*) or percent sign (%).*

Solution. *Alter the name to remove the invalid first character. ArcPy methods exist that allow you to validate table and field names. Consider using either the ValidateTableName or ValidateFieldName function to ensure your name is valid. (Esri, 2020)*

After changing the file name, input data files are ready for data processing.

2.1.3. LTAB Road traffic accident data

In the LTAB (Motor Insurers' Bureau of Latvia) WEB site is available road traffic accident map (*Figure 5. LTAB interactive WEB map (LTAB, 2020)*). It is publicly available and contains two data sets. Both are road traffic accident-related and contain values of the accident costs (OCTA insurance claims). *The objective of the Bureau is to ensure the protection of third persons' interests that have suffered in a traffic accident as well as to promote the stability and development of the compulsory third party liability insurance for inland motor vehicle owners (Latvijas Transportlīdzekļu apdrošinātāju birojs, 2020).*

LTAB provided road traffic accident map consists of two types of data sources: first is LTAB data, collected on basis of European Accident Statement, where State road police involvement has not been required, second – road accident data and OCTA insurance claims registered by the State road police protocols. The second data type is provided by IeM and data points overlaps with IeM CAIS data. Therefore, this data is not included in the Master thesis. However, the dataset used in the Master thesis can be supplemented with the State road police protocol data.

For the purpose of the Master thesis, LTAB provided data on basis of European Accident Statement and it was combined together with the data of IeM CAIS. The example

of the provided CSV file is shown in *Table 4. Road accident data in CSV file, provided by LTAB*, where:

- DATUMS – Date;
- GARUMS – Longitude (WGS-84);
- PLATUMS – Latitude (WGS-84);
- IZMAKSAS – Costs.

DATUMS	GARUMS	PLATUMS	IZMAKSAS
01.01.2016 01:20	26.51680815	55.87236549	763.93
01.01.2016 13:30	24.09564611	56.91769511	639.37
01.01.2016 15:20	27.26620047	57.1326856	138.35

Table 4. Road accident data in CSV file, provided by LTAB

2.1.4. OpenStreetMap data

OpenStreetMap is a project that was developed and launched to create and distribute free geographic data for the world. OSM data is used because of most other maps and data is not free of charge or have legal or technical restrictions on their use, therefore OSM data was chosen for use at those Master theses (*OpenStreetMap, 2020*).

The latest OSM data was downloaded at 07.12.2020. from WEB site:

<https://download.geofabrik.de/europe/latvia.html>

The downloaded OSM data consists of 18 SHP files with a wide range of cartographic data (*Figure 13. The downloaded OSM data in SHP files*). For the Master thesis only 4 of SHP files are used:

- gis_osm_traffic_free_1.shp – Traffic related points (point features);
- gis_osm_pois_free_1.shp – Points of interest (point features);
- gis_osm_roads_free_1.shp – Roads and paths (line features);
- gis_osm_pois_a_free_1.shp – Points of interest (polygon features).

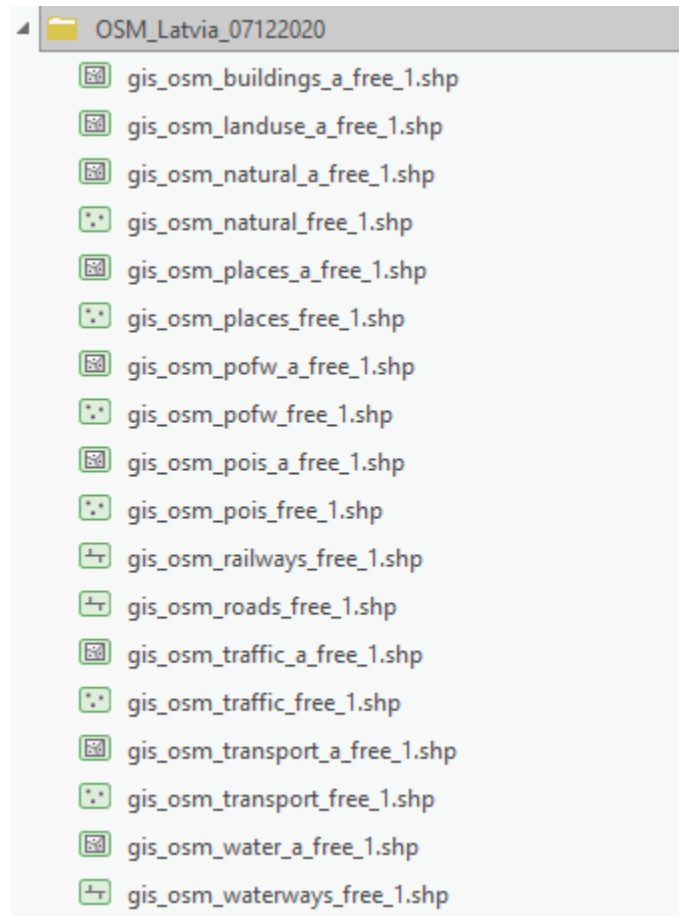


Figure 13. The downloaded OSM data in SHP files

2.2. Data processing model and workflow

The workflow of the road accident WEB map and application consists of several phases and task. All of them requires using the ArcGIS Desktop and WEB based technologies. For the main objective of the Master thesis – developed WEB map and application – few major user-cases must be considered:

- Is this a one-time project?
- Does the data need an update?
- Who is going to review the WEB map and the application?
- How often any changes are required?

Considering all those questions, the Author decided to develop the road accident WEB map and application, that can be updated as needed and datasets as well. Therefore, the Author used ArcGIS Model Builder, instead of manual data processing, to create semi-automatic data processing models to reduce manual data processing to a minimum.

The next figures of model schemas from ArcGIS Model Builder show algorithms of input and output datasets and how data is processed. Each schema contains identical symbology, and each object represents input or output file, names of the process or other parameters. The objects are:

- Blue circle – data processing input file. With the letter “P” object is defined as a parameter and can be changed by the user.
- Orange hexagon – iterator, provides repeat function of the model tasks.
- Green circle – data processing output file. With the letter “P” object is defined as a parameter and can be changed by the user.
- Yellow “*rectangle*” – function, taken from ArcGIS geoprocessing tool library, that performs specific tasks.
- Light blue circle – results or status updates of the results.
- Grey circles – for this task, unnecessary output files, required for the proper run of the ArcGIS tools.
- Black arrow – shows the relationship between object – process (function) and input or output files and a result etc.
- Light arrow – shows (defines) precondition of the performed tasks or the sequence of the tasks in the model.
- Name in the object – represents and describes the input or output file or processes. Helps to navigate a user through the model parameters and processes.

2.2.1. IeM CAIS road accident data processing

00_CAIS_data_template – Model uses CAIS data CSV files to create template feature classes. The model takes input files and converts them to GDB feature class (accident point feature class) or GDB tables (accident-related data tables). The model removes all the records from GDB tables and feature class. It leaves a clean GDB and DBSchema for further processes.

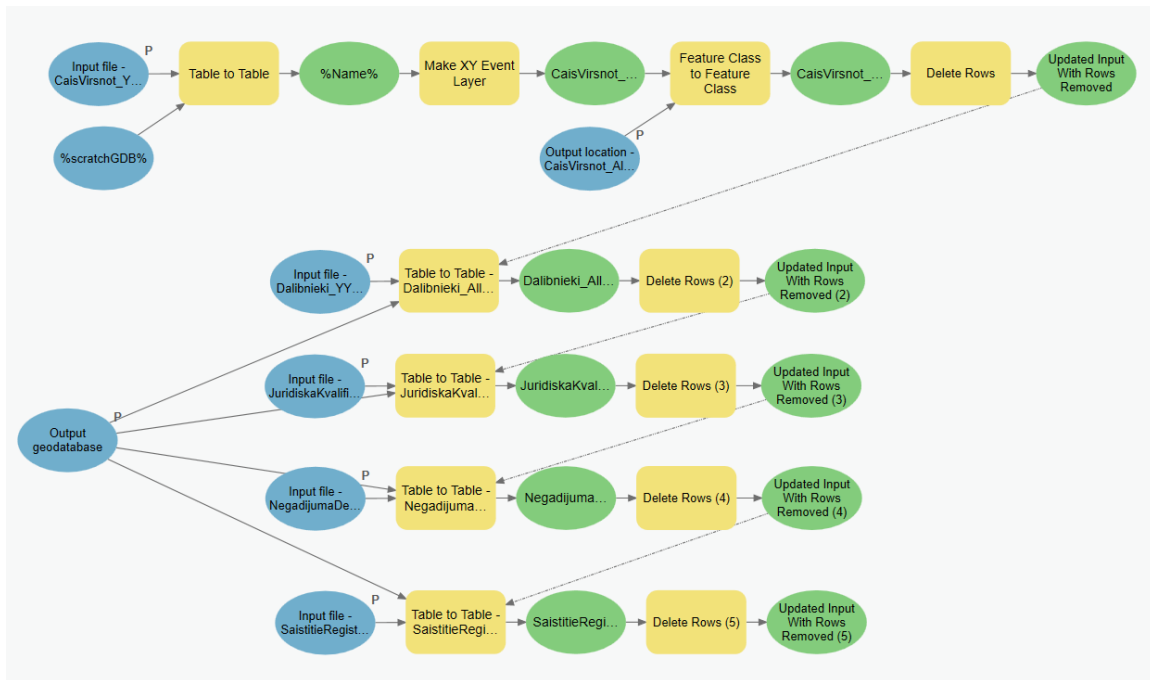


Figure 14. Model - 00_CAIS_data_template

01_CSV_to_GDB_CaisVirsnot – model iterates road accident data from IeM CAIS and creates a point feature layer from CSV input files. The model use coordinates from the CSV file and locates them on the map. It is required for the output file or output feature class location, to use a *Feature dataset* in a GDB. *Feature dataset* must be defined in an LKS-92 coordinate system. If the input file or input file location is set as a file folder, the model seeks for all road accident files in the input file location with the name that contains the character string “*CaisVirsnot**”, where “***” represents other characters. Model iterates these files, create point feature layers and appends them into one single feature layer, deleting intermediate results. The result is IeM CAIS provided road accident point feature layer with relevant attributes.

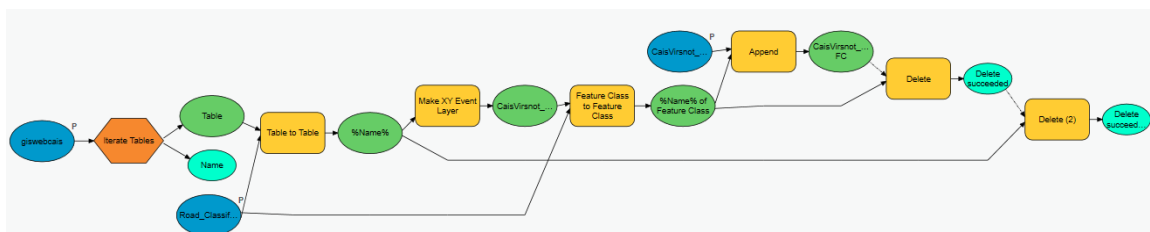


Figure 15. Model - 01_CSV_to_GDB_CaisVirsnot

These data processing models have similar working principles:

- 02_CSV_to_GDB_Dalibnieki;
- 03_CSV_to_GDB_JuridiskaKvalifikacija;
- 04_CSV_to_GDB_NegadijumaDetalas;
- 05_CSV_to_GDB_SaistitieRegistri.

Those models iterate road accident-related data tables from IeM CAIS and create geodatabase tables from CSV input files. The model seeks for a specific road accident CSV file name and converts each CSV file accordingly to the geodatabase table and appends them into 4 geodatabase tables according to the file name. Model deletes all subproducts which were created during the conversion process.

Model seeks for specific file names from input data folder and its subfolders:

- 02_CSV_to_GDB_Dalibnieki – “Dalibnieki*”
- 03_CSV_to_GDB_JuridiskaKvalifikacija – “JuridiskaKvalifikacija*”
- 04_CSV_to_GDB_NegadijumaDetalas – “NegadijumaDetalas*”
- 05_CSV_to_GDB_SaistitieRegistri – “SaistitieRegistri*”

Where symbol “*” requests model to ignore further part of the file name. It allows the model to use any CSV file downloaded from IeM CAIS, ignoring the date and the time appendix in the file name. Schemas of each model are shown below.

