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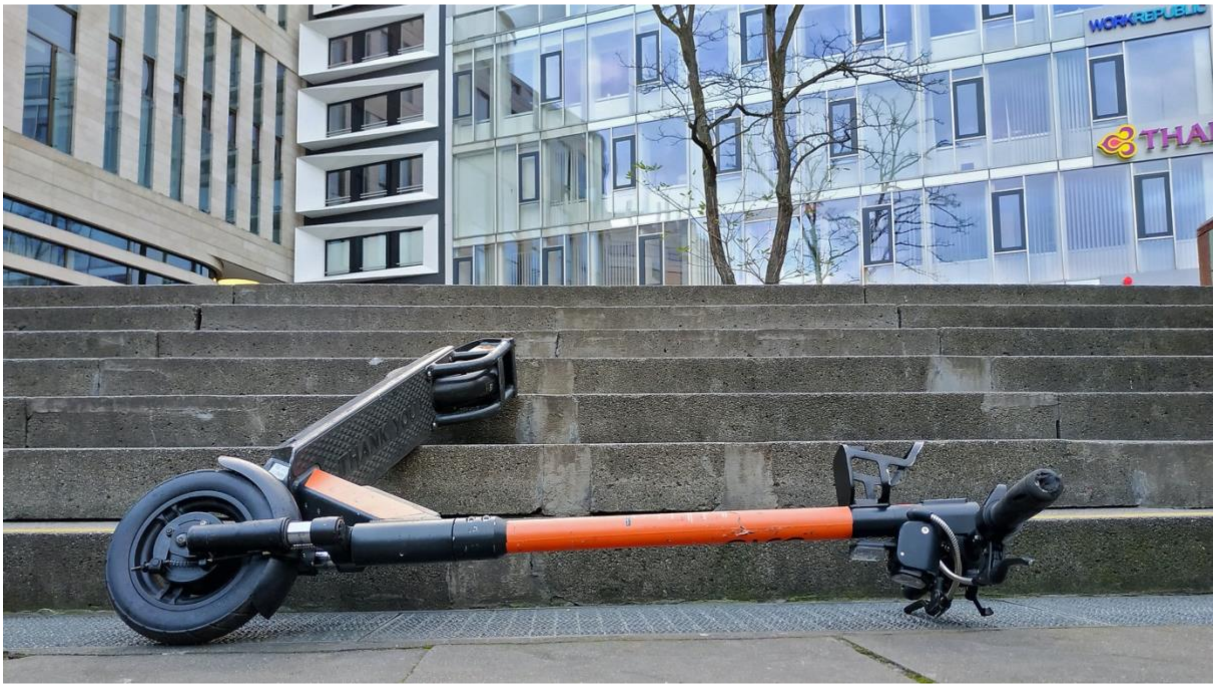

Analysis of traffic crashes involving electric personal mobility vehicles

Bachelor thesis in Mechanical Engineering

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DEPARTMENT OF
MECHANICS AND MARITIME SCIENCES

CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

The future requires environmentally friendly and efficient vehicles for transportation. The vehicles should be safe and easy to use. Electric Personal Mobility Vehicles (e-PMVs) have become popular in cities. Reported crashes for e-PMVs are limited and information about the number of crashes and the injury level is important to get more information in order to prevent future crashes.

The crashes were analysed and evaluated by extracting reported information from databases. The databases used were STRADA and IGLAD. To extract data from the databases a query was written and the main part of the query consisted of a text search algorithm that used a wildcard search to extract relevant cases.

A literature review was done in order to understand, evaluate and develop the best extraction method and the most relevant variables regarding the crashes for e-PMVs.

E-scooters, Segways and hoverboards are the largest categories by number of crashes reported. The results indicate that the majority of accidents involved e-scooters, with mild to medium-level injuries. Most of the crashes were in urban areas with a driver aged between 20 and 30 years old.

Keywords: electric personal mobility vehicles, e-PMV, e-scooters

Sammandrag

Framtiden är i behov av miljövänliga och effektiva transportmedel som bör vara säkra och enkla att använda. Elektriska Personliga Mobilitetsfordon (e-PMVs) har blivit populära i städer. Rapporterade olyckor med e-PMVs är begränsade, information om antalet olyckor och hur skadegraden på olyckorna ser ut är viktiga för att förebygga framtida olyckor.

Informationen analyserades och utvärderades genom utdrag från databaser. Databaserna som användes var STRADA och IGLAD. För att extrahera informationen från databaserna skrevs kod, huvuddelen av koden baserades på en text sök algoritm för att inkludera relevanta olyckor.

Litteraturstudier gjordes för att senaste informationen skulle användas i rapporten och för att säkerställa bästa möjliga sökkriterier användes i text sök algoritmen.

Rapporten fokuserar på e-skotrar, Segways and hoverboards. Resultatet visar att majoritet av olyckorna består av e-skotrar med lindrig eller medium nivå på skadorna. De flesta olyckorna sker i städer och åldern på föraren är mellan 20 och 30 år.

Acknowledgements

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A special thank you to Tobias Anjemark for help with query coding and discussion regarding the query design and Sofia Mellgren for inspiring discussions regarding design and formatting of the report.

Chalmers University of technology through Johan Bankel for supporting and his personal commitment to supporting this project.

Glossary

E-PMV – Electric personal mobility vehicles

STRADA – Swedish Traffic Accident Data Acquisition

IGLAD – Initiative for the global harmonisation of accident data

ACEA – European Automobile Manufacturer's Association

Table of content

1 Introduction

The popularity of electric Personal Mobility Vehicles (e-PMV) in cities around the world is rapidly increasing. The increasing number of vehicles and ease of access has created an increasing risk of e-PMV involvement in crashes and raised questions regarding this type of vehicle category.

The cases from the databases IGLAD and STRADA are used in the report. None of the databases provides a separate category for e-PMVs, furthermore the number of reported cases with accidents and the information from the crashes for this new category of vehicles is unknown. There is limited previous knowledge from published reports regarding this subject.

The information provided in this report can be important for future work with road safety and policy planning for upcoming city projects to reduce the risk for future crashes.

1.1 Background

Crashes involving e-PMVs are growing in number and the importance to study the crashes is to continuously develop a safer environment, both for the drivers, and the possible affected persons of a crash. There are several ways a crash can be reported. There are databases with reports from police, from hospitals, insurance companies or the vehicle manufacturer. The data is most likely not synchronized between the records, however there are exceptions which use data from multiple input sources.

e-PMVs are mainly used by people in larger cities and are a complement to travel from point A to B for short distance trips. They replace trips made by foot, with public transportation and by bikes.

STRADA and IGLAD are two databases that provide data about different types of vehicle crashes. Together, the two databases cover multiple countries and different situations.

1.1.1 Electric Personal Mobility Vehicles

The category of e-PMV is defined as a personal, motorised vehicle to transport up to a speed of 25km/h. The European Union has a category called L according to regulation No 168/2013 vehicles with one-, two-, and four-wheels vehicles (European Economic and Social Commitee, 2013). Most of the e-PMVs discussed in this report are included in the L1e category, which is a subcategory of L. In Sweden an electric scooter is defined as a bicycle if the engine power is less than 250W and cannot reach speeds over 20km/h (Transportstyrelsen, 2020b). If the scooter is defined as a bicycle, then the it can be driven without a license and with the same rules as bicycles. If the requirements are not met the scooter is defined as a motorcycle and requires a license.

Vehicles in the e-PMVs category are, for example, e-scooters/e-kickbikes (Figure 1), hoverboards (Figure 2) , Segway (Figure 3) electric skateboards and unicycles.

Figure 1 E-Scooter/e-Kickbike

Figure 2 Hoverboard

Figure 3 Segway

1.1.2 IGLAD database

IGLAD was created by Daimler AG, ACEA and other research institutes in October 2010. The group works together to define a common standardized data set and is a non-profit organization. The purpose of the data set is to provide an effective platform to use while analysing road accidents and developing road safety policies.

Between 2012 and 2020 three passes with corresponding data have been released. The first phase included 1550 cases from 10 countries published in 2014. Phase 2 included a unified data processing software tool, Unidato, and was released in 2016 with 900 cases from 10 countries. Phase 3 was released in late June 2020 and includes data from phase 1, 2 and 3 together and includes 6650 cases (IGLAD, 2020).

1.1.3 STRADA database

Swedish Traffic Accident Data Acquisition (STRADA) is an information system with data on crashes and injuries within road transport. The source of the data is from police and hospital reports (Transportstyrelsen, 2020a). The advantage of having two separate data sources in one database is to cover a wider range of variables (Howard & Linder, 2014) and a visualization is presented in Figure 4.