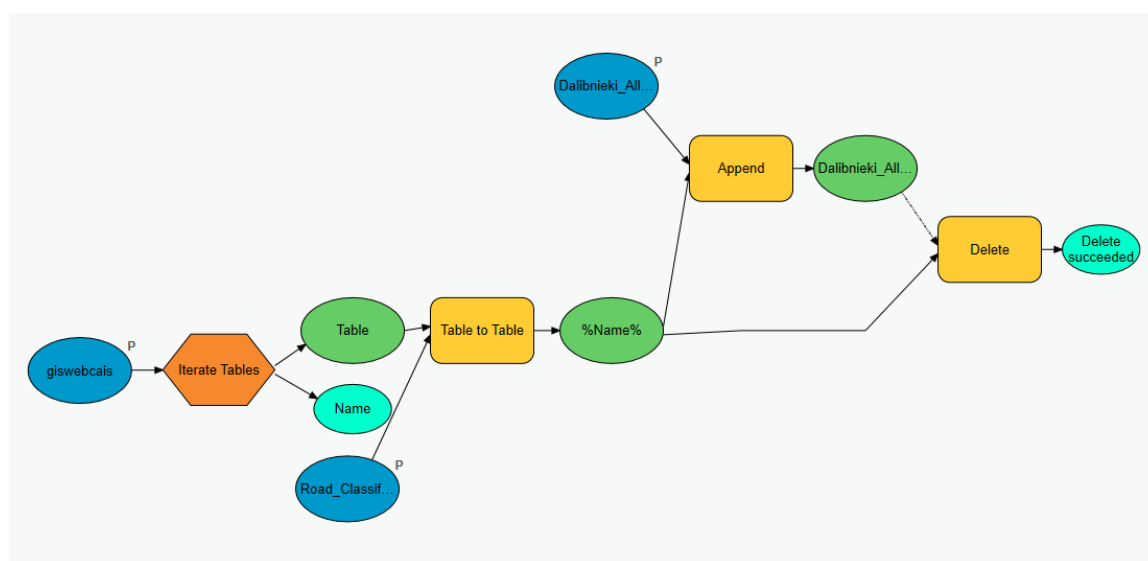


Figure 16. Model - 02_CSV_to_GDB_Dalibnieki

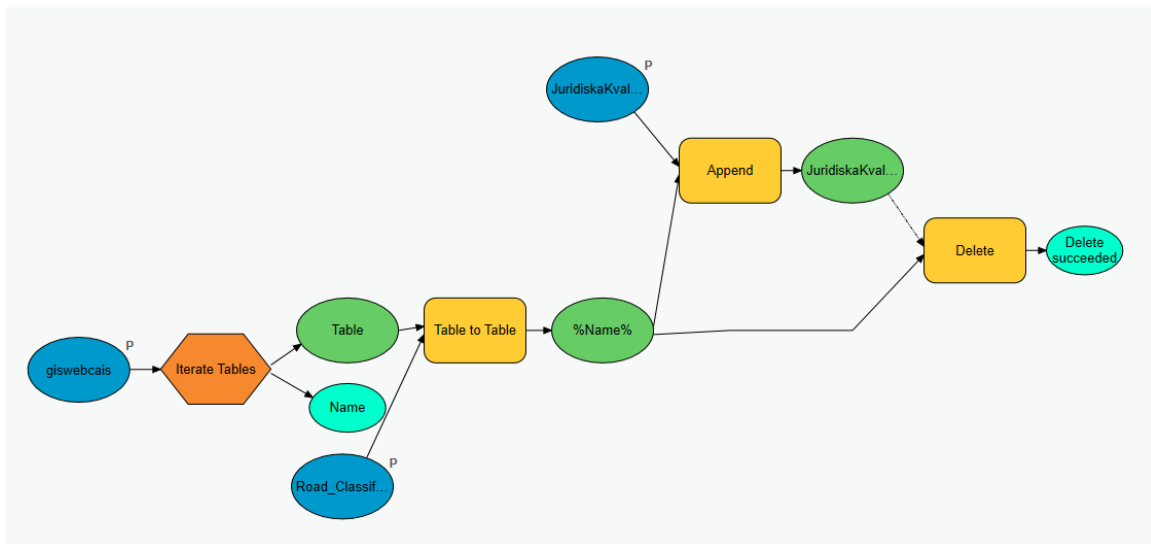


Figure 17. Model - 03_CSV_to_GDB_JuridiskaKvalifikacija

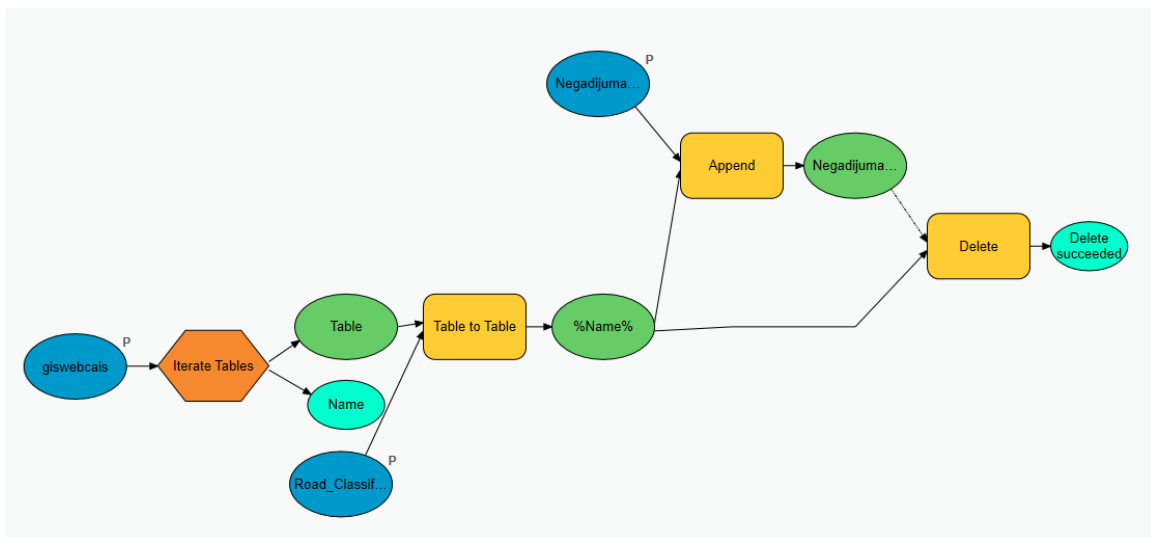


Figure 18. Model - 04_CSV_to_GDB_NegadijumaDetalas

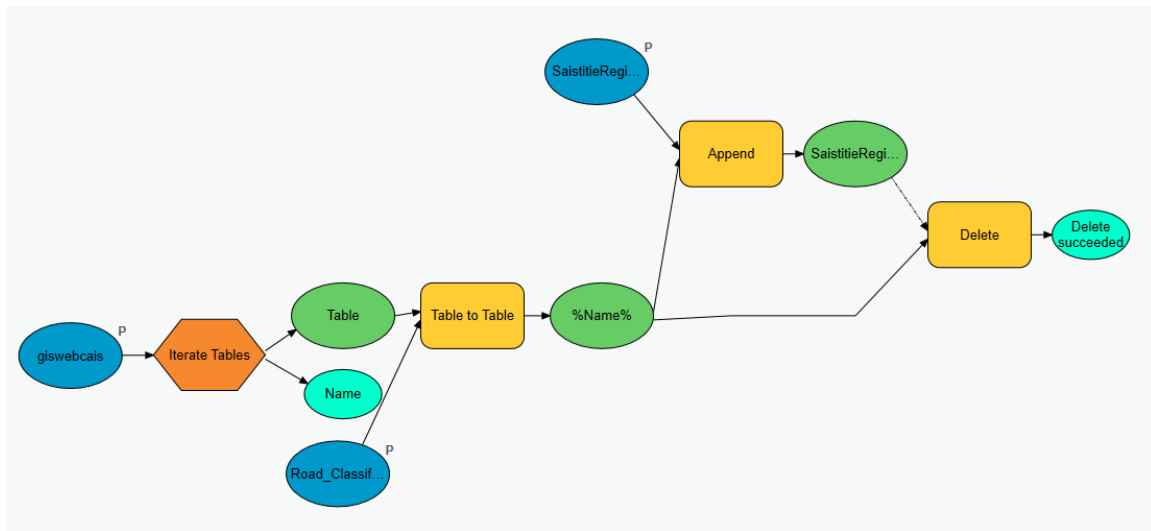


Figure 19. Model - 05_CSV_to_GDB_SaistitieRegistri

2.2.2. IeM CAIS data cleaning

After the basic data processing and conversion from CSV files to GDB feature class and tables, road accident point data must be reviewed and fixed if necessary. After data reviewing Author found data errors. In this case, data errors were considered all records with identical attribute values, especially if “Event ID” (*Notikuma identifikators*) were identical (duplicates). The Author found duplicates and remove them as instructed below.

The Author used ArcGIS “*Find Identical*” Data management tool to find identical records and export them to separate GDB table. There were 1466 identical records found (Figure 20. CAIS data duplicates).

OBJECTID *	IN_FID *	FEAT_SEQ
1	764311	1
2	764312	1
3	764313	1
4	764314	1
5	764315	1
6	764316	1
7	764317	1
8	764318	1
9	764319	1
10	772739	2
11	772740	2
12	772741	2
13	772742	2

Figure 20. CAIS data duplicates

Duplicate table was joined to “*CaisVirsnot_AllData*” to display in ArcGIS Pro software only duplicated records. The Author reviewed them and deleted duplicates leaving only one original object. The review has based on comparison of duplicate date, to approve of data error. Duplicated records are selected and deleted manually, leaving only one – an original record. In this case – from 9 records only 1 will be kept. (*Figure 21. Cleaning data duplicates*)

OBJECTID	Notikuma datums	Notikuma vieta	Notikuma veids	Notikuma status
1320928	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28
1320929	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28
1320930	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28
1320931	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28
1320932	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28
1320933	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28
1320934	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28
1320935	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28
1320936	2019.12.29 12:50:00	Cēsu nov., Cēsis, Rāzna iela 26/28	1 0 0 0 0 0 0 0 0	Cēsu nov., Cēsis, Rāzna iela 26/28

Figure 21. Cleaning data duplicates

Data errors were found by duplicate “Event ID” (*Notikuma identifikators*) and errors are displayed on the map in *Figure 22. Visualised data errors (duplicates)*.

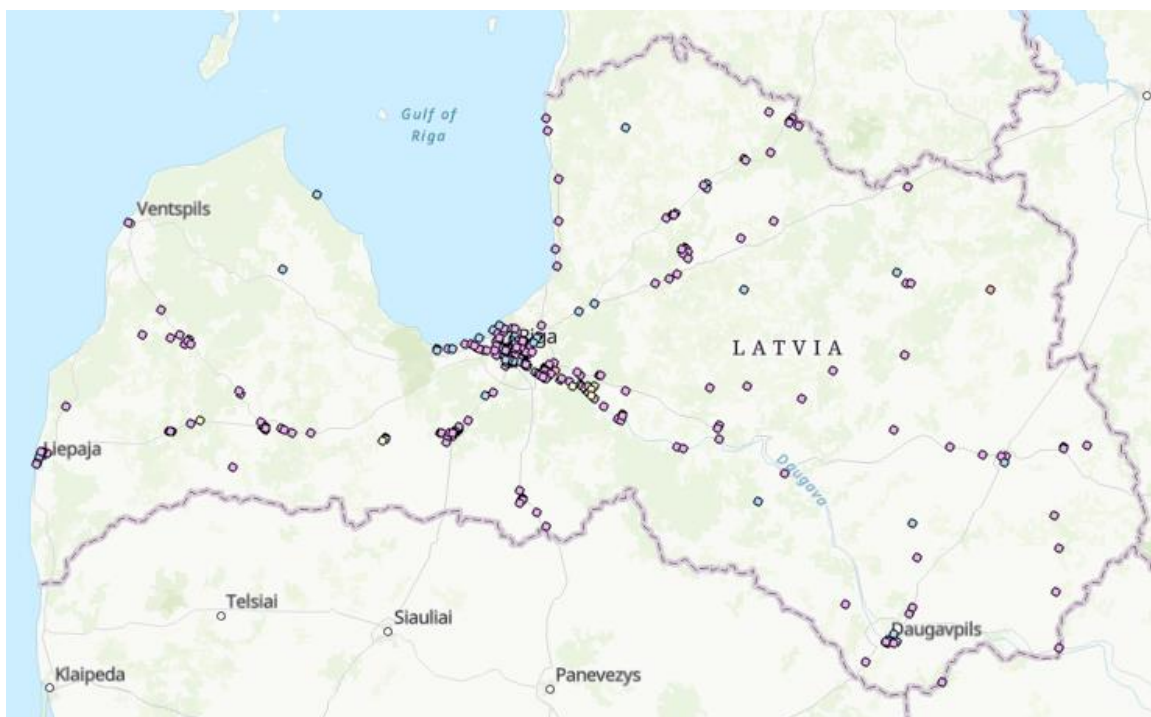


Figure 22. Visualised data errors (duplicates)

After removing all duplicates only one original record was left. Data cleaning results are shown in *Figure 23. Results of CAIS data cleaning*. From 1466 records only 435 original records were kept.

CaisVirsnot_AllData_FindIden				
CaisVirsnot_AllData				
Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy				
OBJEC	S	Notikuma id	Notikuma datums	Notikuma vieta
1343490	Po	178956980	23.03.2020 18:35:00	Rīga, Krišjāņa Valdemāra iela 22
1344369	Po	178956997	30.03.2020 10:56:00	Ķeguma nov., Birzgaļes pag.
1344345	Po	178957003	30.03.2020 10:26:00	Lubānas nov., Lubāna, Ozolu iela un Stacijas iela krustojums
1344503	Po	178957007	30.03.2020 20:10:00	Rīga, Ezera iela 22A
1344305	Po	178957015	30.03.2020 04:10:00	Daugavpils nov., Skrudalienas pag.
1344391	Po	178957016	30.03.2020 12:19:00	Amatas nov., Drabešu pag., Ieriķi, autoceļš A2
1344268	Po	178957026	30.03.2020	Jēkabpils, Brīvības iela

Figure 23. Results of CAIS data cleaning

2.2.3. IeM CAIS data relationship classes

06_Create_Relationship_Class_AllData – model creates relationship classes between road accident point feature layers and descriptive tables, which were converted from CSV file to GDB tables earlier:

- *Dalibnieki_AllData*
- *JuridiskaKvalifikacija_AllData*
- *NegadijumaDetalas_AllData*
- *SaistitieRegistri_AllData*

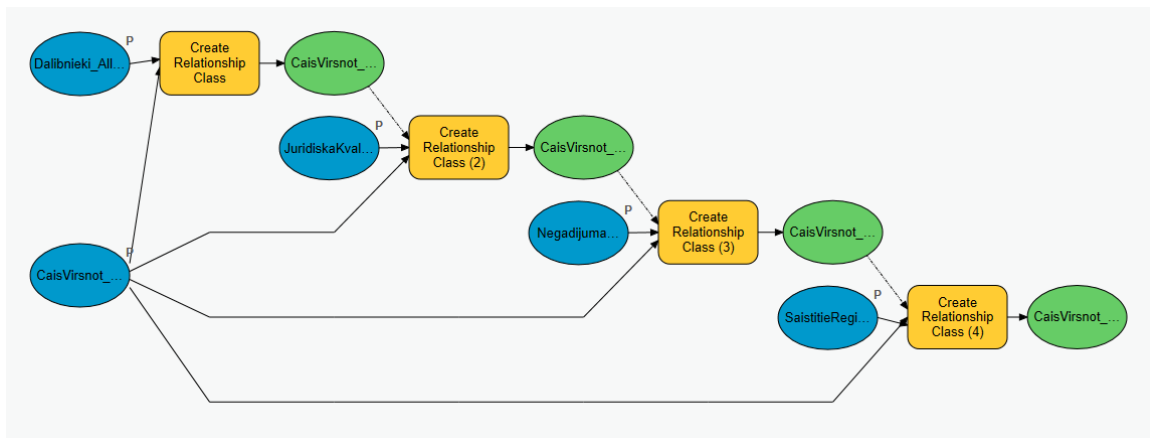


Figure 24. Model - 06_Create_Relationship_Class_AllData

Relationship classes are made, to ensure relation between CAIS road accident data points and descriptive tables. Those tables contain descriptive data of the road accidents and supplements point features. The data structures of the tables (DBScehama) are completely different the point features, therefore it is not recommended to join these tables directly to point features. A better solution is creating a relationship class that ensures the capability to select all related records from related tables when specific point features are selected. This capability allows a user at WEB application or ArcGIS Pro select specific road accident features and automatically select only related records from the related tables. User can review supplemented accident information and get more details about accident and accident details than just a location point.

Figure 25. *Create Relationship class* shows parameters of relationship classes.

- Origin table – CaisVirsnot_AllData is point feature class, to which tables will be related to.
- Destination Table – a table which will be related to the point feature class.
- Relationship Type – SIMPLE – the relationship between independent objects (parent to parent). This is the default of ArcGIS “*Create Relationship class*” geoprocessing tool.
- Forward Path Label – a name to uniquely identify the relationship when navigating from the origin table to the destination table. The ArcGIS default value is used.
- Backward Path Label – A name to uniquely identify the relationship when navigating from the destination table to the origin table. The ArcGIS default value is used.
- Message Direction – None (no messages propagated) – No messages passed. This is the default of ArcGIS “*Create Relationship class*” geoprocessing tool.
- Cardinality – One to many (1:M) – Each row or feature in the origin table can be related to one or several rows or features in the destination table.
- Origin Primary Key – The field in the origin table. “*Notikuma_identifikators*” (*Event ID*) field, that links it to the Origin Foreign Key field in the relationship class table.
- Origin Foreign Key – The field in the relationship class table that links it to the Origin Primary Key field in the origin table. “*Notikuma_identifikators*” (*Event ID*) field is used as the foreign key.

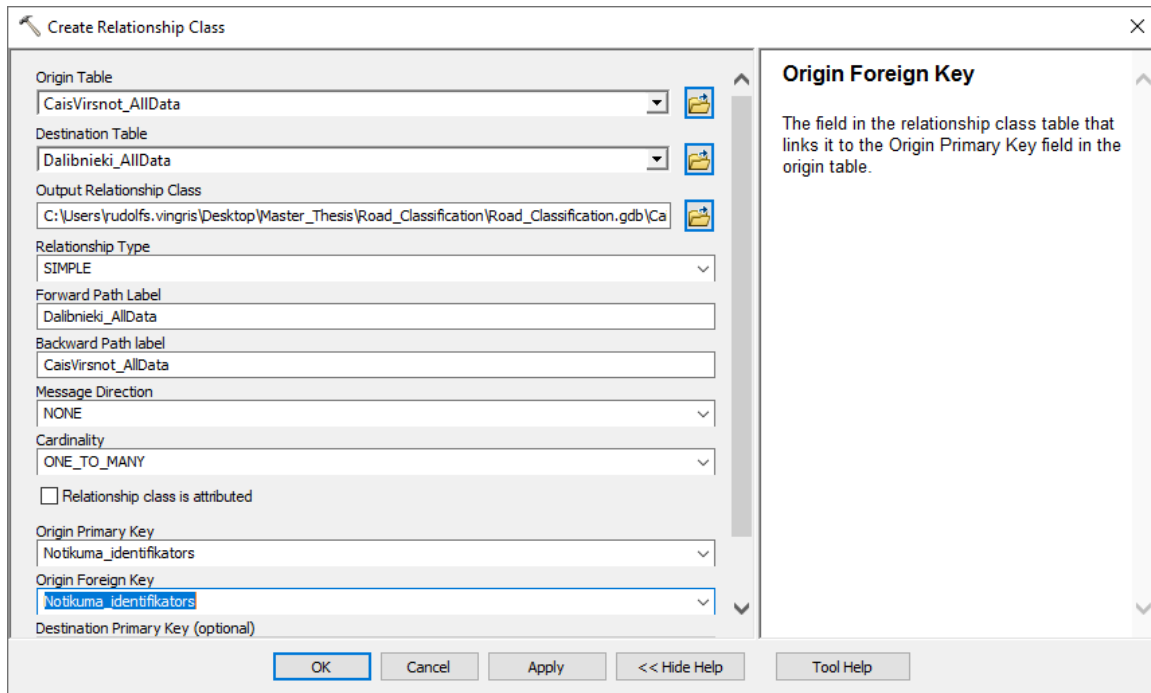


Figure 25. Create Relationship class

After running this process, relationship classes are made in the same database where accident point feature class and accident data tables are stored.

2.2.4. OSM data conversion to geodatabase

Road accident point features displays location of the accident and its supplemented information it allows user to understand each accidents' details un probably the cause of an accident. However, this dataset without additional data does not give justified information about road and street infrastructure and its' safety parameters. Therefore, road infrastructure data must be used. In this Master thesis, OSM data is been used for creating a road network and additional infrastructure which impacts or refers to road safety. Those datasets are:

- street crosswalks;
- traffic lights;
- schools (important objects);
- parks and playgrounds
- etc.

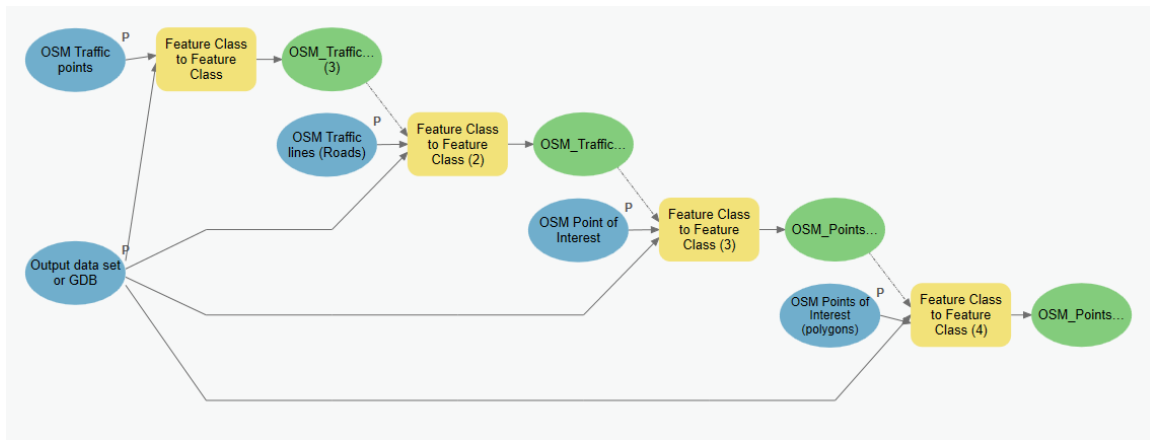


Figure 26. Model - 07_OSM_data_processing

Figure 26. Model - 07_OSM_data_processing model uses only specific OSM shapefiles, set definition queries for the conversion process and converts them to GDB feature classes. The model uses 4 SHP files and sets specific SQL definition queries:

- gis_osm_traffic_free_1.shp (OSM Traffic points)
Definition query:
`fclass IN ('traffic_signals', 'mini_roundabout', 'stop', 'crossing', 'motorway_junction', 'turning_circle', 'speed_camera', 'street_lamp')`
- gis_osm_roads_free_1.shp (OSM Traffic lines (Roads))
Definition query:
`fclass IN ('trunk', 'primary', 'secondary', 'tertiary', 'unclassified', 'residential', 'living_street', 'trunk_link', 'primary_link', 'secondary_link', 'tertiary_link')`
- gis_osm_pois_free_1.shp (OSM Point of Interest)
Definition query:
`fclass IN ('community_centre', 'university', 'school', 'kindergarten', 'college', 'hospital', 'doctors', 'park', 'playground')`
- gis_osm_pois_a_free_1.shp (OSM Points of Interest (polygons))
Definition query:
`fclass IN ('community_centre', 'university', 'school', 'kindergarten', 'college', 'hospital', 'doctors', 'park', 'playground')`

After data processing, model stores filtered OSM data into the output GDB.

08_Road_Street_Buffers_for_OSM_CSN_Analysis – model prepares OSM road line data for analysis. To calculate road accident density in the road segment, it is essential to know the length of the road segment. Therefore, this model adds a new field (*Road_length*) to already processed OSM road lines. In the next step, model calculates OSM road segment length (field *Shape_Length*) into the new *Road_length* attribute field. As the last step of the model, it creates polygon features – buffers around road lines. Buffer radius is set and can be changed by the user.

Buffer radius around street or road (m)	Sum of the Accident points (Total: ~1 320 939)
10 m	~ 764 170
15 m	~ 782 332
20 m	~ 796 888
25 m	~ 827 810

Table 5. Sum of accident points into the buffers

In this Master thesis, buffer radius is set to 10m. *Table 5. Sum of accident points into the buffers* shows, point difference between sums of the accident point is not so great, but 10m buffer provides better precision. Also, 10m buffer aligns with the street area.



Figure 27. Example of street buffer with 10m radius

If road buffers (polygon features) are used in further analytics, it is essential to use *Road_length* attributes values instead of *Shape_Length*. For the polygon features, attribute

field *Shape_length* will describe the perimeter of the polygon, and that is not acceptable for this task.

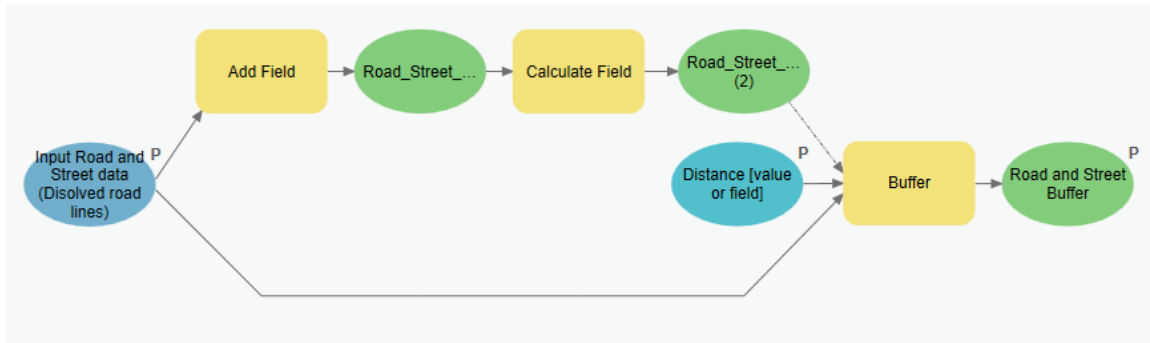


Figure 28. Model - 08_Road_Street_Buffers_for_OSM_CSN_Analysis

2.2.5. Road and street data preparation for analysis

09_AccidentData_Analysis – model is intended to prepare OSM road line data for analysis, where count of road accidents are calculated per whole road or street. This model ignores road segments and creates a buffer around the whole street or road. The whole street or road is defined by the road or street name. The model used previously created road lines and creates new buffer polygons. New buffers are being dissolved based on the road or street name. the model does not make multi-part polygons, therefore it is possible to create a road and street buffers with the same name in different places. For example – if many polygons with the same street name “*Rīgas iela*” are found, there will be created many buffer polygons, following the rule – buffers must intersect or overlap each other. Otherwise, those polygons will be separated, like it is in different cities.

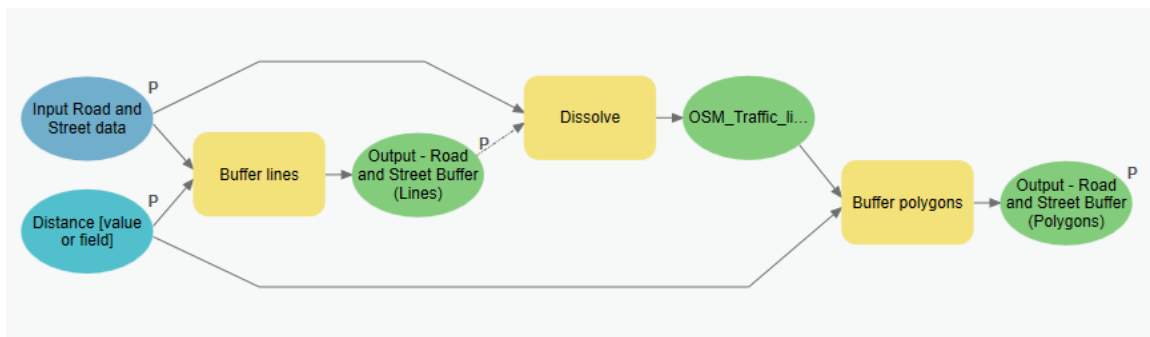


Figure 29. Model - 09_AccidentData_Analysis

2.2.6. Road and street intersection data preparation for analysis

Before road and street safety analysis, the road and street intersection dataset should be created. Road and street intersections are crucial and dangerous parts of the road network. Previous data reviews show that a lot of accidents happen in road and street intersections, there Author considers the necessity of road and street intersection analysis.

For the Master thesis road and street intersections are created manually, following the Authors created guideline:

- OSM road lines must be dissolved by road name;
- Dissolved road lines are spiled into intersections, using ArcGIS tool “*Split (planarize)*”
- Split line feature class must be supplemented with 4, new attribute fields:
 - start_X
 - start_Y
 - end_X
 - end_Y
- Using ArcGIS Field calculator, those 4 fields are calculated with values from the road line start and endpoint coordinate. ArcGIS Calculate geometry tool is used. Settings are shown in *Figure 30. Calculate geometry*.

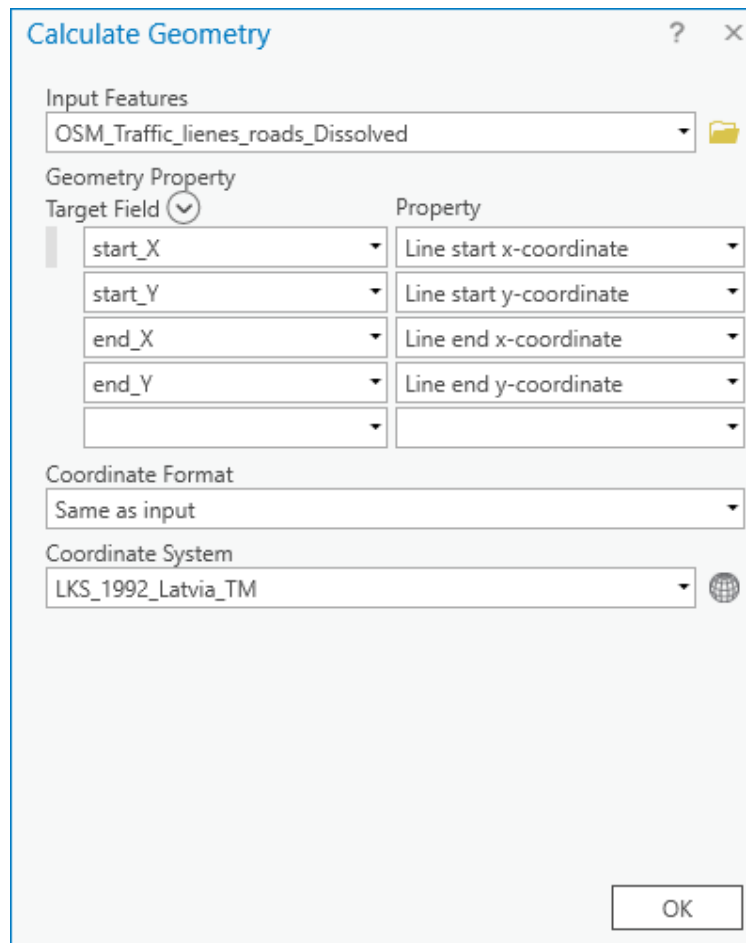


Figure 30. Calculate geometry

- Create a road intersection point layer by using *ArcGIS XY Table To Point* geoprocessing tool. This tool creates two intersection points per each line feature – at the beginning of the line using “start_X; start_Y” coordinate and “end_X; end_Y” coordinate at the end.
- Using *ArcGIS Create Buffers* tool buffers are created around intersection points. In the Master thesis, 15m buffer was chosen based on visual review of the data. *Figure 31. Road and street intersection buffers* show an example of a road accident point fitting into buffers with different radius:
 - 10 m;
 - 15 m;
 - 20 m;
 - 25m.

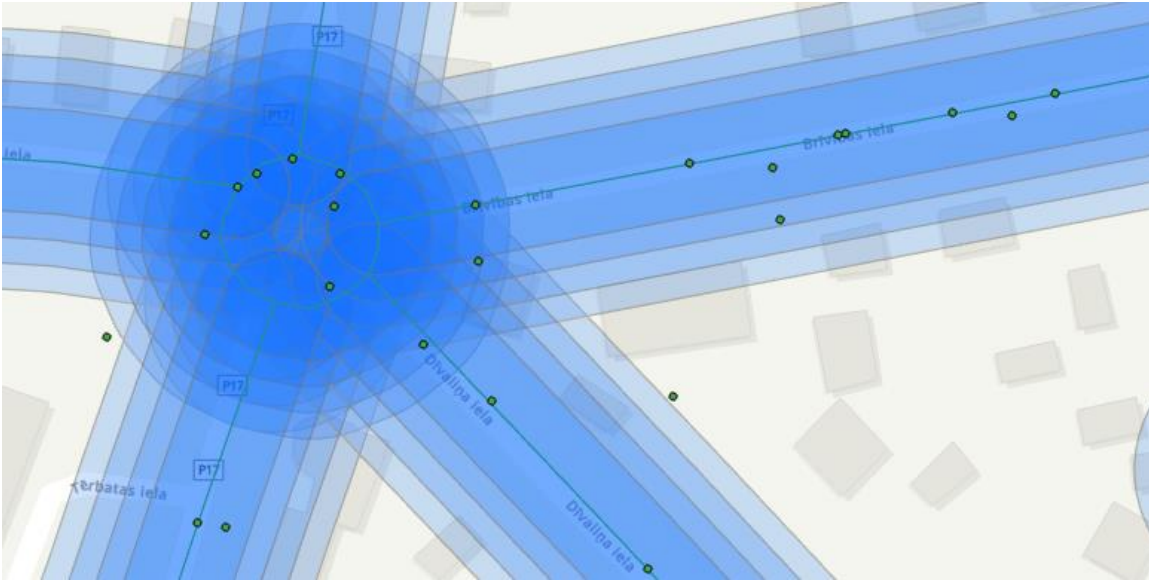


Figure 31. Road and street intersection buffers

- Road and street intersections are dissolved based on geospatial overlapping. It ensures – there is no intersection duplicates and creates a bigger intersection buffer for larger and more complicated street intersections. (Figure 32. Dissolved road and street intersection buffers)



Figure 32. Dissolved road and street intersection buffers

2.2.7. Calculation of OCTA expenses in every intersection

The Author thinks that calculation of OCTA expenses in every intersection might have an important impact on the result of the Master thesis. It is justified with the argument of how much money accidents have cost to insurance companies. And this input information is just a small part of all road accident-related costs. In the Thesis OCTA from the Road police reports, KASKO insurance claims and unreported costs have not been taken into account. Therefore, total and average costs of accidents are much higher.

The Author believes, if average or minor severity road accidents are analysed and compared with the costs of they have caused, road traffic safety responsible authorities can calculate if the road maintenance and improvements of safety activities had been worth it. Based on this calculation, authorities can make better decisions and actions according to safety improvements and get the best value for the money.

Figure 33. Calculation of OCTA expenses shows how the statistics of OCTA costs were calculated. For the calculation, the ArcGIS geoprocessing tool *Summarize Within* were used. Input parameters were set:

- Intersection buffers;
- LTAB road accident data:
- Field *IZMAKSAS* (Costs) for calculation of:
 - Sum of all accident point within the intersection buffer;
 - Mean or average cost value of all the accidents in each intersection buffer;
 - Minimum – finds the lowest cost of an accident;
 - Maximum – finds the highest cost of an accident.