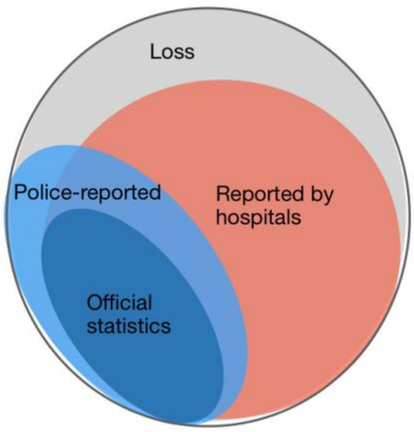


Figure 4 Visualization over what source has reported cases in STRADA based on Transportstyrelsen (2020a)

STRADA includes personal information and other information which could be of a sensitive nature. This implies limited access to the database for researchers with permission from the Swedish Ethical Review Authority or authorities with special permission. The permission determines the risk of violating the personal information and the positive outcome of allowing access to the data. The data is pseudonymised, which means personal identity number and other personal information is exchanged to code.

1.2 Purpose

The aim of the report is to summarize how many cases of crashes involving e-PMVs are available and present the most important factors for why the crashes occurred. The report will also include an analysis of what different types of vehicles within the category of e-PMVs are represented in crashes. The data is limited IGLAD and STRADA databases and includes information from literature reviews.

1.3 Research questions

How many cases of crashes for e-PMVs are reported in the databases?

What types of e-PMVs are involved in the crashes?

Why are e-PMV involved in a crash?

How many vehicles are included in a crash?

Is the driver injured when crashing with e-PMVs and what type of injury?

Is there any specific location for the crashes?

2 Literature review

This section includes information and facts from reports related to e-PMVs. The reviews have been concluded throughout the project and are a complement to the databases.

The crashes may result in injuries of the driver of ePMVs but also sometimes injuries to other parties involved in the crash (Transportstyrelsen, 2020a).

2.1 Number of reported cases

Concerns about the absence of an own category for e-PMVs and therefore an increased risk of not identifying relevant crashes is discussed in many reports. The use of text search in a description box is highly sensitive for misspelling, other definitions and abbreviations, which in turn increases the risk of identifying false crashes (MOVEA, 2019).

The rapidly rising number of crashes is supported with results from MOVEA (2019) which states that only two crashes were reported during 2018, compared to 150 cases for the first eight months of 2019. The crashes were reported in STRADA and only for the area in Stockholm, Sweden. Trafikverket (2020) reports 629 crashes with e-scooters for 2019 in Sweden which again supports the growing number of crashes.

According to Santacreu (2020), crash data collected by e-scooter rentals indicates a decreasing trend of crashes with e-scooters. The analysis was based on data from reported crashes to the rental companies. Moreover, the author points out that the reports could be misleading since the method for reporting crashes is questionable.

For Gothenburg, the reports of accidents of e-scooters has grown since the introduction of e-scooter rentals during the end of 2018. The report covers both light and more serious accidents (Trafikkontoret, 2020) and Trafikkontoret states the number of reported crashes is proportional to the number of trips fulfilled with e-scooters.

2.2 Possible variables of interest

Different reports were focused on different variables. The sources for the different reports allowed the author to evaluate different aspects. The variables of interest from the literature review were collected so that it was possible for comparison and evaluation from the databases.

2.3 Location, time and day for the crash

Trafikkontoret (2020) reports that there is a large volume of crashes on Saturdays and around the weekends in general and around 80% of the crashes are single vehicle crashes. The report also presents that the location of the accidents is almost 50% for bike lanes and around 25% on the sidewalk. Therefore, the information regarding day and location is interesting and valuable in order to evaluate the crash.

2.3.1 Injury level

One reason for e-PMV driver injuries identified by Santacreu (2020) is that the riders of e-PMVs rarely use helmets as protection, despite the fact that many rental companies and some countries legally require this type of safety equipment (Voi, 2020).

Severeness of crashes was compared against normal bikes and indicates that the amount of light injuries was fewer than for bicycles. The severe injuries for e-scooters had a higher ratio than for the bikes (MOVEA, 2019).

2.3.2 Gender

Male riders are overrepresented in the e-scooter injuries (Santacreu, 2020; International, 2018). This is not the case for the report based on crashes in Stockholm, Sweden where the crashes are split equally between male and female drivers (MOVEA, 2019).

2.3.3 Type of accident

The type of accident is reported as mostly crashes not involving any other party (MOVEA, 2019) and are in line with Trafikkontoret (2020).

2.3.4 Traffic rules

The driver of the vehicle is responsible for understanding and applying the traffic rules applied to the vehicle. The rules are different in different countries. In Sweden, bicycles with a driver age over 15 are allowed to use the road but encouraged to use the bike lane as much as possible (Transportstyrelsen, 2020c).

2.4 Key variables

To understand the crash of the e-PMVs some variables are more important than others. The choice of variables was made with knowledge from the literature review, discussions with supervisors, Andreas and Giulio, together with experience from evaluating the variables from the database.

2.4.1 Variables of interest

The decided variables of interest are presented in Table 1 and cover the information needed to get a complete understanding of e-PMVs crashes.

Table 1 Interesting variable for evaluating and analysing the crashes

Title	IGLAD variable	STRADA variable
Age	AGE	Age
Accident sourcecause	MAINFACT	CircumstanceCode, AccidentDescription
Accident type	ACCTYPE, COLLTYPE	Acctype
AgeWho	AGE, GENDER	Age, Sex
Alcohol	ACCDESC, MAINFACT	InfluencedByAlcohol, Permillage
Time of accidentDate and time	YEAR,WDAY,TIME	acc_date, DateUnsure, DateUnknown, TimeUnknown
Day of the week	WDAY	acc_Date
Distraction	FACTOR1-3	CircumstanceCode
Drugs	MAINFACT	CircumstanceCode
Gender	GENDER	Sex
Injury places	MAIS	MAIS, Injury
Level of injury	INJSEVER, AIS, MAIS	InjuryExtent, MAIS, InjuryExtentHosp, AIS
Location	GPSLAT,GPSLONG, LOCATION	x_coord, y_coord, Municipality, Roadname, Placetype
Speed	INISPEED1-2, COLSPEED1-2	

3 Method

This section describes the methods used in this project.

3.1 Social and Ethical aspects

STRADA and IGLAD databases both includes sensitive data about the crash which under the Swedish act concerning the Ethical Review of Research Involving Humans (SFS 2003:460) (Codex, 2020) there should be an agreement that the benefit from the study is greater than the risks for individuals included. Therefore, the project applied a strict policy for extraction of data.

The extraction of information from the database was done by supervisor and also the decision on what variables was allowed to extract for use of this report. The choice of allowed variables was based to avoid the exposure of any personal information which could connect the collision to any person.

3.2 Quantitative study

The report is analysed with a quantitative study. A quantitative study is relaying on multiple data collection which in this case refers to a large number of crashes and often involves the use of computational and statistical as well as mathematical tools to derive a result. The amount of data is preferably large and is typically conducted by surveys. The advantages of a quantitative study are that the results can condensed to be statistics, has error estimates, definitive and is standardized (Sukamolson, 2007).

3.3 Limitation of access to databases

The access to the STRADA database was limited due to personal and ethical aspects. To avoid any violation of these an extraction was made manually by my supervisor. The extraction was made by an online webservice query at the STRADA web client and resulted in multiply files for each criterion in Table 2. The files were shared and merge into one table with MS Access. The manually extraction from STRADA used a wildcards search with the keywords presented in Table 2.

Access to the IGLAD database was possible and no manual extraction was needed.

Table 2 Text strings for the text search algorithm to find e-PMVs in IGLAD

Criteria	Category
aimo	e-scooter
beam	e-scooter
bird	e-scooter
blinkee	e-scooter
bolt	e-scooter
bunny	e-scooter
circ	e-scooter
cityscoot	e-scooter
costzon	e-scooter
e sparkcykel	e-scooter

e-fordon	e-vehicle
e-sparkcyckel	e-scooter
e-sparkcykel	e-scooter
efordon	e-vehicle
ekickbike	e-scooter
el-drivna	e-vehicle
el-fordon	e-vehicle
el-scooter	e-scooter
el-scoter	e-scooter
el-skateboard	e-scooter
el-skooter	e-scooter
el-skoter	e-scooter
eldriven sparkcyckel	e-scooter
eldriven sparkcykel	e-scooter
eldrivna	e-vehicle
elektrisk kickbike	e-scooter
elektrisk skoter	e-scooter
elektrisk sparkcyckel	e-scooter
elektrisk sparkcykel	e-scooter
elektriskskoter	e-scooter
elfordon	e-vehicle
elmoped	e-vehicle
elscooter	e-scooter
elscootrar	e-scooter
elscoter	e-scooter
elskateboard	e-scooter
elskooter	e-scooter
Elskoter	e-scooter
elsparkcyckel	e-scooter
elsparkcykel	e-scooter
enpersons	e-vehicle
esparcykel	e-scooter
espark cykel	e-scooter
glion	e-scooter
glyde	e-scooter
gotrax	e-scooter
hoverboard	hoverboard
howerboard	hoverboard
kaabo	e-scooter
kaabo	e-scooter
kickbike	e-scooter
kickscooter	e-scooter
lanmaker	e-scooter
lime	e-scooter
moow	e-scooter

movo	e-scooter
nanrobot	e-scooter
ninebot	segway
razor	e-scooter
razor share	e-scooter
scoot	e-scooter
seggway	segway
segway	segway
sekway	segway
seqway	segway
självbalanserande	e-vehicle
skip	e-scooter
spark cyckel	e-scooter
spark cykel	e-scooter
sparkcyckel	e-scooter
sparkcykel	e-scooter
swagtron	e-scooter
swiftmile	e-scooter
tier	e-scooter
unagi	e-scooter
voi	e-scooter
vosh	e-scooter
wind	e-scooter
xiaomi	e-scooter
xprit	e-scooter
zero 9	e-scooter

3.4 Query

To extract the crashes of interest from the databases a query was used. The query guaranteed that only relevant crashes was extracted from the databases.