The model creates an output feature class with summarized statistics and is ready for further analysis.

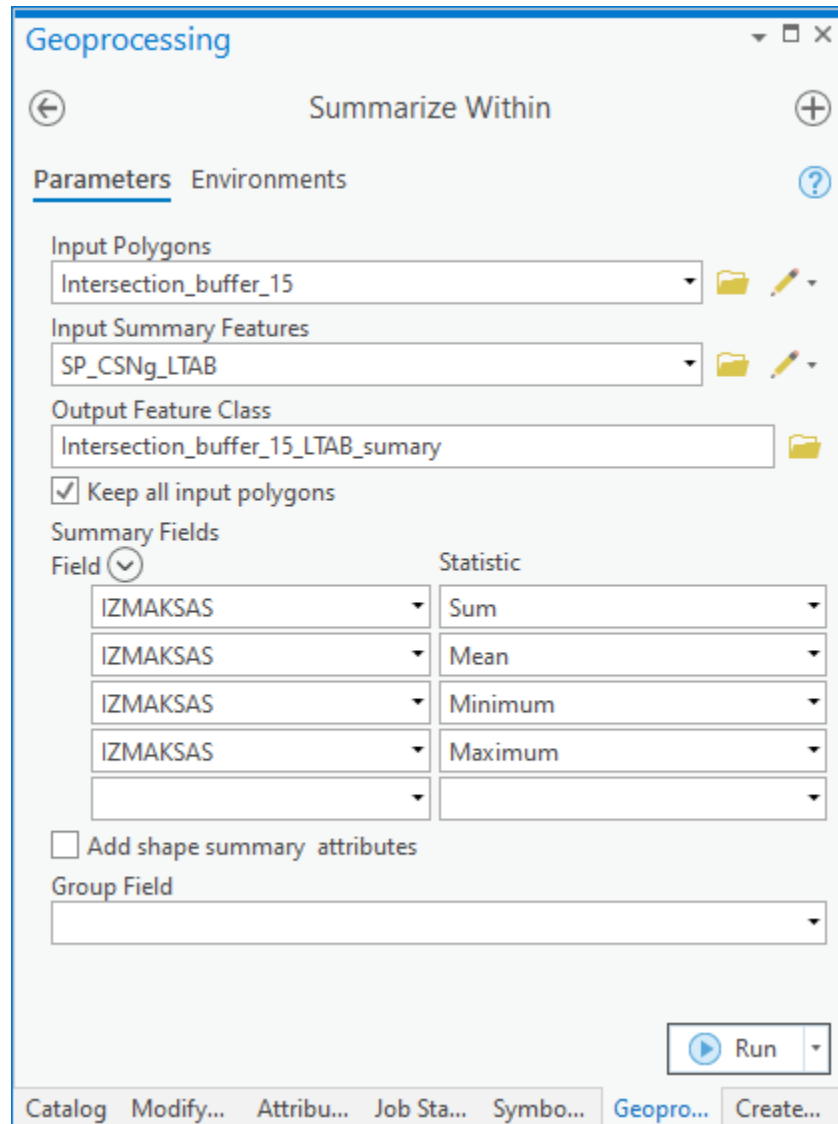


Figure 33. Calculation of OCTA expenses

2.2.8. Data analysis

10_1_Road_Street_Analysis – model uses previously prepared IeM CAIS accident, road buffer data and LTAB road accident data, that needs to be converted from CSF file to GDB feature class. In the Master thesis this process was performed manually, using the same principles as converting CAIS accident point data:

- ArcGIS tool *XY Table To Point* – creates point feature layer from CSV file.

- In CSV file point coordinates are written in WGS-84 coordinates system. As the output feature class location is the geodatabase data set in LKS-92 coordinate system, the conversion process ensures, that output feature class is defined in LKS-92.

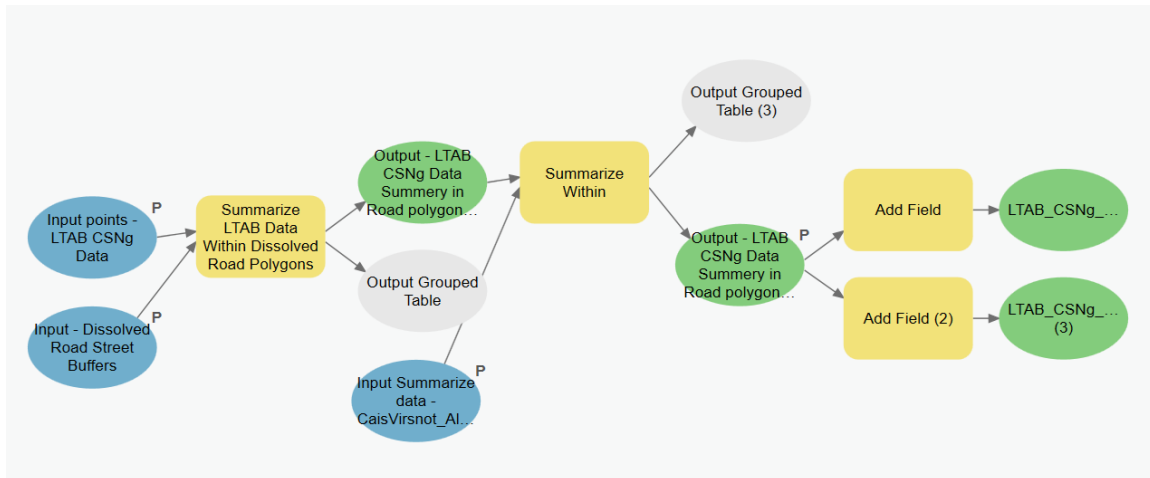


Figure 34. Model - 10_1_Road_Street_Analysis

Figure 34. Model - 10_1_Road_Street_Analysis shows, that input files are

- LTAB road accident data;
- IeM CAIS road accident data;
- Road buffers created from the OSM road lines.

Model summarizes road accidents within the territory of each buffer. Then it adds two new attribute fields for further calculations:

- segment_safety_class – used for safety class calculation.
- accident_rate – used for calculation of accident density per km

10_2_Intersection_Analysis – model working principles are identical to 10_1_Road_Street_Analysis. The only difference – model use intersection polygons instead of road line buffers.

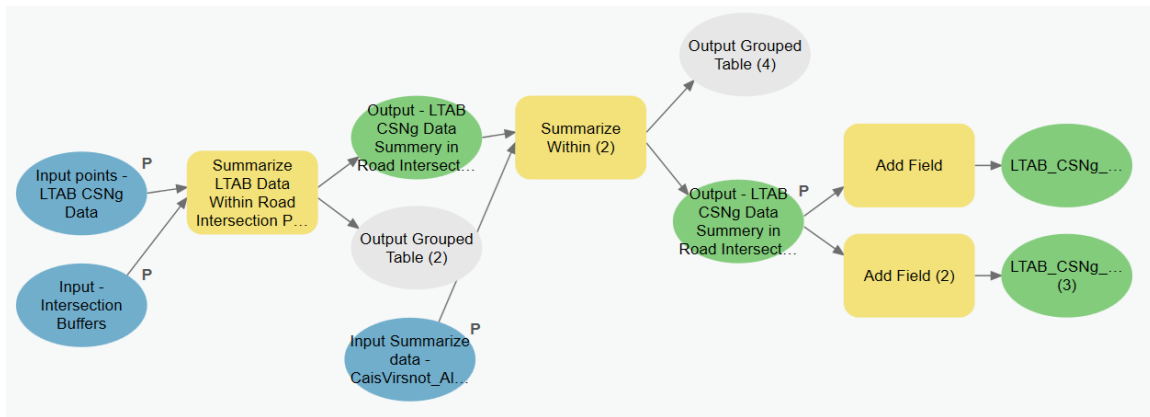


Figure 35. Model - 10_2_Intersection_Analysis

2.3. Road safety classification

Road safety classification idea is taken from EuroRAP to classify road network into five safety levels. (Lawton, 2020) Those safety levels are classified based on *Table 2. Road safety classification levels*, where lowest risk roads are classified and rated with “5 stars” and highest risk roads are classified and rated with “1 star”.

Accident rate per 1 km is calculated by ArcGIS field calculator using programming language Python expression:

$$accident_rate = (!Point_Count! + !Point_Count_1!) * 1000 / !Road_length!$$

Where;

accident_rate – is calculated field;

!Point_Count! – sum of LTAB accident points within the road line buffer;

!Point_Count_1! – sum of IeM CAIS accident points within the road line buffer;

1000 – coefficient, converts point density from point/m to point/km;

!Road_length – road length attribute, which was calculated earlier from road lines.

Road segment safety class was calculated automatically using SQL expression:

$$Reclass(!accident_rate!)$$

Code block:

```
def Reclass(accident_rate):
    if (accident_rate >= 0 and accident_rate <= 660):
        return 5
    elif (accident_rate > 660 and accident_rate <= 1320):
        return 4
    elif (accident_rate > 1320 and accident_rate <= 1980):
        return 3
    elif (accident_rate > 1980 and accident_rate <= 2640):
        return 2
    elif (accident_rate > 2640):
        return 1
```

Accident rate values are based on the statistics shown in *Figure 36. Statistics of the field "Accident rate (per 1km)"*. Reviewing the histogram and splitting into 64 bins (maximum, that is allowed by ArcGIS Pro). It is shown that most of the *accident_rate* values fit in the interval 0- 3330 (approximate).

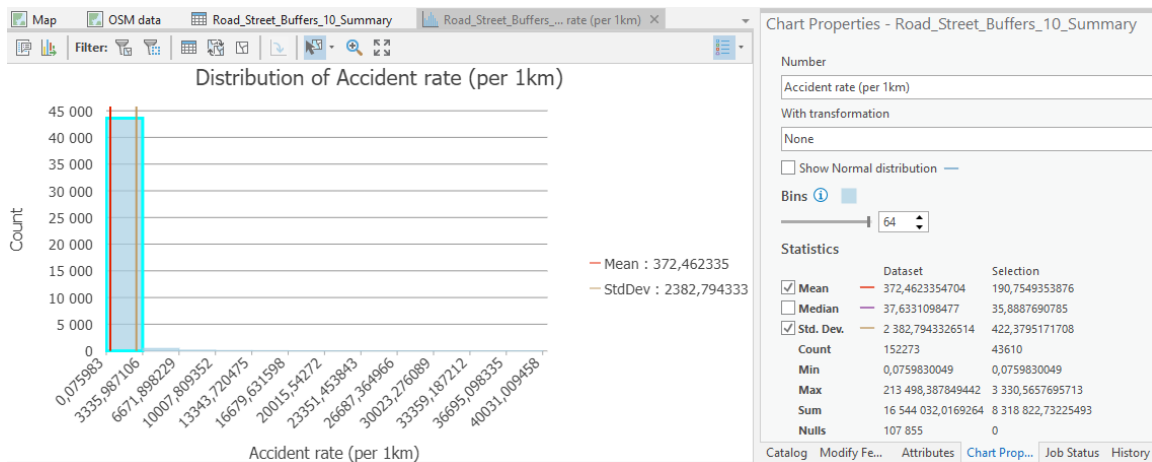


Figure 36. Statistics of the field "Accident rate (per 1km)"

Therefore, the maximal value was divided into 5 equal intervals, to ensure – each interval can have a road safety rating from 1 to 5. That led to the interval sequence and is shown in *Figure 37. Accident rate intervals and road segment safety class*.



Figure 37. Accident rate intervals and road segment safety class

2.4. WEB map and application

The process of designing a WEB application is split into three parts, where each of them are performed in different ArcGIS application. *Figure 38. Map design in ArcGIS Pro* shows that the first task is data and basic map preparation in ArcGIS Pro. As it is a desktop software it does not require to use internet resources, therefore all processes can be performed faster than if AGOL would be used instead.

In ArcGIS Pro Author prepared all data and data processing models (like described in “*Data processing model and workflow*” chapter) and designed the basic map.

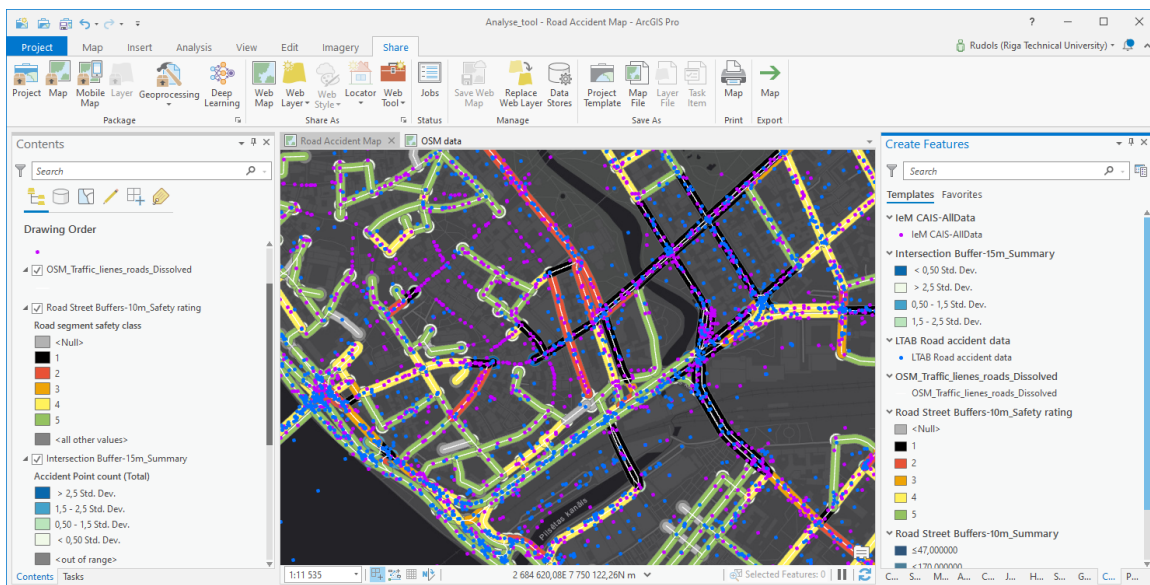


Figure 38. Map design in ArcGIS Pro

The map design in ArcGIS Pro is generic and is used for a general overview of data sets, and also for data analysis and preparing results of the Master thesis. Symbology is based on thematic cartography principles, where symbols, representations or symbol styles are designed al logically structured. (*Štrauhmanis, 2002*) For example – the road intersection buffer style is based on the total sum of accidents happened in the intersection. If the sum of accidents is greater, then a darker colour is applied in a colour scheme.

On the other hand – point symbology is left as the default and very simple and more advanced symbology is set in AGOL WEB map.

AGOL is WEB based ArcGIS application which allows users to create and design WEB maps and store data in ArcGIS WEB servers. It allows to perform data analysis and run geoprocessing tools.

WEB map in AGOL can be created in two ways:

- By adding data manually to AGOL and putting all the data layers on the map and afterwards create the design of the map.
- Publishing (sharing) the ArcGIS Pro designed map to AGOL, using ArcGIS Pro publishing tool.

The Author chose to use the second option – publishing the ArcGIS Pro map because the process of publishing is more efficient than adding data layers one by one to AGOL and designing map in WEB environment.

Figure 39. WEB map configuration in ArcGIS Online shows the map designing and change of symbology for an already published map and data. The Author thinks that some of the symbology capabilities are easier to use in WEB environment – like setting up the heatmap, which does not show all the road accident point, bet shows the “heat” of the are and density of the points. It is also easier, faster, and more efficient to configure the colour schemes according to other layers and the style of the map and application.