3.4.1 Query design

The design of the query was made in MS Access and was written in SQL. Neither STRADA nor IGLAD had any category for only e-PMVs vehicles which excluded the possibility to find all relevant cases by filtering on vehicle type. Instead the query was designed to use a text search algorithm and combined with wildcards to include any crashes which matched a text string. The query was designed to find and include all relevant crashes. To avoid including irrelevant cases with crashes the code was written to only include the specific text string combined with some special symbols.

3.4.2 Text search technique

For the text search function, relevant e-PMVs name was used. The names were collected from literature reviews and was complemented with alternation of possible misspelling. The full table of text strings is presented in Table 2.

The text strings were divided into 5 different categories. The categories were e-scooter, e-skateboards, hoverboard, Seqway and e-vehicle. E-vehicle included text strings that did not match any of the other categories and the full list is presented in Table 2.

3.5 Data extraction

The tables were extracted from MS Access to MS Excel to easier analyse and study the extracted data. The data from STRADA was imported and several subqueries was used in Access and the results was create in a table which was extracted to excel.

3.5.1 STRADA

The main query using text search-technique was used to extract the *Olycks_Id* and the corresponding criterion match.

3.5.2 Subquery for elimination of irrelevant crashes

A subquery with another layer of criterion was added to eliminate crashes not relevant for this report was used. The query excluded occupants driving:

- *Personbil*
- *Elmoped*
- *Sparkcykel* and *kickbikes* if the drivers age was below 15

3.5.2.1 Filtering criterion for excel

In Excel the datasheet was altered and manipulated to present the result. The following structure was used and will be referred to in the report:

- Original extraction from MS Access (All data)
- Collision_AllVehicles (Person level)
- Collision_onlyEPMV (Person level)
- Crashes (Accident level)

A MS Excel-sheet, *Collision_AllVehicles*, was created which could include any number of rows as long as the *Olycksid* and *Ålder* (the age of the driver) was not identical from the original exctraction. Another sheet, *Collision_onlyEPMV,* was created by using filter to remove irrelevant cases which were observed by manual evaluating the description and *Sammanvägd_trafikkantkategori* (vehicle category). The filter removed any cases with *Sammanvägd_trafikantkategori* (vehicle category), *Buss (*Bus), *Lastbil (*Truck), *Motorcykel (*Motorbike) and *Spårvagn (Tram).*

A sheet, Crashes, containing only one collision from each crash was created.

The person level sheets were created by letting excel remove the duplicates by evaluating *Olycks_Id* and *Ålder*. This removed the crashes which had duplicates reported. Full list of removed crashes is presented in Appendix A. The duplicates came those crashes whose description contained at least two keywords in Table 2 and were thus found by each corresponding query in the STRADA web client. The duplicate rows were identical except some variables which contained no or unknown information.

3.5.3 IGLAD

The IGLAD returned very few results. The main query for elimination of irrelevant crashes was used in the same way as for the STRADA database.

A subquery with another layer of criterion was added to eliminated crashes non relevant for this report was used. The query excluded

- Beam
- Wind

3.6 Variables to evaluate in the report

This section is analyzing and evaluating the data from the query used on the databases, IGLAD and STRADA. The exact variable and corresponding data name for the database is presented in Table 1.

The low number of cases in IGLAD and the data protection of the STRADA made in not possible to address all the variables in Table 1.

3.6.1 Number of cases

The quantity of reported crashes was vital to get a valid result of the analysis. The amount of crashes for e-PMVs reported in IGLAD was vary few. The amount of crashes from STRADA was sufficient to continue the analysis and evaluation.

To evaluate the location of the crash many variables was available such as GPS coordinates, country- and area code, within and outside urban areas. For data extracted from STRADA the restriction of access made it only possible to analyse the area for the collision. The data provided data if the crash was made in a rural or urban area. In some collision the data was not reported and any conclusion about the collision area could be made.

A variable for what weekday for the crash was available from IGLAD and from STRADA.

The time of the crash was available in both databases.

The vehicle type was a variable in IGLAD that was chosen from a set of 19 codes with corresponding labels. Since e-PMVs are not a separate category, the crashes must be fitted into one of the 19 codes.

In Strada the primary element type was reported. The possibilities to find a pattern to include or use this category was limited since the reported data was varying without any pattern. The collision was sometimes categorised as pedestrian, bicycle, motorbike or other.

3.6.2 Injury

The injury severity assessment was based on grouped values of the Injury Severity Score (ISS). The score divides the injury into categories based on how sever and what body part was hurt with a respect to a specific weighting system called Abbreviated Injury Scale (AIS) (Association for the Advancement of Automotive Medicine, 2020).

3.6.3 The driver

The age of the driver was a variable that is provided in both IGLAD and STRADA. The information is important in the sense of getting an understand of what kind of persons are involved in crashes.

Since of earlier conclusion of gender from other reports discussed earlier in section 2.3.2 stated that male drivers involvement in crashes was overrepresented. Both databases provide a variable for gender which made the possibility of evaluating the gender.

4 Results

In this section the result from the data extraction from STRADA is presented. Since the data extraction from IGLAD gave insufficient number of crashes not every section includes results from IGLAD. For STRADA the data was extracted 2020-08-19 and excludes reports of crashes after that.

4.1 No results

Some variables and data were not possible to determine or present. Reasons for that was availibilty of sufficient data. IGLAD did not provide enough number crashes and STRADA had restricted access. The following variables was still considered interesting but has no results in this report:

- Reason behind the crash
- Single or multiply person crash
- Drugs
- Alcohol
- Experience
- Distraction
- Helmet

4.2 Number of cases

The number of cases reported from the extraction of data from the databases is presented from IGLAD and STRADA.

The number of reported crashes in IGLAD are few. The number of reported e-PMV crashes for STRADA together with the number from IGLAD is presented in Table 3.

Table 3 Number of reported crashes and collisions

Database	Total number of collisions	Crashes reported with e-PMVs	Collisions reported with e-PMVs
IGLAD	6 650	3	3
STRADA	777 000	1 265	1 312
Grand total	**783 650**	**1 268**	**1 315**

4.3 Distribution between different vehicle types

Evaluation of the method for removing duplicates in excel was done. The result is presented in Table 4 and showed the category *e-scooter* was reduced by 20%, e-vehicle was reduced by

32% from 19 to 13 before applied filter. E-skateboard, hoverboard and Segway was almost untouched.

Table 4 Collisions deleted after duplication removal and applied filter

Category	Original	Collision_AllVehicles	Collision_OnlyEPMV	Percent removed
e-scooter	1307	1043	1026	21%
e-skateboard	12	12	12	0%
e-vehicle	19	17	13	32%
hoverboard	74	74	74	0%
Segway	191	187	187	2%
Totalsumma	1603	1333	1312	18%

The amount of crashes involving e-PMVs are presented in Figure 5. The result is based on both accident level.

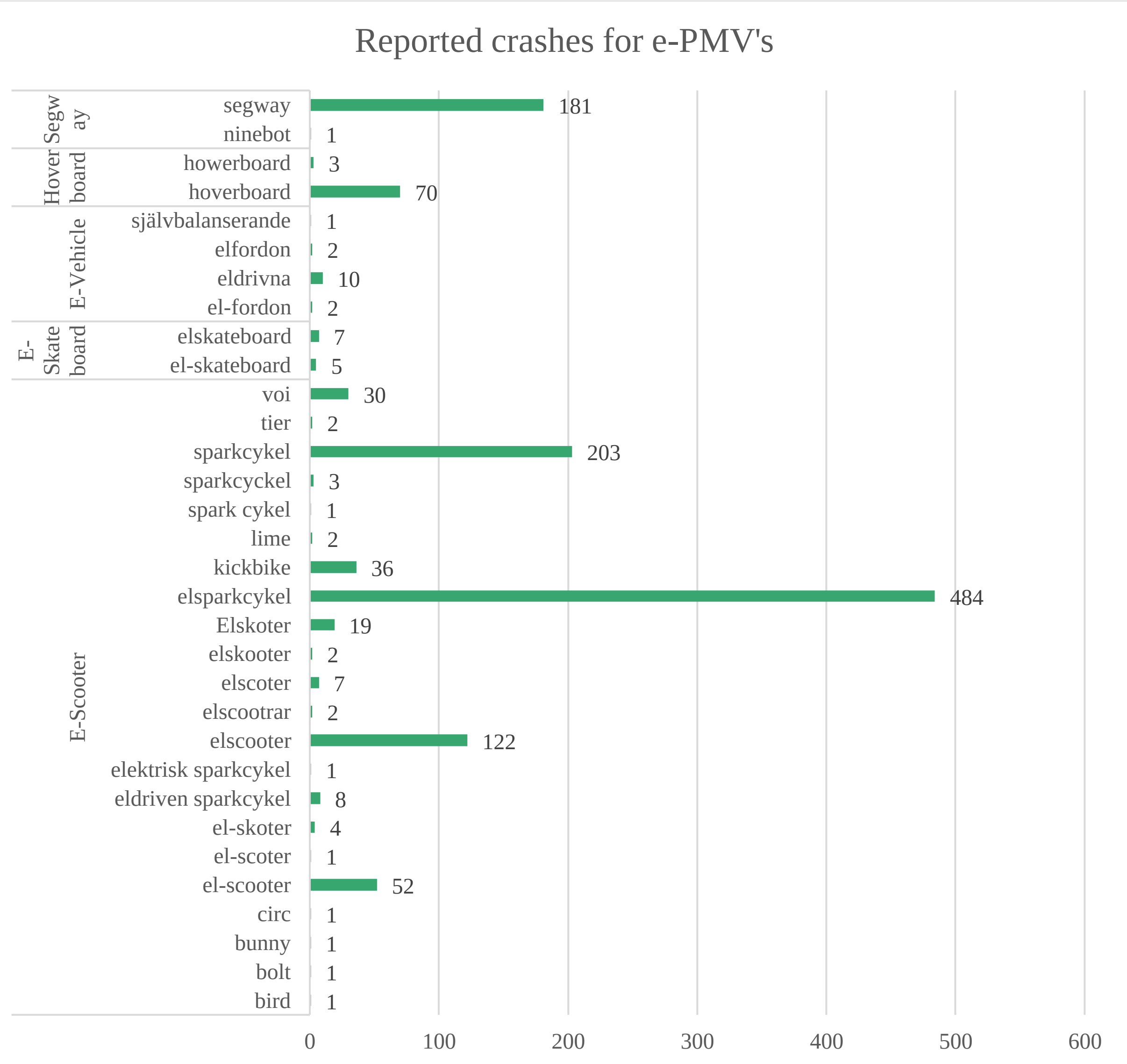


Figure 5 Reported crashes for different keyword and category from STRADA

The results indicated a big part of the reported crashes are with E-scooters which has 78% of the total reported crashes for e-PMVs as shown in Figure 6.

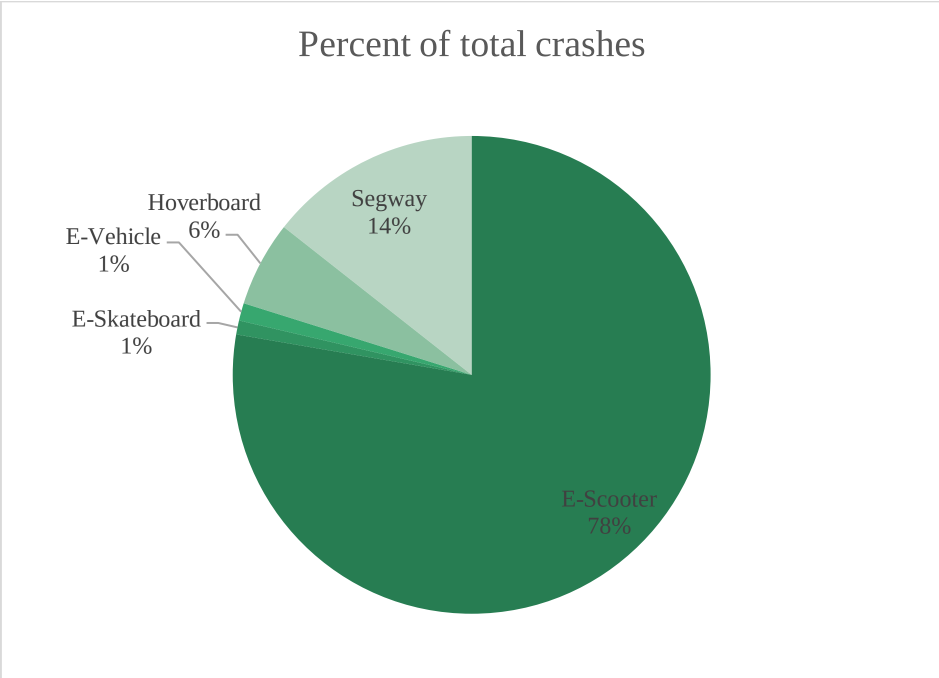


Figure 6 Distrubution of main vehicle types in e-PMV crashes from STRADA

In Table 5 the distribution of crashes and collision is presented between the categories.

Table 5 Distribution of crashes and collisions reported for each category

Category	Crashes	Collision_OnlyEPMV	Percent crashes	Percent collision
e-scooter	983	1026	78%	78%
e-skateboard	12	12	1%	1%
e-vehicle	15	13	1%	1%
hoverboard	73	74	6%	6%
Segway	182	187	14%	14%
Grand total	**1265**	**1312**		

4.4 Injuries from crashes

Injuries from STRADA are presented in Figure 7 and the result point towards that the most crashes categorises as slight injury (ISS 1-3). Figure 8 presents a more detailed look on which injury level is represented per category from STRADA.