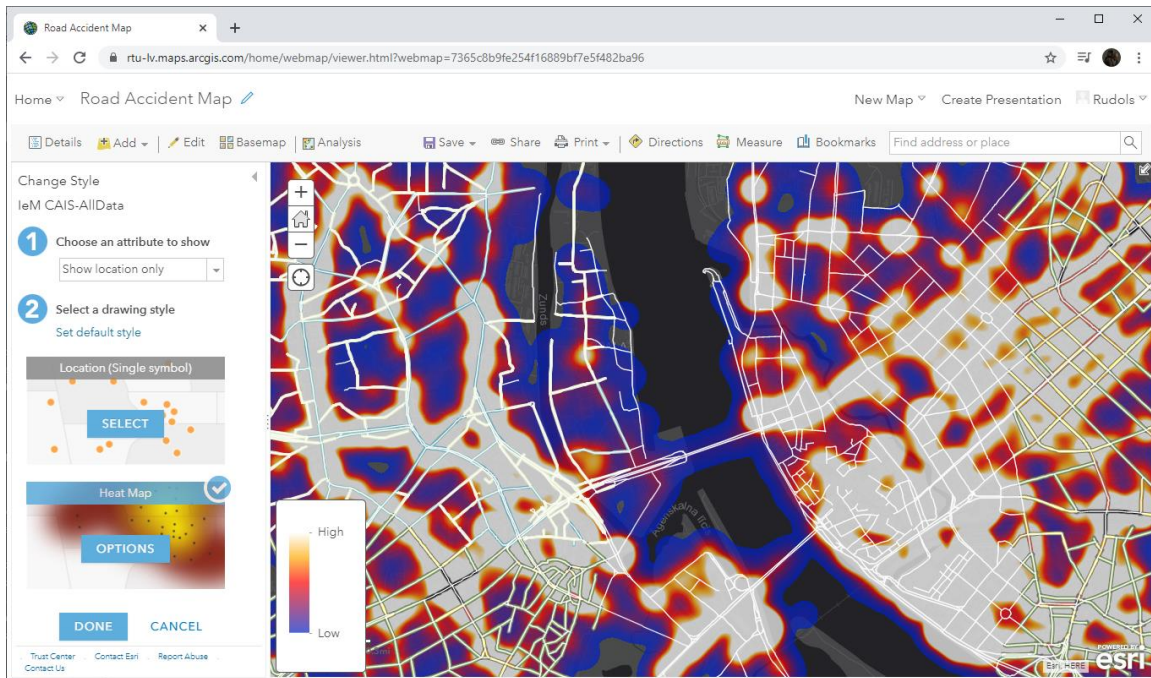


Figure 39. WEB map configuration in ArcGIS Online

AGOL WEB map as the result and the product for the end-user, is not the best solution. The WEB map in AGOL contains data editing, geoprocessing and analyse tools, configuration capabilities and are complicated to use and it requires some ArcGIS knowledge. Therefore, user-friendly environment must be created. For this purpose, ArcGIS Online Web AppBuilder is been used.

Web app builder use previously created, designed, and prepared data and maps, removing unnecessary capabilities. Create an application in Web AppBuilder is a quite simple task, however, it can become more complicated with using more advanced data and map.

The Author uses Web AppBuilder to display road accident data map with limited capabilities. The Author has set these capabilities for the WEB map in WEB application:

- View;
- Select;
- Filter data;

In Figure 40. Configuration of WEB application in ArcGIS Web AppBuilder is displayed how the environment of WebApp builder looks. It shows that application widgets

(tools) are easy to use and deploying into an application by simply adding them to application template.

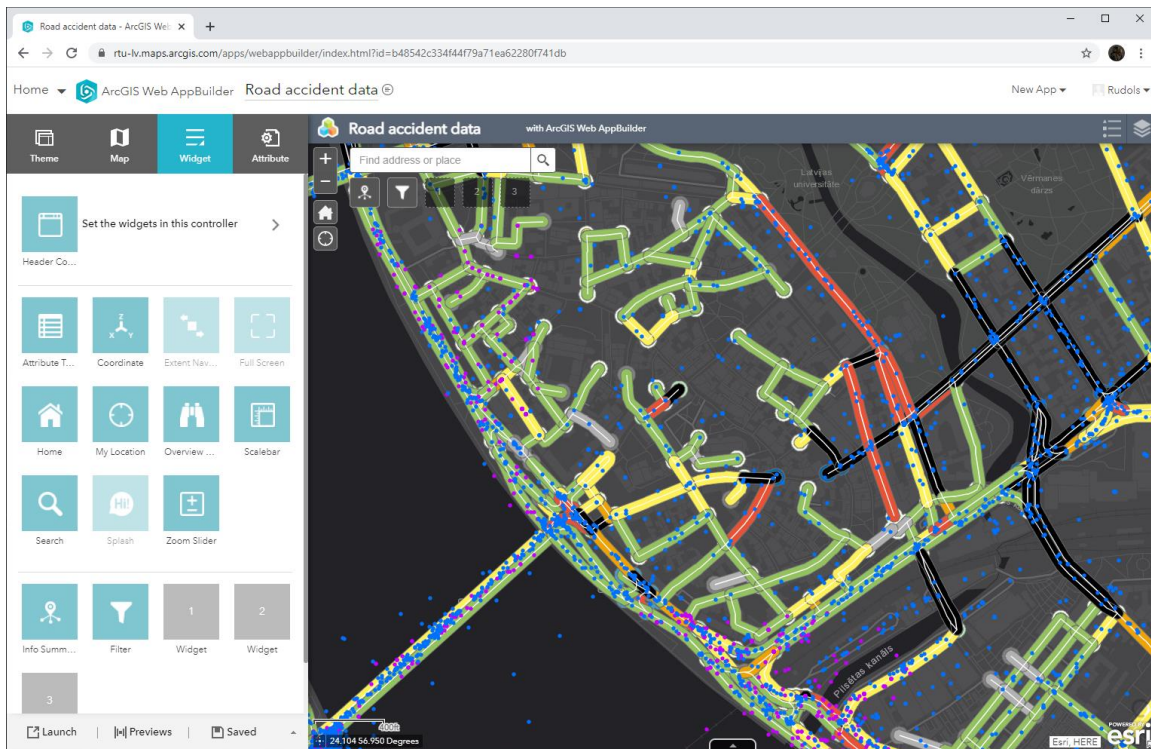


Figure 40. Configuration of WEB application in ArcGIS Web AppBuilder

The configuration of application does need any knowledge of programming languages, however, it can help, to create more advanced applications. In *Figure 41. Configure Filter widget* Author shows how a widget is been configured. For example – Filter widget use SQL expression, however, instead of typing expression manually, the application developer can choose the attribute field and values from a simple dropdown menu.

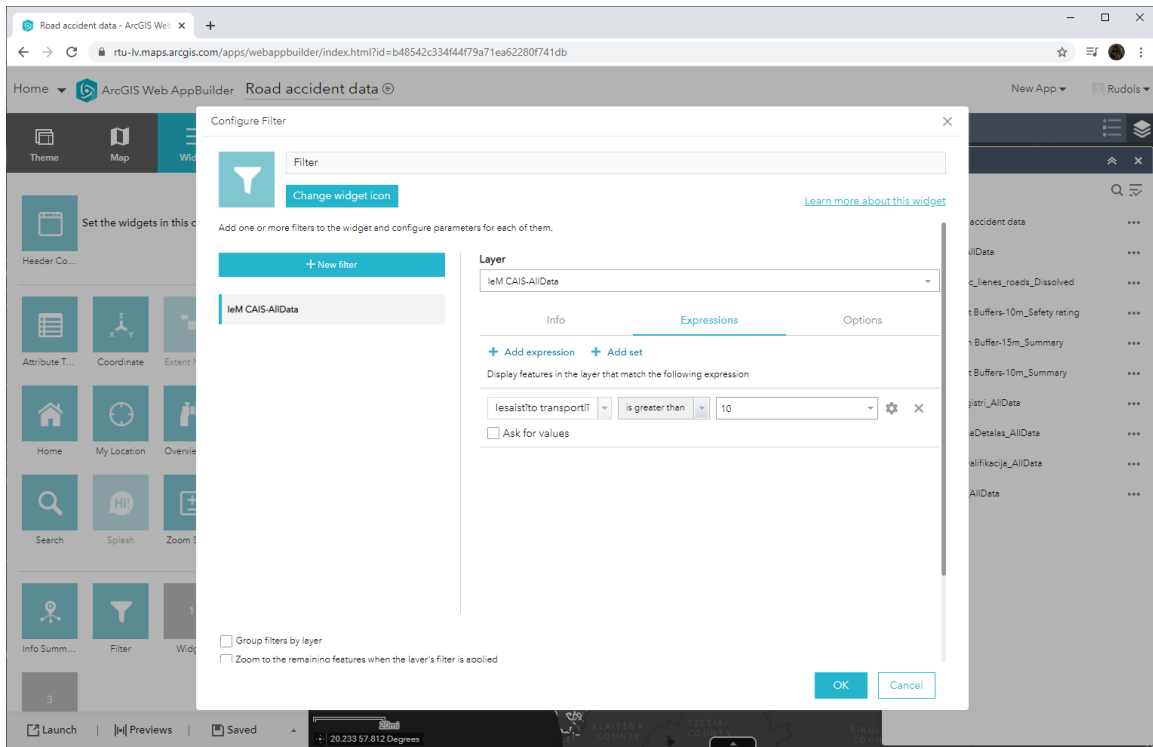


Figure 41. Configure Filter widget

3. RESULTS

3.1. Road accident WEB application

The visualisation of the application is shown in *Figure 42. Road and street accident WEB application*. It displays the capabilities of the map, like:

- Viewing;
- Turning on/off layers;
- Setting filters (activate filter widgets);
- And reviewing accident point or street buffer data.
- The application allows performing some basic map operations like Zoom in/out; Pan; Address search.

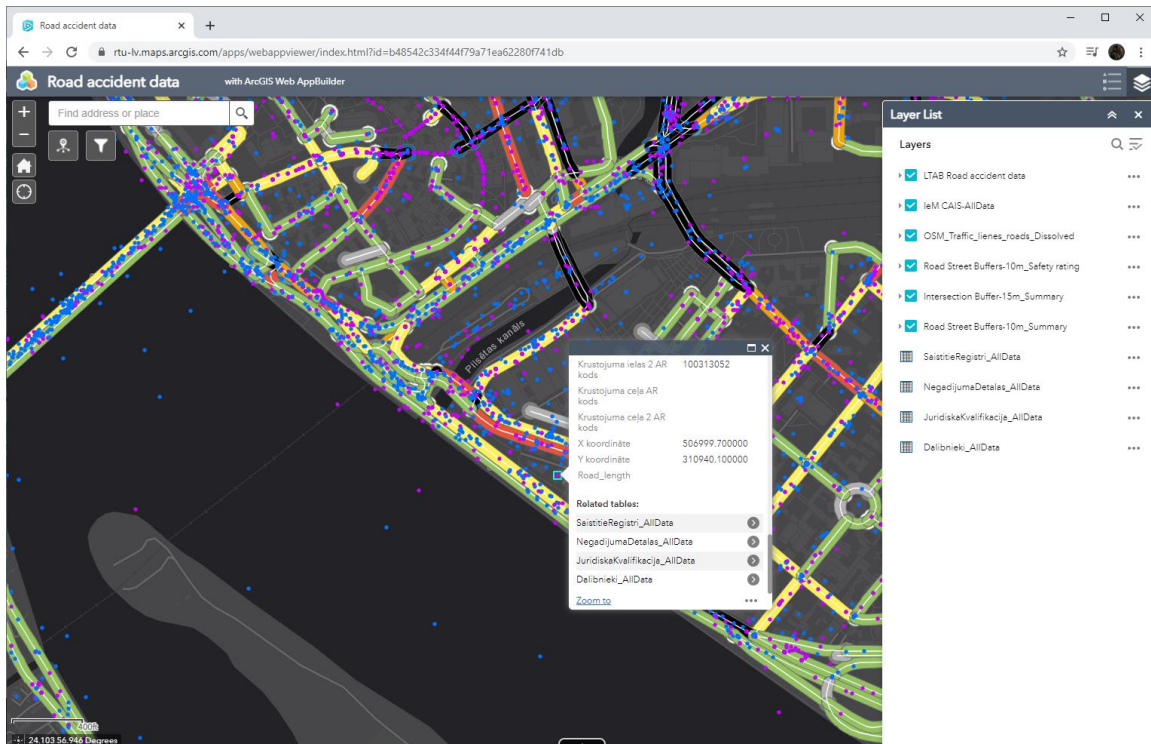


Figure 42. Road and street accident WEB application

Road accident application is available here: <https://ej.uz/on69>

Full path to the application: <https://rtu-lv.maps.arcgis.com/apps/webappviewer/index.html?id=b48542c334f44f79a71ea62280f741db>

3.2. Results of road accident analysis

The road accident data sets, like point features of IeM CAIS and LTAB, like road segment and street intersection polygon features, can be reviewed and analysed in many ways, using different types of data analytics principles and approaches. For example, the Author provides a few basic visualisation figures and statistic charts of the road accident data. End users (like road safety engineers and managers) can calculate and review statistics of their individual requests, using ArcGIS Pro or WEB application.

Figure 43. IeM CAIS data - Counts of Accident points by Months over Years represents IeM CAIS road accident point data in the “Data clock” chart. It consists of ~1,321 million points, recording accidents since December 2010. White colour represents less than 2389 accidents per month, while the darkest colour represents road accidents from 23 308 till 27 522 accidents per month.

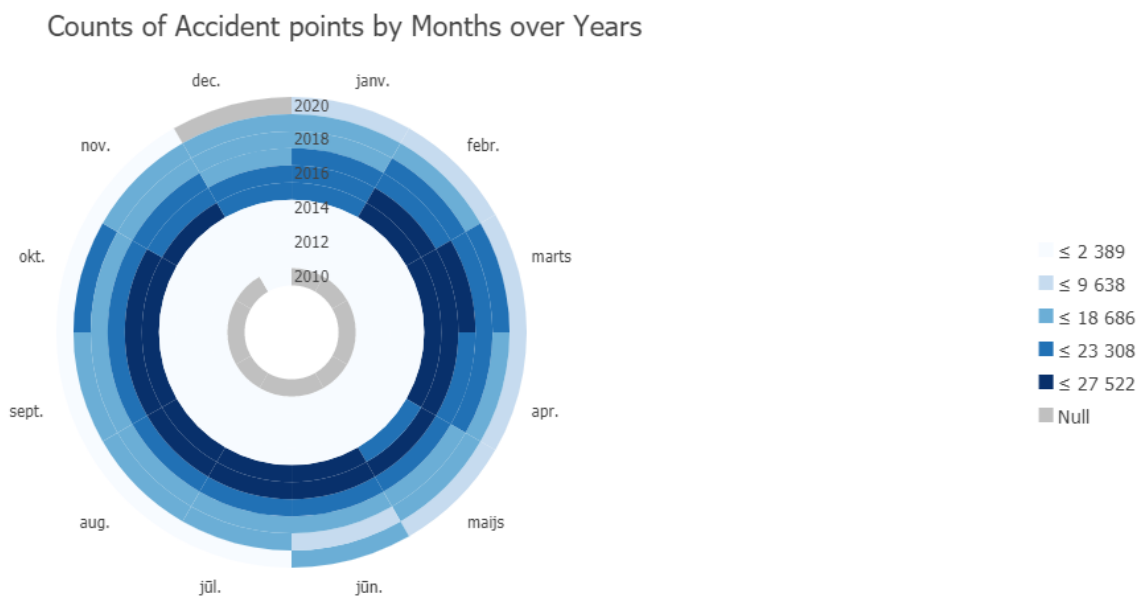


Figure 43. IeM CAIS data - Counts of Accident points by Months over Years

There can be many assumptions made of the order of accident distribution in “Data clock” and this would-be task for traffic safety engineers. However, it is clearly – according to IeM CAIS data, the number of total road accidents is reduced since 2016 / 2017 comparing yearly and monthly statistics.

Figure 44. LTAB data - Counts of Accident points by Months over Years represents LTAB road accident point data in the “Data clock” chart. Like previous IeM CAIS “Data clock” chart, this also shows accident data distribution in yearly and monthly time frame, where white colour represents the lowest values (less than 90 accidents) and darkest from 2204 till 2454. LTAB data set contains less data than IeM CAIS, therefore, the values are also lower.