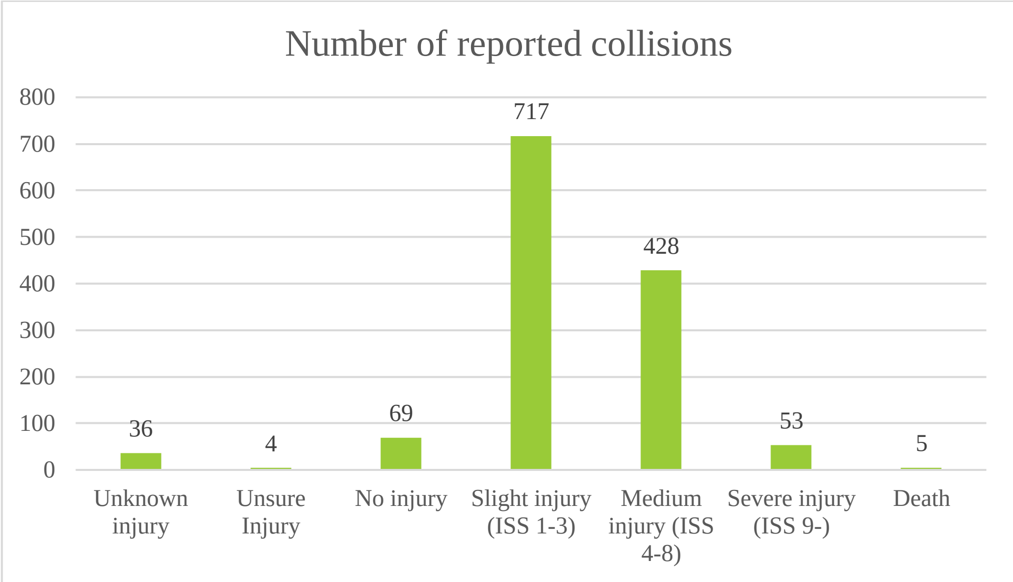


Figure 7 Injury severity for road users involved in ePMV crashes in STRADA

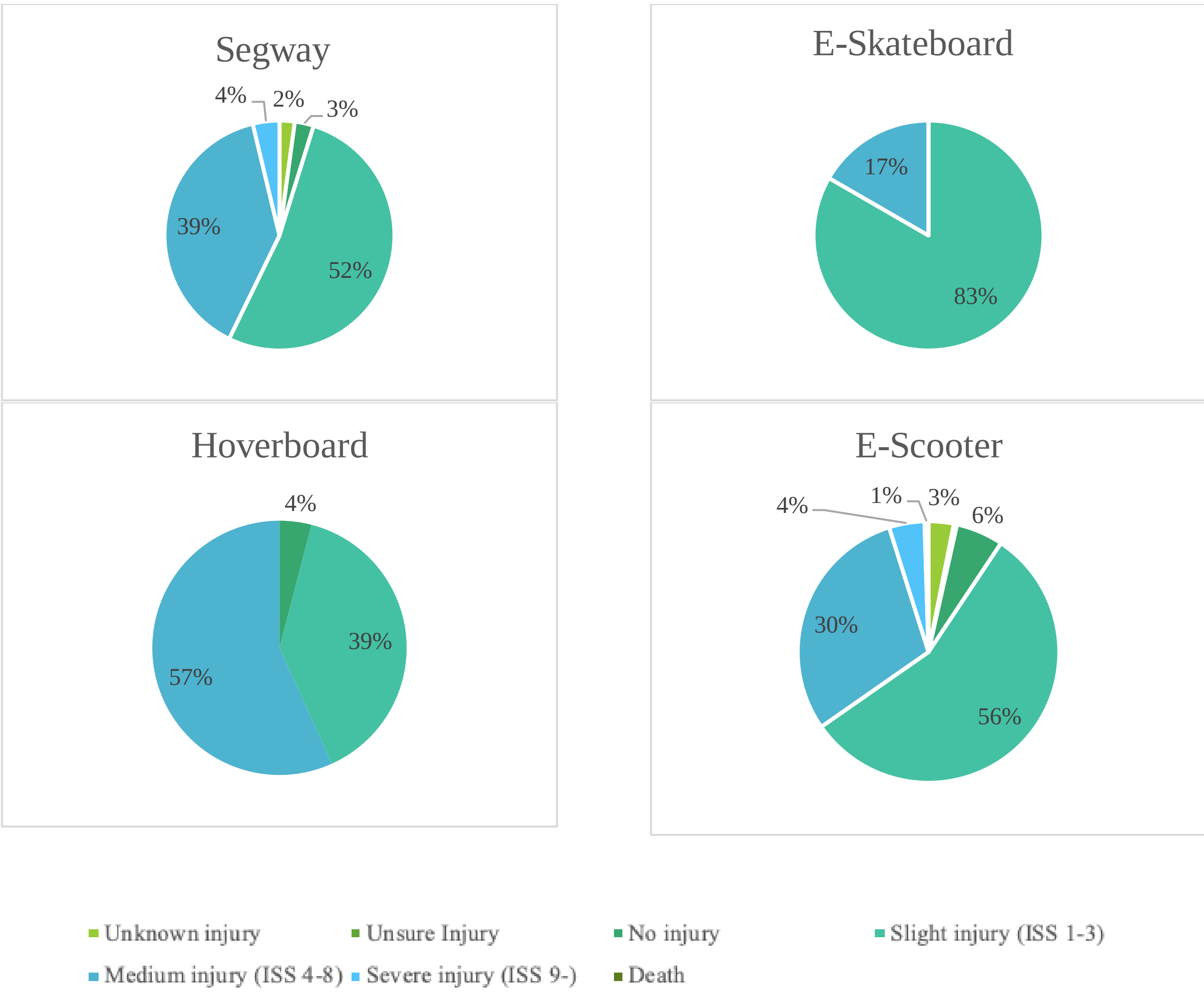
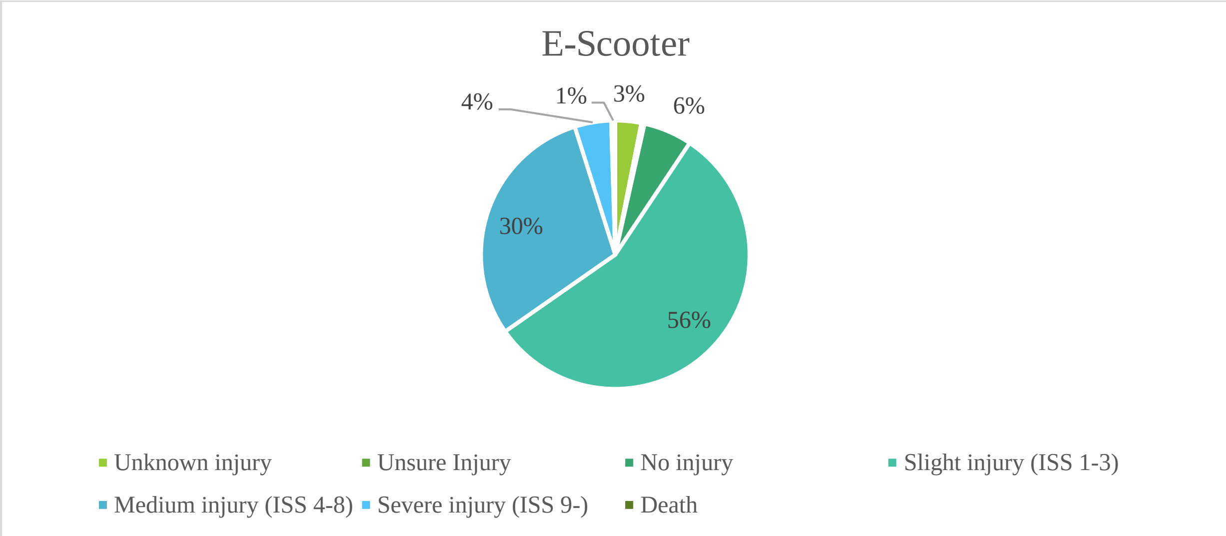


Figure 8 Distribution of injury level for Segway, e-skateboard, hoverboard and e-scooter from STRADA



4.5 Location

Crashes involving e-PMVs occur mainly in urban areas and is presented in Figure 9. The Segway is overrepresented in the unknown/not reported category with around 200 counts.

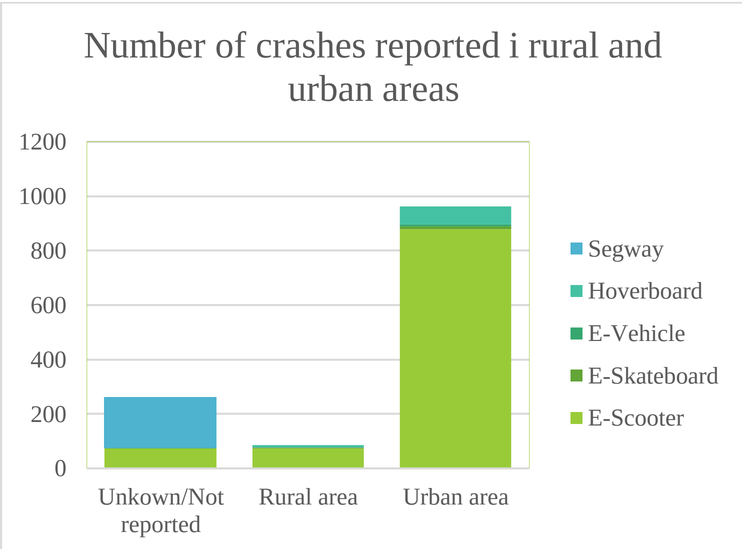
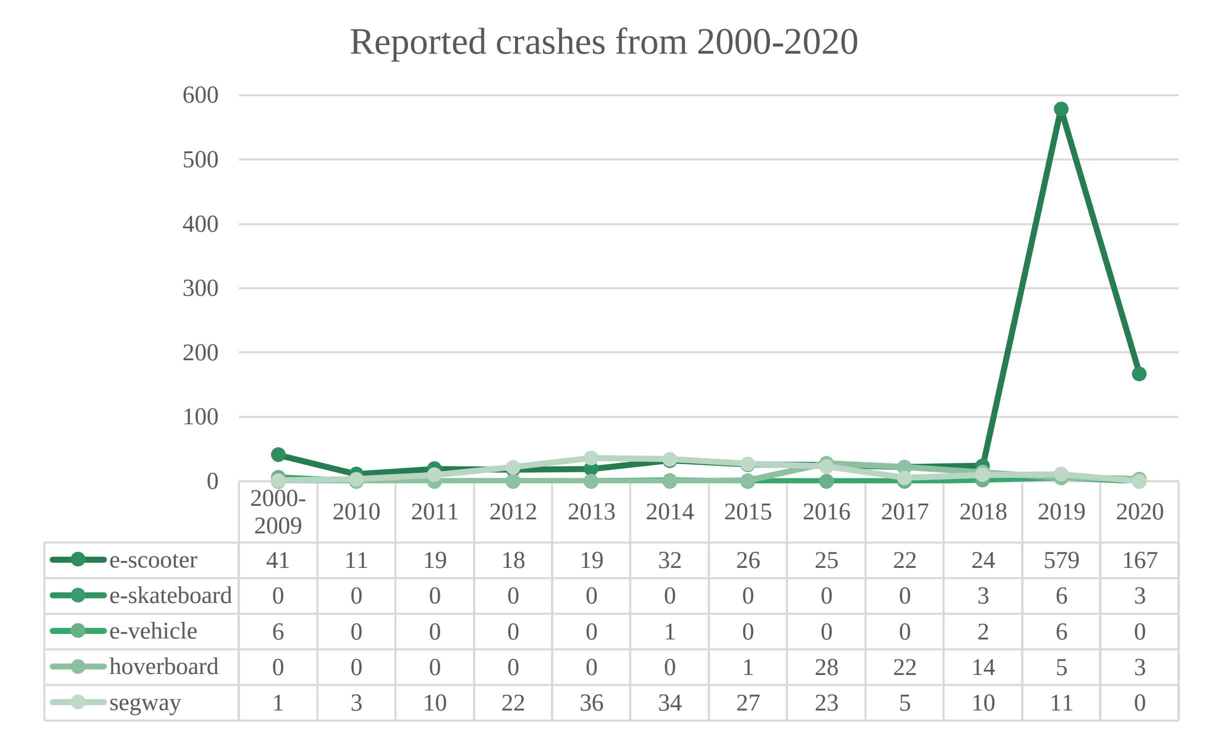