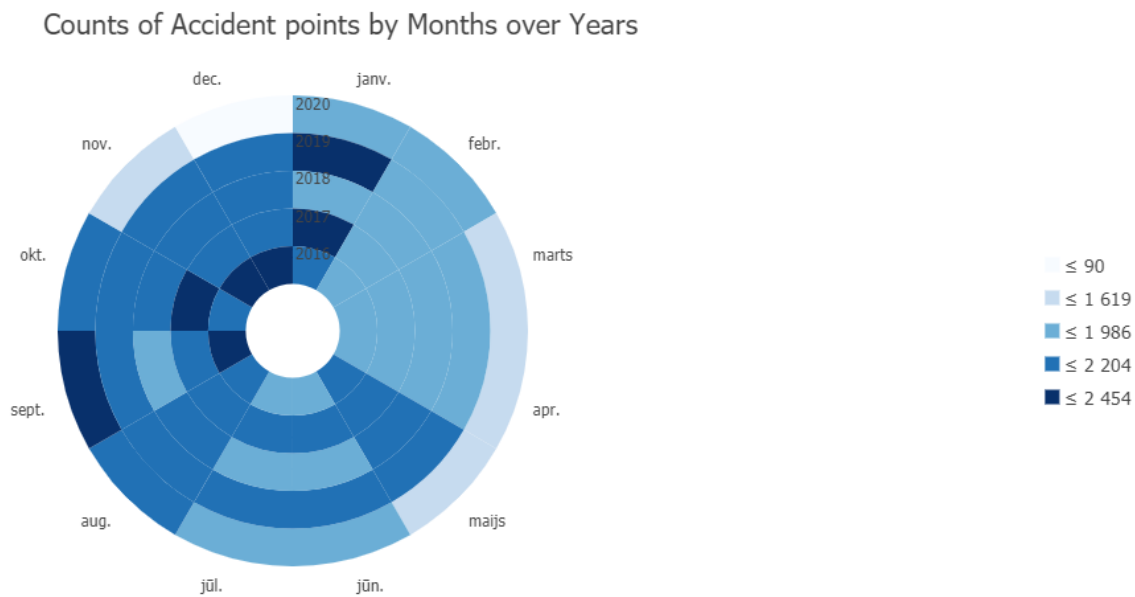


Figure 44. LTAB data - Counts of Accident points by Months over Years

LTAB accident data chart could also be a task for road safety engineers, to analyse patterns of the chart and accident distribution. In this case, without any advanced data reviewing and analysing, the only obvious assumption can be made – according to LTAB data, the total number of road accidents are consistent from February till April through the years of the reported data. Author of the Master thesis does not interpret data charts and does not provide any assumption of accident frequency causes, leaving those assumptions for road safety engineers.

Table 6. Road and Street Buffers (10m) represents statistics of calculated road and street segment length, their safety class and costs calculated from LTAB data. “Total” values - represents all data used in geospatial analytics, including values, that did not have

any road accident data and could not be classified under any of five safety classes. Road segments without any road accident data were calculated with value <Null> and does not appear in road safety classification due to lack of the data.

Road segment safety class	Objects	Total road length (km)	Costs (EUR)
1	1070	69,801	13 727 454,19
2	452	42,162	5 197 477,69
3	763	84,389	7 052 920,05
4	1944	229,986	14 332 593,93
5	40189	17 532,723	42 676 244,68
Total:	152273	67 315, 458	77 237 395,38*

Table 6. Road and Street Buffers (10m)

*** 77 237 395,38 (EUR)** - total costs of all accidents cannot be summarised by counting all safety classes, because some of the accident points are in two or more road polygon buffers, therefore giving incorrect cost calculation. Total costs of accidents are calculated from LTAB accident data tables.

Intersection Buffer (15m) data contains automatically generated **107 477** objects, that includes:

- Maximum of road accidents in one intersection buffer: **2609**, with the cost of **17 274,36** EUR.
- Maximum cost in one intersection buffer: **190 886** EUR, with the **267** road accidents.

Calculation was based on LTAB provided road accident data, containing OCTA insurance claims, where the total cost of reported OCTA claims is **77 237 395,38** EUR and the highest claim is **71 572,32** EUR.

Figure 45. Relationship between road intersection accidents and total costs displays data distribution if a count of road accident is compared with accident costs. The

figure shows the densest accident concentration between 0-200 cases in intersection and costs of up to 60 000 – 70 000 EUR.

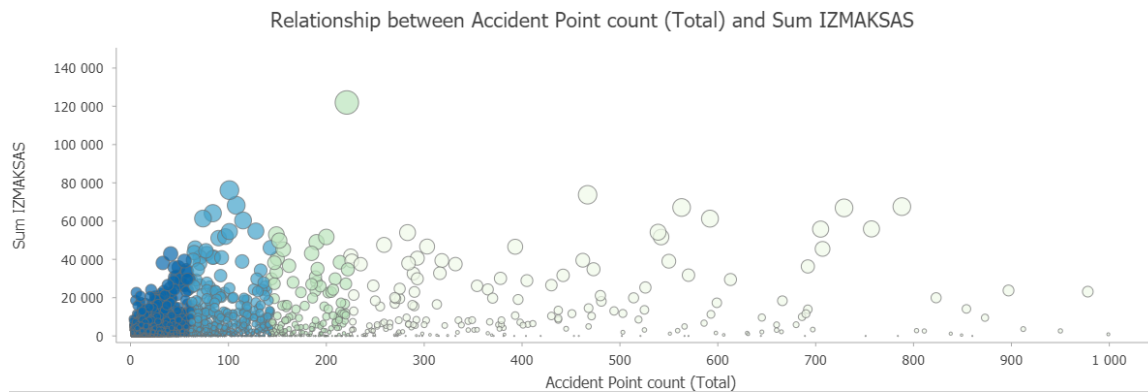


Figure 45. Relationship between road intersection accidents and total costs

The Author revises two different street intersections:

1. Vienības gatve un Ozolciema iela (Figure 46. *Vienības gatve / Ozolciema iela - Higher accident count, lower costs*)
2. Brīvības gatve un Gustava Zemgala gatve (Figure 47. *Brīvības gatve un Gustava Zemgala gatve - Lower accident count, higher costs*)

In the first intersection data and figure shows one of the highest number of accidents, which makes that intersection one of the most dangerous in Riga. However, the reported costs are ~23 000 EUR, which is not the highest among other intersection with fewer accidents.

The Author thinks, it might be substantiated with the “T” type intersection, where speeds might be lower causing less damage. However, this is a topic for road safety engineers and professionals for further discussions.

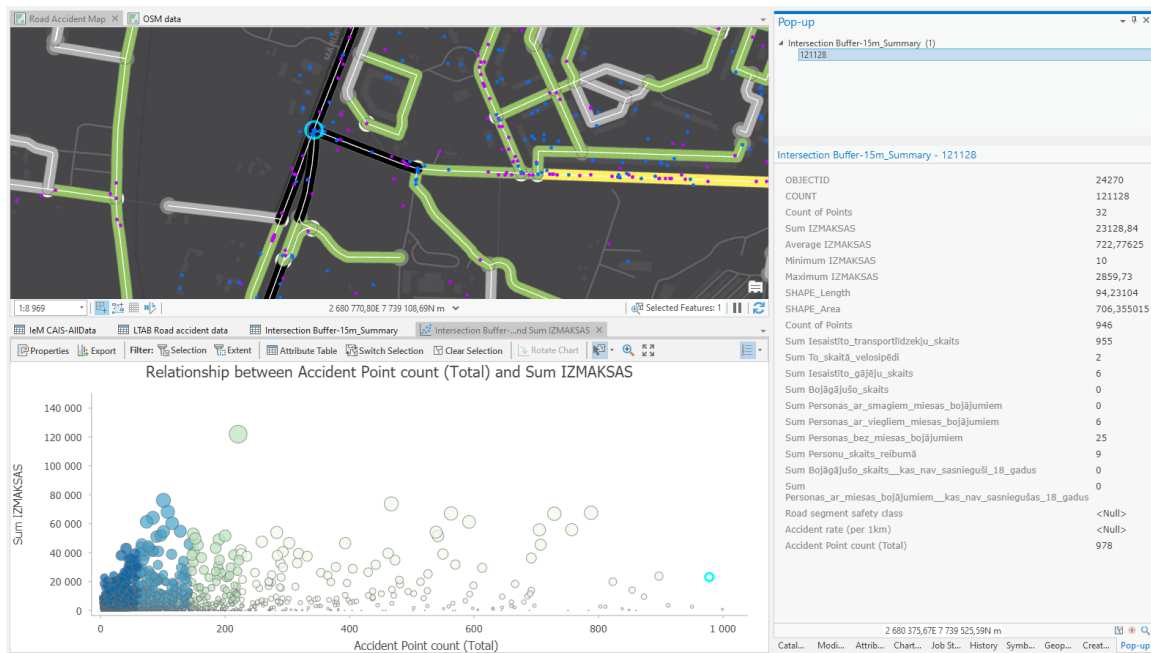


Figure 46. Vienības gatve / Ozolciema iela - Higher accident count, lower costs

Figure 46. Vienības gatve / Ozolciema iela - Higher accident count, lower costs shows, the intersection is located between high-risk streets, classified with the lowest Road segment safety class – 1.

The opposite situation is shown in Figure 47. Brīvības gatve un Gustava Zemgala gatve - Lower accident count, higher costs, where the count of accidents are almost 4-5 times less while costs are almost 6 times more (~122 000 EUR). The Author thinks, the cause of the expensive accidents is related with two magistral streets (2 lanes each direction) intersection in one level, where speeds are higher than in Ozolciema-Vienības gatve intersection.

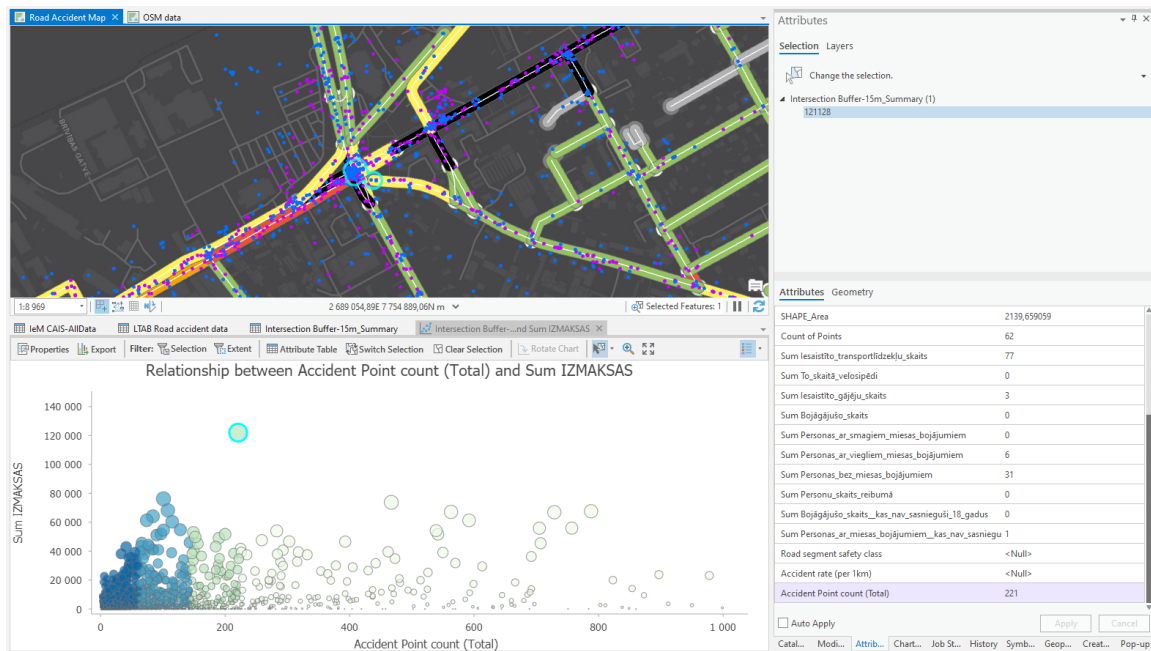


Figure 47. Brīvības gatve un Gustava Zemgala gatve - Lower accident count, higher costs

Despite the numbers of accidents and costs, Author suggests road safety engineers and safe traffic planning managers review this data and analyse the situation, reviewing and considering possibilities to improve road traffic safety. Especially, Author suggests spending more attention to intersections in the range of 600 accidents and more, and accidents with the total costs of 40 000 EUR and more.

CONCLUSIONS, SUGGESTIONS AND PROPOSALS

In those Master theses, Author has reviewed different road safety strategies and found Dutch version of the safe system as one of the best to reach for, where the safe system approach aims at eliminating and/or reducing so-called “system gaps”. These are “latent gaps,” or individual weaknesses in components of the system. In this case, Author proposes WEB based GIS application and road accident map, where road and traffic responsible authorities can review and analyse “system gaps”, and act accordingly to the “value for the money” principle to prevent causes of new accidents.

The Author suggests including new and upgraded data and data sources into the WEB map. Those data sets data sources are:

- Replace OSM road and street line data with LVC road centre lines.
 - LVC road centreline data must be joined with LVC traffic intensity data.
 - Implement Linear reference system in LVC road centre line dataset, tad it can be used for linear referencing.
 - LVC used sensor data can be included (like traffic counters).
 - Create a geometric network of the LVC road centre lines, that it can be used for navigation purposes.
- Road sign feature class, which displays road sign type and location.
- Another crucial road infrastructure data, that may impact road safety.

Because a lot of accident points are registered outside the street and road areas, Author suggests executing accident data cleaning, where actual coordinates of the accident points are specified.

The Author suggests including LTAB provided OCTA insurance claim data, reported by road police. This data set needs to be justified with the IeM CAIS data.

The Author proposes implementing a multicriteria decision-making process in WEB application for planning a safe travel route.

The Author suggests implementing road budget management system according to conference “Latvian road and street budget management with GIS tools” (Annex), that road and street budget can be managed regarding road traffic safety, and the principle “value for the money” can be ensured.

According to the **Hypotheses** defined in the introduction, the Author has proved – it is possible to create a GIS tool based on WEB and desktop technologies, which allows to analyse and classify roads into safety levels.

REFERENCES

- European Commission. (2020). *Road safety. Key Figures*. Retrieved from European Commission. Road Safety: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/scoreboard_2020.pdf
- Alavi, S. H. (2018). *Constructing and developing an integrated smart spatial database for Malmö Municipality, Case study: Västra innerstaden in Malmö*. Lund: Department of Physical Geography and Ecosystem Science, Lund University.
- Amir Pooyan Afghari, Md Mazharul Haque, Simon Washington. (2020, 144). Applying a joint model of crash count and crash severity to identify road segments with high risk of fatal and serious injury crashes. *Accident Analysis & Prevention*.
- Assefa, D. (2018). *Developing Data Extraction and Dynamic Data Visualization (Styling) Modules for Web GIS Risk Assessment System (WGRAS)*. Lund: Department of Physical Geography and Ecosystem Science, Lund University.
- Dong, S. (2016). *Comparisons between Different Multi-criteria Decision Analysis Techniques for Disease Susceptibility Mapping*. Lund: Department of Physical Geography and Ecosystem Science, Lund University.
- Elvik, R. (2019, 127). How to trade safety against cost, time and other impacts of road safety measures. *Accident Analysis and Prevention*, pp. 150-155.
- Esri. (2020). 000361: *The name starts with an invalid character*. Retrieved from ArcGIS Pro: <https://pro.arcgis.com/en/pro-app/latest/tool-reference/tool-errors-and-warnings/001001-010000/tool-errors-and-warnings-00351-00375-000361.htm>
- European Accident Statement. (2020, December 21). Retrieved from Motor Insurers' Bureau of Latvia: <https://www.ltab.lv/en/european-accident-statement/>
- European Commission, Directorate General for Transport. (2018, February). *Cost Benefit Analysis, European Commission, Directorate General for Transport*. Retrieved from European Commission, Directorate General for Transport: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/ersosynthesis2018-costbenefitanalysis.pdf

- European Transport Safety Council. (2018, February). *Briefing: 5th EU Road Safety Action Programme 2020-2030*. Retrieved from https://etsc.eu/wp-content/uploads/5th_rsap_2020-2030_etsc_position.pdf
- EuroRAP. (2020). *Star Rating*. Retrieved from EuroRAP: <https://eurorap.org/star-rating/>
- EuroRAP. (2020). *Where we work*. Retrieved from EuroRAP: <https://eurorap.org/where-we-work/>
- Gholam Ali Shafabakhsh, Afshin Famili, Mohammad Sadegh Bahadori. (2017, 4 (3)). GIS-based spatial analysis of urban traffic. *Journal of Traffic and Transportation Engineering*, pp. 290-299.
- Greene, L.-G. (2017). *Deadly Designs: The Impact of Road Design on Road Crash Patterns along Jamaica's North Coast Highway*. Lund: Department of Physical Geography and Ecosystems Science, Lund University.
- Information Centre of the Ministry of the Interior. (2020). *About us*. Retrieved from Information Centre of the Ministry of the Interior: <https://www.ic.iem.gov.lv/en/about-us>
- Ionela Adriana Tisca, Nicolae Istrat, Constantin Dan Dumitrescu, Georgica Cornu. (2016, 39). Issues concerning the road safety concept. *Procedia Economics and Finance*, pp. 441-445.
- Ionela Adriana Tisca, Nicolae Istrat, Constantin Dan Dumitrescu, Georgica Cornu. (2016, 39). Issues concerning the road safety concept. *Procedia Economics and Finance*, pp. 441-445.
- Younus Maqbool, Ankit Sethi, Jagdeep Singh. (2019, April). Road safety and Road Accidents: An Insight. *International journal of information and computing science*, pp. 93-105.
- Jonathan J. Rolison, Shirley Regev, Salissou Moutari, Aidan Feeney. (2018, 115). What are the factors that contribute to road accidents? An assessment of law enforcement views, ordinary drivers' opinions, and road accident records. *Accident Analysis and Prevention*, pp. 11-24.
- K. Pérez, W. Weijermars, N. Bos, A.J. Filtnesse, R. Bauer, H. Johannsen, N. Nuyttens, L. Pascal, P. Thomas, M. Olabarria, The Working group of WP7 project. (2019, 130).

- Implications of estimating road traffic serious injuries from hospital data. *Accident Analysis and Prevention*, pp. 125-135.
- Latvia's Open Data portal. (2020). *VAS "Latvijas Valsts ceļi"*. Retrieved from Latvia's Open Data portal: <https://data.gov.lv/dati/lv/organization/lvceli>
- Latvijas Transportlīdzekļu apdrošinātāju birojs. (2020). *About MIB*. Retrieved from Motor Insurers' Bureau of Latvia: <https://www.ltab.lv/en/about-mib/>
- Lawton, B. (2020, January). *EuroRAP*. Retrieved from Crash Rate Mapping: <https://eurorap.org/crash-rate-mapping/>
- LVC. (2020). *About LVC*. Retrieved from Latvijas Valsts ceļi: <https://lvceli.lv/en/about-lsr/page/company/>
- Marco Bassani, Leonardo Rossetti, Lorenzo Catani. (2020, 45). Spatial analysis of road crashes involving vulnerable road users in support of road safety management strategies. *Transportation Research Procedia*, pp. 394-401.
- Markus, P. (2016). *Design and development of a prototype mobile geographic information system for real-time collection and storage of traffic accident data*. Lund: Department of Physical Geography and Ecosystem Science, Lund University.
- OpenStreetMap. (2020). *Main Page*. Retrieved from OpenStreetMap: https://wiki.openstreetmap.org/wiki/Main_Page
- Pruchniewski, J. A. (2019). *ARC Advisory Group Report Names Esri GIS Market Leader*. Retrieved from [businesswire.com: https://www.businesswire.com/news/home/20190131005210/en/](https://www.businesswire.com/news/home/20190131005210/en/)
- Puķītis, A. (2013). *Ceļu drošības audits. Vadlīnijas*. Rīga: Ceļu satiksmes drošības direkcija.
- Roman Kmet, Zdenek Dvorak, Marek Kvet. (2019, 40). Map of traffic accidents. *Transportation Research Procedia*, pp. 1418-1425.
- Sarsam, S. I. (2016, Volume 3, Issue 2). Pavement Maintenance Management System: A Review. *Trends in Transport Engineering and Applications*, pp. 19-30.
- Sekulic, M. (2019). *Multi-Criteria GIS modelling for optimal alignment of roadway by-passes in the Tlokweng Planning Area, Botswana*. Lund: Department of Physical Geography and Ecosystem Science, Lund University.

- Stūrmanis, E. (2009, 6.sējums). Uzņēmuma mēroga ģeogrāfiskās informācijas sistēma. *RTU zinātnisko rakstu krājums. Ģeomātika*, pp. 34-40.
- Subhi M. Bazlamit, H. S.-S. (2017, 182). Pavement Maintenance Applications using Geographic Information Systems. *Procedia Engineering*, pp. 83-90.
- Štrauhmanis, J. (2002). *Tematiskā kartogrāfija*. Rīga: RTU Izdevniecība.
- Vafeiadis, E. (2019). *Exploring the distribution of accessibility by public transport using spatial analysis*. Lund: Department of Physical Geography and Ecosystem Science, Lund University.
- Val Noronha, Richard L. Church. (2002). *Linear Referencing and Other Forms of Location Expression for Transportation*. Santa Barbara: Vehicle Intelligence & Transportation Analysis Laboratory, University of California.
- Vingris, R. (2020). Latvian road and street budget management with gis tools. *23rd Conference for Junior Researchers „Civilinė inžinerija ir geodezija“*. Vilnius: Vilnius Gediminas Technical University.
- Wegman, F. (2017, 40). The future of road safety: A worldwide perspective. *IATSS Research*, pp. 66-71.

APPENDICES

Appendix 1

5 Line Features

5.1 Roads and Paths ("roads")

All kinds of roads from motorways to gravel tracks as well as cycleways, footpaths, etc.

Additional attributes:

Attribute	PostGIS Type	Description	OSM Tags
ref	VARCHAR(20)	Reference number of this road ('A 5', 'L 605', ...)	ref=*
oneway	VARCHAR(1)	Is this a oneway road? "F" means that only driving in direction of the linestring is allowed. "T" means that only the opposite direction is allowed. "B" (default value) means that both directions are ok.	oneway=*
maxspeed	SMALLINT	Max allowed speed in km/h	maxspeed=*
layer	SMALLINT	Relative layering of roads (-5, ..., 0, ..., 5)	layer=*
bridge	VARCHAR(1)	Is this road on a bridge? ("T" = true, "F" = false)	bridge=*
tunnel	VARCHAR(1)	Is this road in a tunnel? ("T" = true, "F" = false)	tunnel=*

Roads of type 5111 (motorway) and 5112 (trunk) are always oneway.

The following feature classes exist in this layer:

code	layer	fclass	Description	OSM Tags
511x	roads		Major roads	
5111	roads	motorway	Motorway/freeway	highway=motorway
5112	roads	trunk	Important roads, typically divided	highway=trunk
5113	roads	primary	Primary roads, typically national.	highway=primary
5114	roads	secondary	Secondary roads, typically regional.	highway=secondary
5115	roads	tertiary	Tertiary roads, typically local.	highway=tertiary
512x	roads		Minor Roads	
5121	roads	unclassified	Smaller local roads	highway=unclassified
5122	roads	residential	Roads in residential areas	highway=residential
5123	roads	living_street	Streets where pedestrians have priority	highway=living_street
5124	roads	pedestrian	Pedestrian only streets	highway=pedestrian
513x	roads		Highway links (sliproads/ramps)	
5131	roads	motorway_link	Roads that connect from one road to another of the same or lower category.	highway=motorway_link
5132	roads	trunk_link		highway=trunk_link



code	layer	fclass	Description	OSM Tags
5133	roads	primary_link		highway=primary_link
5134	roads	secondary_link		highway=secondary_link
514x	roads		Very small roads	
5141	roads	service	Service roads for access to buildings, parking lots, etc.	highway=service
5142	roads	track	For agricultural use, in forests, etc. Often gravel roads.	highway=track without tracktype specification
5143	roads	track_grade1	Tracks can be assigned a "tracktype" from 1 (asphalt or heavily compacted) to 5 (hardly visible). A detailed description is here: http://wiki.openstreetmap.org/wiki/Tracktype	... with tracktype=grade1
5144	roads	track_grade2		... with tracktype=grade2
5145	roads	track_grade3		... with tracktype=grade3
5146	roads	track_grade4		... with tracktype=grade4
5147	roads	track_grade5		... with tracktype=grade5
515x	roads		Paths unsuitable for cars	
5151	roads	bridleway	Paths for horse riding	highway=bridleway or highway=path with horse=designated
5152	roads	cycleway	Paths for cycling	highway=cycleway or highway=path with cycle=designated
5153	roads	footway	Footpaths	highway=footway or highway=path with foot=designated
5154	roads	path	Unspecified paths	highway=path without cycle/foot/horse=designated
5155	roads	steps	Flights of steps on footpaths	highway=steps
			Unknown	
5199	roads	unknown	Unknown type of road or path	highway=road

Appendix 2

23-osios Lietuvos jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis“ teminė konferencija
Proceedings of the 17th Conference for Junior Researchers „Science – Future of Lithuania“

CIVILINĖ INŽINERIJA IR GEODEZIJA / CIVIL ENGINEERING AND GEODESY

2020m. gegužės 15 d. Vilnius

15 May, Vilnius, Lithuania

eISSN 2029-7149

eISBN 978-609-457-826-7

Article Number: pinzs.0000

<http://jmk.pinzs.vgtu.lt>

LATVIAN ROAD AND STREET BUDGET MANAGEMENT WITH GIS TOOLS

Rudolfs Vingris

master student

Vilnius Gediminas Technical University,

e-mail: rudolfs.vingris@stud.vgtu.lt

Annotation. In this article, the author reviews the publicly available information about problems of the maintenance process of the Latvian state roads. Based on this information, the author analyses and interprets the road maintenance budget by using geospatial analysis methods. This article describes a Geographic Information System (GIS) model that allows traffic experts to plan and analyse traffic budget revenue and expenditure planning, administration, and visualizations for the society if a road fund decision is made and comes effective.

Keywords: Latvia, Road, Budget, Management, GIS

Introduction

For many years Latvian road users (vehicle drivers, bicycle riders, pedestrians, etc.) are complaining about the quality of Latvian road pavements and quality of their maintenance. Social surveys and comments in social media like news portals, Twitter and Facebook, etc. shows that society is not satisfied how income from taxes are spent and government has been blamed for not taking appropriate actions to solve issues and find proper solutions for budget spending.

Total budget of Republic of Latvia in 2020 is 10 billion EUR and only 0.46 billion EUR are spent for transport and telecommunication industry.

According to the newest information from Latvian Ministry of Finance the planned budget expenses for Ministry of Transport in 2020 is 457.7 m EUR. The budget allocation by sectors is shown in the table below.

Data shows that 280.7 m EUR are spent for roads and infrastructure maintenance which is 61.4% of the Ministry of Transport annual budget in 2020. This money comes from total state budget and can be changed by political decisions. This is the main reason why author seeks for an opportunity to develop a tool which would help to analyse and plan road budget if it would not depend on political decisions but on real situation and data of economic situation in country.

Planned expenditures in 2020 – 457.2 million EUR		
	Million (EUR)	Percent (%)
Sector management and policy planning	6.7	1.5
Roads	280.7	61.4
Railway	69	15.1
Aviation	0.1	0.02
Transit transportation	1.2	0.3
Passenger transportation	91.2	19.9
Communications	8.3	1.8

Table 1. Budget expenses of the Ministry of Transport (Ministry of Finance 2020)

Latvian road fund

According to LSR published Road newspaper the Road fund is not even on the table to discuss in the government or other state institution. The government doesn't plan to change the system how State budget is planned and allocated between economic sectors. From political point of view, it is understandable why government does not want to change this system as it can affect budget of other industries. However, author believes that there could be a proper solution and compromise. Therefore, there should be developed methodology and tool which could analyse the current situation and design fu-

ture scenarios in order to help on decision making if the Road fund would be established.

Reviewing the road budget, numbers stands out on how much money has been spent for road maintenance

and how much for road management and other activities which directly does not improve quality and safety of road network.

	Execution	Annual plan			
	2018	2019	2020	2021	2022
Investments					
Total expenditure, EUR	346 265 627	317 244 497	280 703 696	254 835 099	254 817 754
Maintenance of electric vehicle (EV) charging infrastructure	187 844	358 107	348 165	335 030	317 685
Targeted grants for municipal roads (streets)	50 101 934	50 859 681	53 776 945	53 776 945	53 776 945
Maintenance and renovation of state roads	171 125 855	172 675 926	189 802 124	189 057 124	189 057 124
Management of state roads	11 856 337	12 310 000	11 691 000	11 666 000	11 666 000
Cohesion Fund (CF) funded limited selection projects implemented by "Latvian State Roads" (2014-2020)	32 605 388	4 095 000	5 200 000	-	-
European Regional Development Fund (ERDF) funded limited selection projects implemented by SJSC "Latvian State Roads" (2014-2020)	68988603	60700000	17300000	-	-
European Regional Development Fund (ERDF) funded electric vehicle (EV) infrastructure projects (2014-2020)	3 344 879	2 375 520	1 956 757	-	-
"Latvian State Roads" projects, implemented under Objective 3 "European Territorial Cooperation"	6 929 091	5 396 433	564 828	-	-
Repayments to the national basic budget of Objective 3 "European territorial co-operation" funding	1 104 222	4 473 830	63 877	-	-
Projects of other European Union policy instruments	-	4 000 000	-	-	-
Use of contingency funds	21 473	-	-	-	-

Table 2. Road budget classification (Ministry of Finance 2020)

Author assumes that if State road fund is renewed it will develop fair distribution of incoming taxes. Unfortunately, this is political decision because in this case other ministries and industries can lose some percent of their budget, therefore this issue must be triggered by government.

Road fund renewal would mean recover the system where the road tax is included into fuel cost and appended or merged to excise duty. This system would provide fair tax policy between road users. If the road usage tax has been appended to the fuel cost, then income from fuel tax would be equal usage of road infrastructure. At the

end, every road infrastructure user would pay equal amount of road usage tax according how much or less they have been using road infrastructure.

Author is planning to design the GIS tool which will show combination of road network usage, fuel tax incomes, and road network management related data. As a side value for this tool author plans to implement traffic and road safety information as well as road accident data. It will provide wide perspective of road and traffic situation which is or might be affected by road budget management.

Road users especially motorized vehicle owners and drivers are in the category who are the least satisfied with

the quality of roads, road tax system and tax spending on road maintenance. There are few general issues which are not reasonable according to road user interests:

1. The earnings from road taxes, excise and other transport related taxes are not redirected to transports industry budget. Instead funding for State road maintenance is coming from general State budget and its amount is made by political decisions.
2. Vehicle owners must pay the same tax for owning a vehicle despite of how often they use it. In that case, tax system is not equitable to vehicle owners.
3. Due to bad road pavement quality, vehicles are put at risk to damage suspension and vehicle parts. At the end it makes road user to ask rhetorical question – why should they pay road usage taxes if the government cannot maintain State roads properly?

Between journalists, experts and society there have been many discussions to renew Road fund, however it has not been actual topic in governmental level. Author believes that renewal of Road fund can increase road budget. Combined with proper fund administration it will lead to better road system management and will increase incomes for road pavement maintenance budget.

Methods of tool development

In this article author reviews possible solutions to develop Geographical information system (GIS) tool which is running on real (or simulated) data and economic situation in country. This tool supposed to be on

ArcGIS platform-based WEB tool, which will indicate several factors like:

1. Tax income from different sources:
 - a. road network tax,
 - b. excise duty from fuel,
 - c. automobile tax,
 - d. fines for road traffic offenses,
 - e. etc.
2. Use of taxes and fund incomes.
3. Investments from projects.
4. Gross and net sales from gas stations.
5. Road network system.
6. Information about registered vehicles and road users.
7. Traffic volumes.
8. Road safety information.
9. Other road network related data.

The aim of planned GIS tool is to provide society and public institutions with visual and trustable tool that show critical areas in road network management and would allow to make political and economical road management decisions based geospatially processed and analysed data.

The developed GIS tool will solve these general tasks:

1. Display road usage and other road usage related tax data by regions.
2. Display road usage, traffic volumes and road safety information.
3. Display road network pavement quality data.
4. Geospatial analytics of those data sets.