Figure 9 Distribution between urban and rural location of accidents reported with e-PMVs from STRADA

4.6 Time of accident

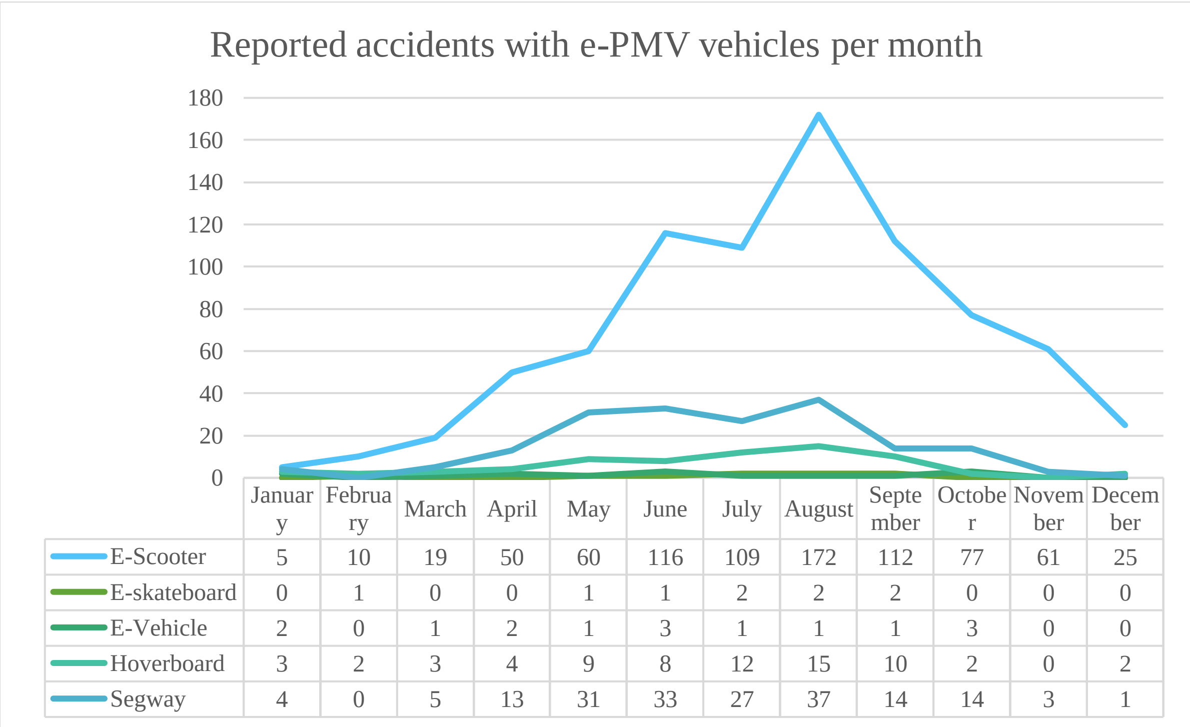
The reported crashes per year has a large growth for e-scooters during 2019. The results for 2020 in Figure 13 correspond to crashes included in the STRADA web client until 2020-08-19.



	2000-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
e-scooter	41	11	19	18	19	32	26	25	22	24	579	167
e-skateboard	0	0	0	0	0	0	0	0	0	3	6	3
e-vehicle	6	0	0	0	0	1	0	0	0	2	6	0
hoverboard	0	0	0	0	0	0	1	28	22	14	5	3
segway	1	3	10	22	36	34	27	23	5	10	11	0

Figure 10 Reported crashes per year for e-PMVs vehicles from STRADA

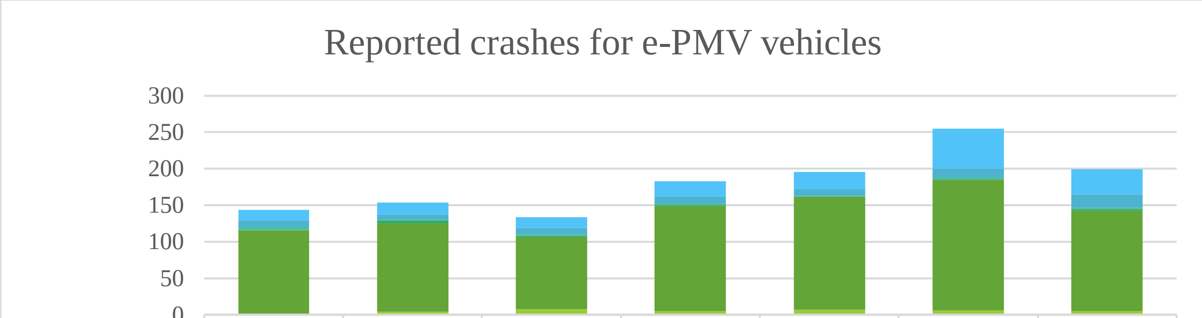
In STRADA the month for the reported crashes indicates that more crashes are reported during the summer with a peak in august for e-scooters. For the other vehicle categories more crashes are reported during summer with an even spread over the months May to September. Note that the crashes for 2020 are excluded in this result since only crashes until 2020-08-19 are reported it will twist the graph by adding numbers to the first 7 months.



	January	February	March	April	May	June	July	August	September	October	November	December
E-Scooter	5	10	19	50	60	116	109	172	112	77	61	25
E-skateboard	0	1	0	0	1	1	2	2	2	0	0	0
E-Vehicle	2	0	1	2	1	3	1	1	1	3	0	0
Hoverboard	3	2	3	4	9	8	12	15	10	2	0	2
Segway	4	0	5	13	31	33	27	37	14	14	3	1

Figure 11 Reported crashes with e-PMV vehicles per month from STRADA

The results for weekday distribution of crashes is presented in Figure 12 with a peak for Saturdays with 20% of the total crashes reported. Segway has around 30% of the crashes reported for Saturdays. Around 65 % of the total crashes happens between Thursday and Sunday.



	Monday	Tuesday	Wednesday	Thursday	Friday	Satuday	Sunday
Segway	15	17	15	21	24	55	34
Hoverboard	9	6	9	9	9	12	19
E-Vehicle	4	2	2	3	1	2	1
E-skateboard	1	4	2	1	1	1	2
E-Scooter	114	121	98	144	154	179	138
E-Kickbike	1	4	8	5	7	6	5

Figure 12 Reported crashes with e-PMV vehicles per weekday from STRADA

The e-scooter is represented in the majority of the crashes reported and a chart for only e-scooter are presented in Figure 13. The figure shows a small increasement of reported crashes for Thursday-Sunday. Compare to the other categories, presented together in Figure 14, which shows a large increasement of crashes reported for Saturday and Sunday.

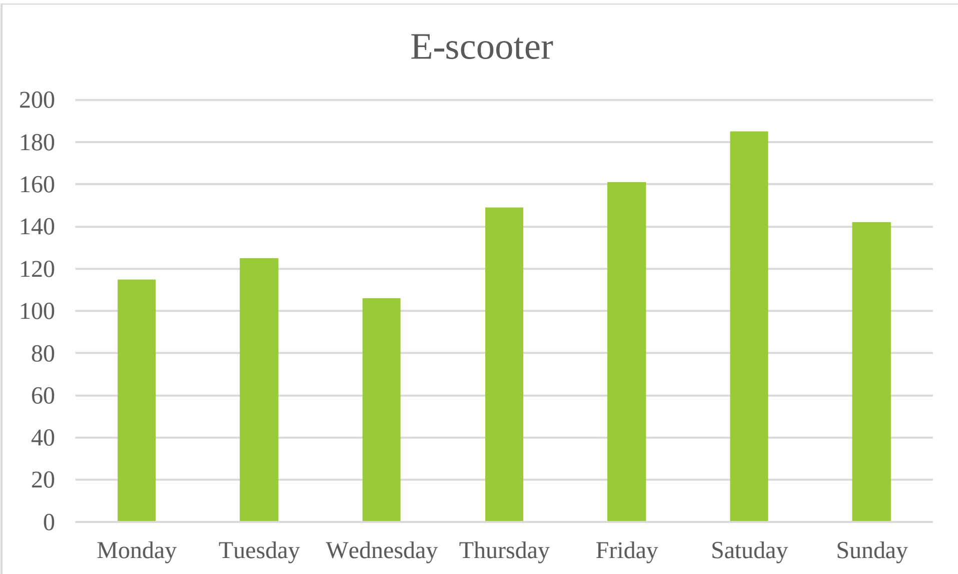


Figure 13 Reported crashes with e-scooter vehicles per weekday from STRADA

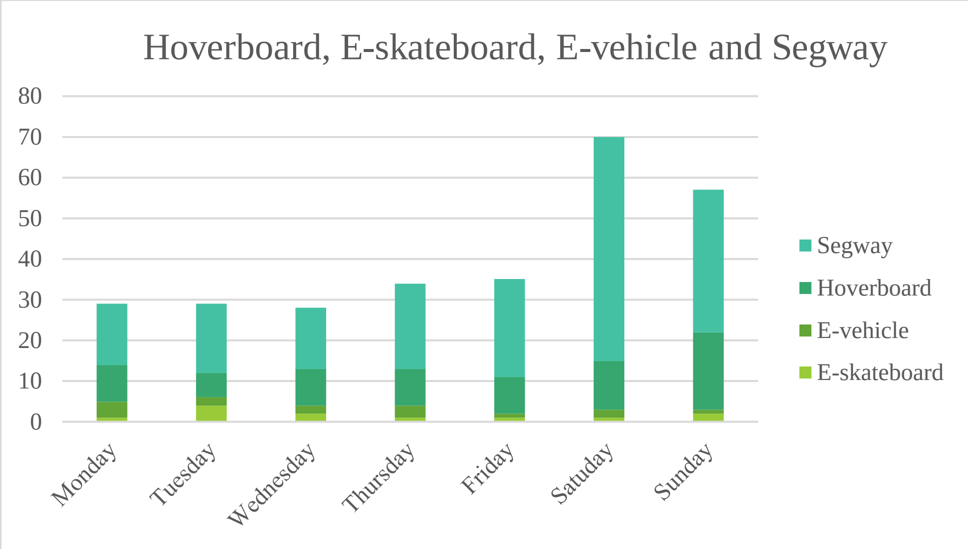


Figure 14 Reported crashes with e-PMV vehicles (except e-scooter) per weekday from STRADA

The results indicated a peak for the crashes around 15:00-16:00. The Segway has the most of none reported values. Segway and hoverboard have 65 % of their crashes reported between 12:00 and 18:00.

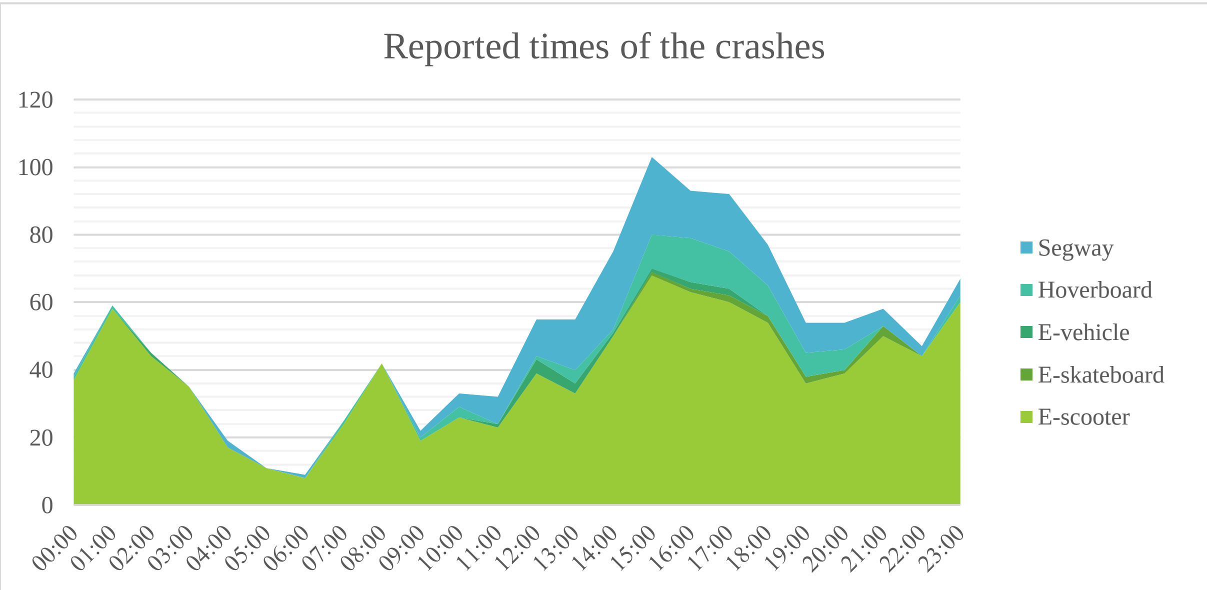


Figure 15 Reported time for the crash for e-PMV vehicles from STRADA

4.7 The driver

This section is presenting results about the driver of the e-PMV.

The age of the drivers is presented in Figure 16 and majority of the drivers, 46 %, are between 18-32 years old.

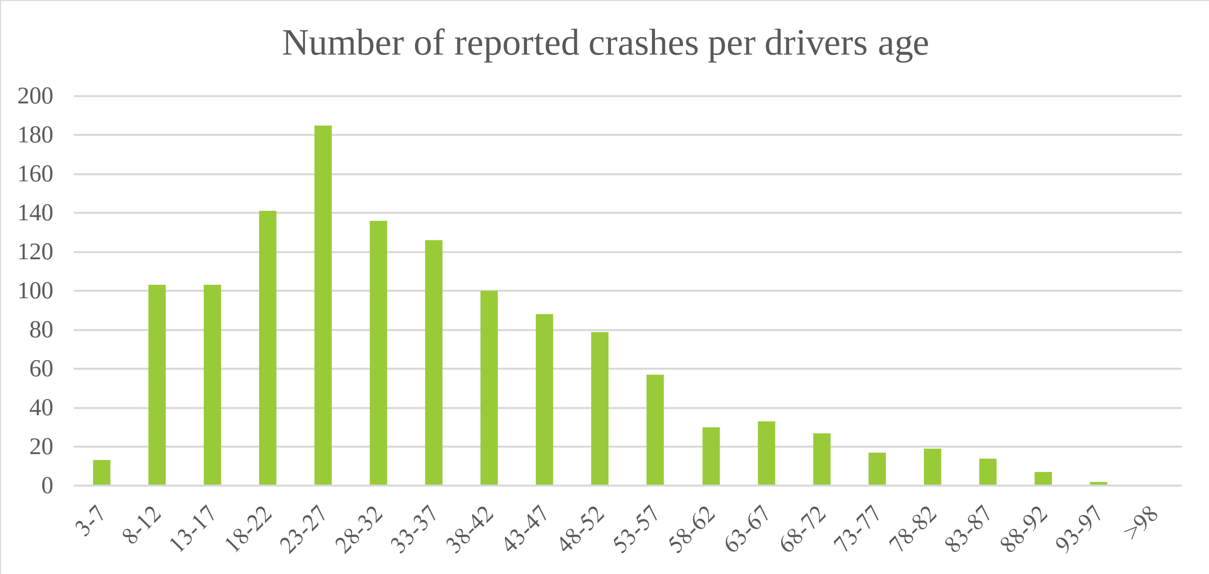


Figure 16 The driver age from reported crashes with e-PMV vehicles from STRADA

For e-scooter the majority of the drivers are between 23-27 years old. There is less than 5% with a driver age over 50 years old and presented in Figure 17.

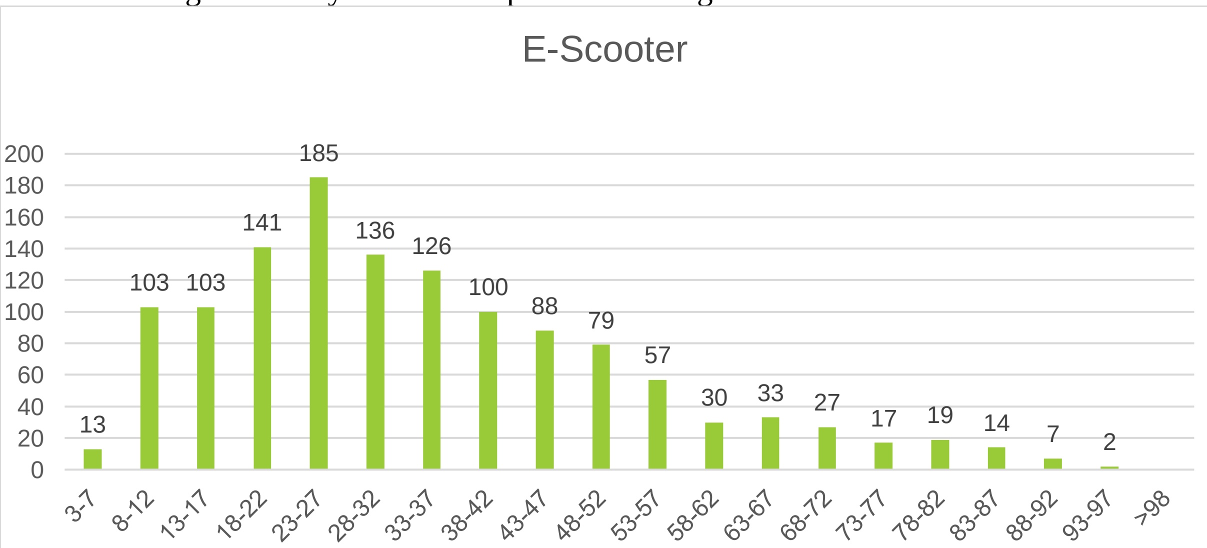


Figure 17 The reported age of the driver for the category E-scooter from STRADA

For e-skateboard and e-vehicle the drivers reported are spread out. For E-skateboard the ages are between 12 and 52 presented in Figure 18. The E-Vehicles are spread out between 5-97 years old and with the majority over 40 years old (Figure 19).