State Road Network

Latest available official statistic from Latvian State Roads (LSR) is from 2018.

Classification of roads	Road length as at 31 December 2018, km			
	Bituminous pavement	Crushed stone and gravel pavement	Without pavement	Total
State roads:	9 254	10 812	-	20 066
main roads (A)	1 673	-	-	1 673
regional roads (P)	4 638	815	-	5 453
local roads (V)	2 939	9 944	-	12 883
auxiliary roads	4	53	-	57
Municipal roads and streets:	6 108	32 345	-	38 453
roads	1 206	28 941	-	30 147
streets	4 902	3 404	-	8 306
Forest roads	26	10 276	1 616	11 918
Total roads and streets	15 388	53 433	1 616	70 437

Table 3. Latvian road length statistic in 2018 (Latvian State Roads 2018)

Modelling road fund management by GIS tools

A geographic information system (GIS) is a framework for gathering, managing, and analysing data. Rooted in the science of geography, GIS integrates many types of data. It analyses spatial location and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships, and situations - helping users make smarter decisions.

Author wants to show how geospatial data information interacts between data sets and how GIS system can analyse, manage and visualise:

1. Tax income from different sources and its distribution by administrative territories:
 - a. road network tax,
 - b. excise duty from fuel,
 - c. automobile tax,
 - d. fines for road traffic offenses,
 - e. etc.
2. Use of taxes and fund incomes in national and regional levels.
3. Investments from national and international projects.
4. Gross and net sales from gas stations.
5. Road network system and infrastructure.
6. Information about road users and registered vehicles that includes data about type of vehicles, year of production emissions etc.
7. Traffic volumes and road usage.
8. Road safety information – road accident data, risk areas etc.
9. Other road network related data.

Model is planned to be a web application based on Environmental Systems Research Institute (ESRI) developed GIS software platform called ArcGIS, which includes:

1. ArcGIS for Desktop – used for developing data structure and separate customized modules of the tool.
2. ArcGIS Online – used for representation and analysis tool for end user.

Model is intended to be publicly available with possibility to secure it and use for governmental or specific institution purposes. For publicly available tool the data will be generalized or even artificially created and randomized. Because of data sensitivity and availability, it is a big threat that some of data will not be accessible for the tool. However, for publicly available tool, data precision and accuracy are not essential. The aim is to provide government and institutions with tool that can work based on the user data.

domized. Because of data sensitivity and availability, it is a big threat that some of data will not be accessible for the tool. However, for publicly available tool, data precision and accuracy are not essential. The aim is to provide government and institutions with tool that can work based on the user data.

GIS tool running principle

Latvian road and street budget management GIS Latvian road and street budget management GIS tool is going to consist of several modules:

1. Map – general module for data representation. This module is intended to be user friendly data visualisation. It will display default data and will represent results of user performed data analysis.
2. Layer list – view controls for data display. End user can choose which data sets user would like to review and use for analysis. Layer list allows an end user to combine different layers in different combinations. It will allow user to exclude unnecessary data sets for their interests.
3. Custom tools – Spatial analyse tools which will allow to perform geospatial analysis based on default and user preceded data. There are planned to be several analysis tools or used methods to get results. E.g.:
 - a. Income tax analysis by administrative territory and density of road infrastructure.
 - b. Income tax analysis by gas station locations.
 - c. Road network maintenance and other public project analysis according road and road infrastructure workload.
 - d. Road accident analysis according to road infrastructure quality and budget (or other project) spending on risk points in road infrastructure.
 - e. Etc.
4. Default tools – tools that allows user to navigate on the map and perform basic tasks which are common in many geospatial portals and WEB maps like map zoom in/out, pan, measure distance or are, search for an address or other geographical place etc.

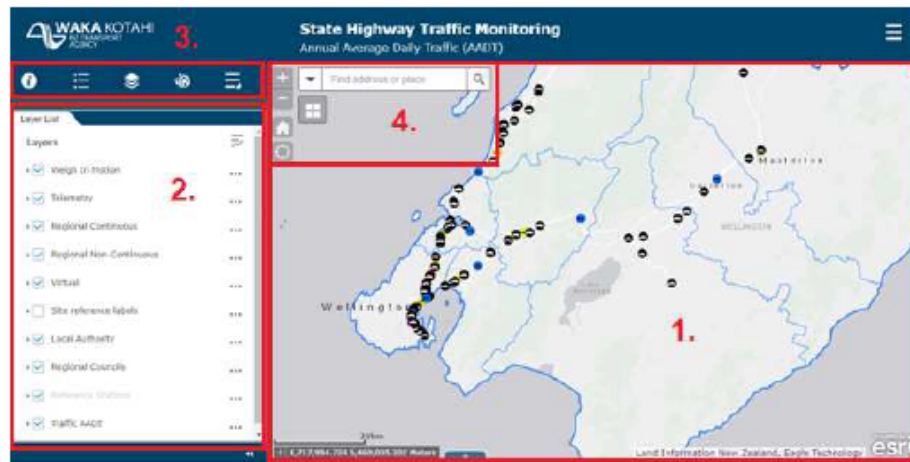


Figure 1. Visual example of GIS web application (New Zealand Transport agency 2020)

GIS tool design process and workflow

To develop the road fund management GIS tool author has set 7 step workflow. Each step is a separate phase of project which should be executed in following order.

1. Information and data research and investigation – first step is to research available literature about road infrastructure. This information and data include road safety and traffic data, development of analysis methodology and concepts of designing GIS analytic tools.
2. Default and research data analysis – this step includes basic or default data collection and preparation for further processing. It also covers research and business data technical reviewing, analysing and processing for the next step – designing the database and database schema. There are several data and data sources author would like to use as default data. According to default data availability, this data also might be artificially made. Possible data sources:
 - a. State Revenue Service (SRD) - direct administrative authority under the supervision of the Minister of Finance, which ensures the accounting of tax payments and taxpayers; the collection of taxes, duties and other mandatory payments specified by the State in the territory of the Republic of Latvia; collects taxes, duties and other mandatory

payments into the budget of the European Union; and implements the customs policy and organizes customs matters.

- b. Road traffic and safety directorate (RTSD) - provides and maintains system for vehicle registration, driver qualification examinations and issuance of driving licenses, provision of technical inspection, performs road safety audit and general supervision, as well as creates and maintains a state register of vehicles and their drivers, informs and educates road traffic participants.
- c. Latvian State Roads (LSR) - performs the management of the state road network, administration of the State Road Fund and organisation of public procurement in order to provide the publics with profitable, durable, safe and environmentally friendly state road network.
- d. Latvian Fuel Traders Association (LFTA) - voluntary association of Latvian fuel traders. Founded with the aim of being a partner to the government and participating in the development of the regulatory framework for the industry
- e. Jana seta Map Publishers (JSMP) - leading company in the market of maps in the Baltic States. "Jana seta Map Publishers" offers a wide range of carto-

graphical editions as well as services of various kinds including polygraphy works, GIS and programming.

- f. Ministry of the Interior (MI) - the leading institution in home affairs sector which includes such subsectors as fight against crime, protection of public order and security, protection of individual rights and lawful interests, state border security, fire safety, fire security, rescue, civil protection, record keeping and documentation of population, as well as migration.
 - g. Freely available data from mobile applications – Waze, Google maps, Maps (Apple).
 - h. etc.
3. Designing database schema (DB schema) – DB schema is structure described in a formal language and is designed by author (DB administrator or an DB architect). Based on collected data DB schema will be designed to fulfil requirements of the developed tool and would have original input data structure as much as it is possible.
 4. Tool development – the process involves design of the tool and data representation – the WEB map. The road budget management tool is planned to be designed with ArcGIS WEB App Builder which is part of ArcGIS software platform and allows to design web applications. Some functionalities are planned to be designed with ArcGIS desktop software ArcGIS ModelBuilder and published to ArcGIS Online where it would be integrated into general tool. Tools made with ArcGIS ModelBuilder are compatible with Python scripting language and can be combined with additional tools which functionality can be designed using Python 2.7 (or newer) programming language.
 5. Tests will be performed during development process and before tool is going to be launched and published. Tests will cover all the tasks and processes set in methodology that tool must perform. Tests will be performed by third parties and feedback will be collected for improvement of the tool or fixing bugs.
 6. The tool is going to be launched and published when test results will approve tool ability to perform ¾ of the requirements set in methodology.

The tool is going to be published according to input data restrictions. It might be possible the tool is going to be published with everyone securing restricted data.

Conclusion and results

1. The Latvian road budget is not enough to cover all needs and keep all road network in good condition. Therefore is important to seek for different methods and options to optimize and use road budget properly.
2. In Latvian government and in other institutions renewal of Latvian road fund is not priority at the moment.
3. Author believes that renewal of Latvian road fund and proper road tax management can improve road network pavement quality and road safety.
4. Author is proposing a GIS tool which represents benefits from renewal of road fund and would give a visual example how proper tax management can be used to improve road pavement quality as well as road safety.

Acknowledgments

Supervision by Prof Dr Eimuntas Kazimieras Paršeliūnas, Vilnius Gediminas Technical University.

References

- Subhi M. Bazlamit, Hesham S. Ahmad*, Turki I. Al-Suleiman (Obaidat), 2017. Pavement Maintenance Applications using Geographic Information Systems, 7th International Conference on Engineering, Project, and Production Management. Procedia Engineering 182 (2017) 83 – 90. Al-Zaytoonah University of Jordan, Department of Civil and Infrastructure Engineering, P.O. Box: 130 Amman 11733 Jordan
- Markus, P. 2016. Design and development of a prototype mobile geographic information system for real-time collection and storage of traffic accident data, Student thesis series INES nr 403, Department of Physical Geography and Ecosystem Science, Lund University, Solvegatan 12 S-223 62, Lund, Sweden.
- Faris G. Faris, Mustafa D. Mahir, 2012. Using of Modern GIS in Road Condition Index, Journal of Ad-

vanced Science and Engineering Research Vol 2, No 3 September (2012) 178-190, ISSN 2231-8844.

Bertha Santos, Pedro G. Almeida, Leonor Maganinho, 2019. Data Collection Methodology to Assess Road Pavement Condition Using GNSS, Video Image and GIS, IOP Conf. Series: Materials Science and Engineering 603 (2019) 042083

F. Ali and Z. Batool, 2016. Geographic information system (GIS) based highway asset management system for motorways: case study of major Pakistan's motorways. Pakistan Journal of Science (Vol. 68 No.3 September, 2016)

The Ministry of Finance:

https://www.fm.gov.lv/lv/sadalas/valsts_budzets/valsts_budzeta_vizualizacija/budzets2020/

https://www.fm.gov.lv/lv/sadalas/valsts_budzets/valsts_budzeta_vizualizacija/budzets2020/17_satiksmes_ministrija/2286-2-autoceli/

https://www.fm.gov.lv/lv/sadalas/valsts_budzets/valsts_budzeta_vizualizacija/budzets2020/17_satiksmes_ministrija/2286-2-autoceli/

Latvian state roads:

https://lvceli.lv/wp-content/uploads/2019/10/AA-oktobris_2019_galaversija.pdf

<https://lvceli.lv/uncategorized/fm-autocelu-finansejums-japiesaisita-ekonomiskajai-attistibai/>

https://lvceli.lv/wp-content/uploads/2019/08/Latvijas_Valsts_Celi_2018_A4_tumszals_20190716_B.pdf

con-

[tent/uploads/2019/08/Latvijas_Valsts_Celi_2018_A4_tumszals_20190716_B.pdf](https://lvceli.lv/wp-content/uploads/2019/08/Latvijas_Valsts_Celi_2018_A4_tumszals_20190716_B.pdf)

State Revenue Service:

<https://www.vid.gov.lv/en/about-us-0>

ESRI:

<https://www.esri.com/en-us/what-is-gis/overview>

LATVIJAS KELIŲ IR GATVIŲ BIUDŽETO VALDYMAS GIS PRIEMONĖS

Rudolfis Vingris

Santrauka

Latvijos Respublikos biudžetas skirtas transporto ir komunikacijų sektoriui 2020 metais yra 457.2 milijonų EUR, iš kurių 255.3 milijonų EUR yra numatyta keliams ir jų priežiūrai. Tačiau tokio biudžeto nepakanka, kad tinkamai būtų prižiūrėti keliai, o gyventojai ir svečiai būtų patenkinti kelių kokybe.

Nuolat kalbama apie kelių fondo atnaujinimą, tam skiriamą dalį mokesčių už kūrą, automobilių eksploatavimą ir pan., t.y. su transportu susijusios veiklos turi būti nukreiptos kelių priežiūrai.

Tačiau Transporto ministerija ir kitos atsakingos institucijos nesusitaria dėl tokio fondo steigimo.

Šiame straipsnyje autorius apžvelgia viešai prieinamą informaciją apie kelių priežiūros problemas. Remdamasis šia informacija autorius analizuoja ir interpretuoja kelių priežiūros biudžetą taikant geordvinius analizės metodus. Straipsnyje aprašoma geoinformacinės sistemos (GIS) modelis, kuris įgalina transporto ekspertams plamoti ir analizuoti transporto biudžetą, administravimą ir vizualizavimą visai bendruomenei, jei fondas bus įsteigtas ir taps efektyviu.

CONSENT TO THE USE OF PERSONAL DATA

05.01.2021
(Date)

With this consent I, Rūdolfs Vingris (hereinafter referred to as the Data subject) agree to the processing of my personal data for the learning purposes of other students by Vilnius Gediminas Technical University, legal entity code 111950243, address – Saulėtekio al. 11, LT-10223 Vilnius (hereinafter referred to as the Data controller). I agree to the processing of the following personal data (mark the relevant item):

- ☐ name, surname, Bachelor's final thesis;
- ☐ Bachelor's final thesis without name and surname;
- ☐ name, surname, Master's final thesis;
- ☒ Master's final thesis without name and surname.

Personal data processed for this purpose will not be transferred by the Data controller to any third parties, students will be allowed to access the final theses in the internal information system.

The personal data of the Data subject will be used for this purpose for a maximum of 5 years.

By this consent, the Data subject confirms that he / she is aware of the following rights:

- Access to his/her data and how it is processed (right of access);
- Require the rectification or, depending on the purposes of the processing of personal data, the addition of incomplete personal data (right of rectification);
- Destroy his/her data or suspend the processing of data (excluding storage) (right to destroy and right to be "forgotten");
- Require the Data controller to restrict the processing of personal data (right to restrict);
- The right to transfer data (right to transfer);
- Do not consent to the processing of personal data when such data are processed or are intended to be processed for other purposes;
- File a complaint with the State Data Protection Inspectorate.

The Data subject has the right to withdraw his consent at any time.

Rūdolfs Vingris 
[Name, surname and signature of Data subject]

Data controller details:
Vilnius Gediminas Technical University
Legal entity code: 111950243
Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
Tel. (+370 5) 274 5030
E-mail: vgtu@vgtu.lt
VAT payer code: LT119502413
Data protection officer tel. (+370 5) 251 2191, e-mail: dap@vgtu.lt

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Rūdolfis Vingris (20195790)

(Student's given name, family name, certificate number)

FACULTY OF ENVIRONMENTAL ENGINEERING

(Faculty)

Innovative Solutions in Geomatics study programme

(state code 6281EX001)

(Study programme, academic group no.)

**DECLARATION OF AUTHORSHIP
IN THE FINAL DEGREE PROJECT**

30.12.2020.

(Date)

I declare that my Final Degree Project entitled **“TRAFFIC SAFETY ANALYSIS BASED ON GEOSPATIAL CLASSIFICATION OF STREETS”** is entirely my own work. The title was confirmed on 30 November, 2020 by Faculty Dean's decree No. 135ap. I have clearly signalled the presence of quoted or paraphrased material and referenced all sources.

I have acknowledged appropriately any assistance I have received by the following professionals/advisers: Prof Dr Eimuntas Kazimieras Paršeliūnas, Vilnius Gediminas Technical University.

The academic supervisor of my Final Degree Project is Prof Dr Eimuntas Kazimieras Paršeliūnas, Vilnius Gediminas Technical University.

No contribution of any other person was obtained, nor did I buy my Final Degree Project.


(Signature)

Rūdolfis Vingris
(Given name, family name)