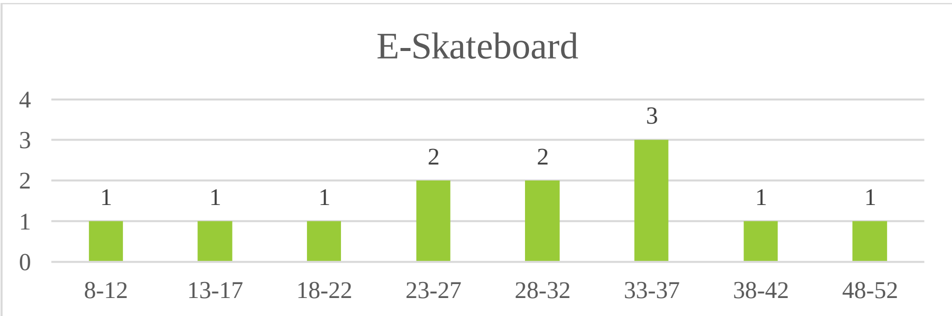


Figure 18 The reported age of the driver for the category e-skateboard from STRADA

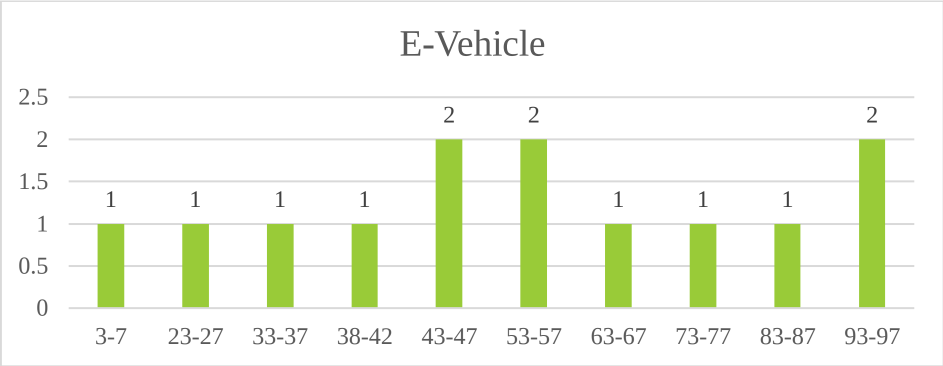


Figure 19 The reported age of the driver for the category E-Vehicle from STRADA

The hoverboard does show that the drivers age of the collisions is younger that for the other categories. With 68% of the drivers age below 14 years old. The rest is spread out up to 55 years old and can be viewed in Figure 20.

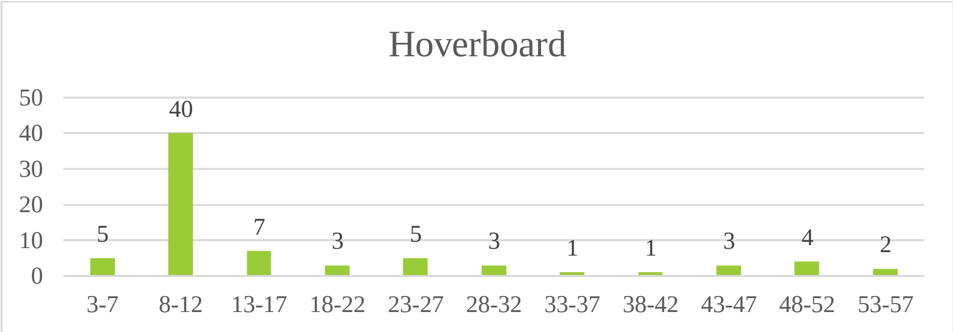


Figure 20 The reported age of the driver for the category hoverboard from STRADA

The drivers of Segway had a drivers age between 5 and 82 years old. The distribution between the ages are equal and is presented in Figure 21.

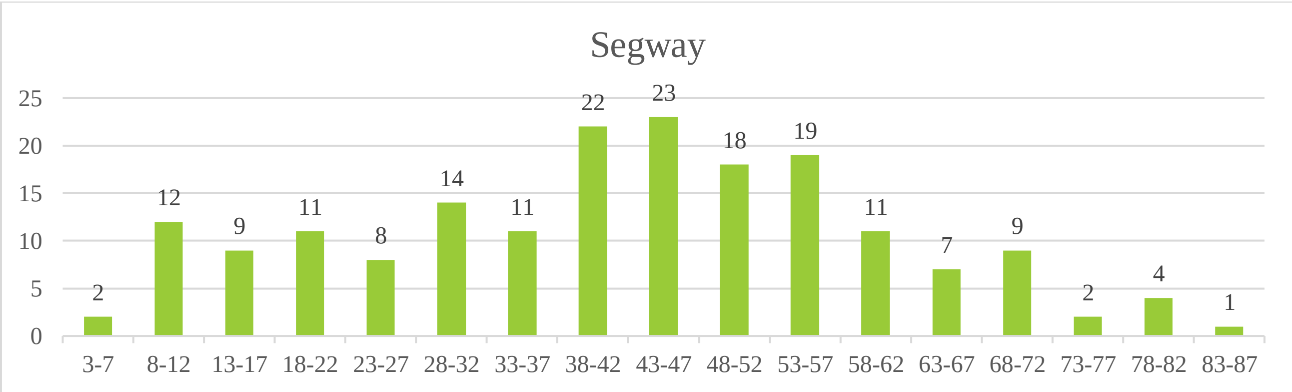


Figure 21 The reported age of the driver for the category Segway from STRADA

The gender of the driver for all cases is presented in Figure 22. 57% of drivers in e-PMV crashes are males.

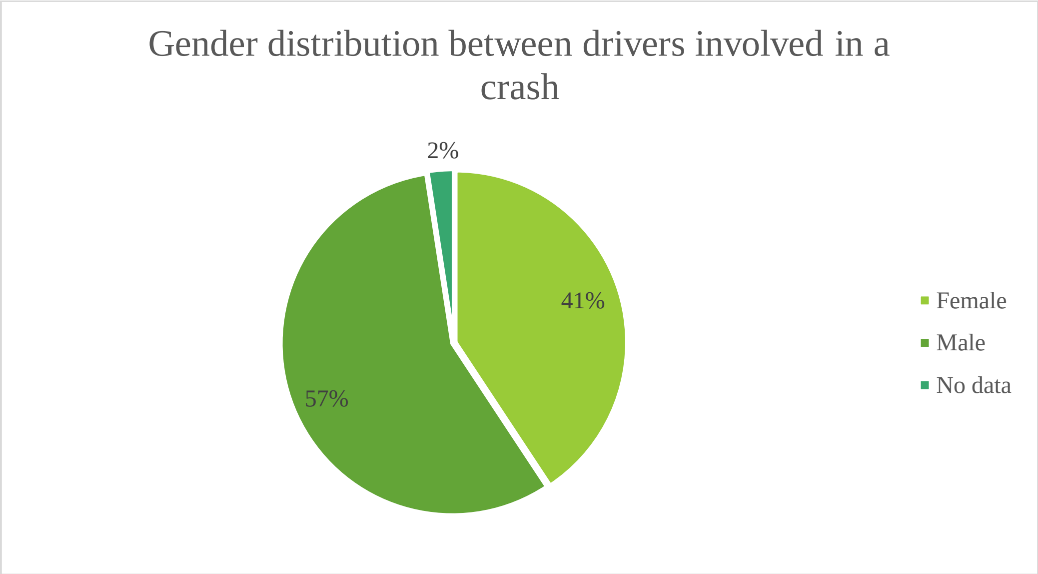


Figure 22 Distribution of gender for reported crashes from STRADA

Among fatally or seriously injured people in e-PMVs crashes in STRADA the number of male drivers is slightly higher with 64% (Figure 23) compared to 57% when all level of injuries is included.

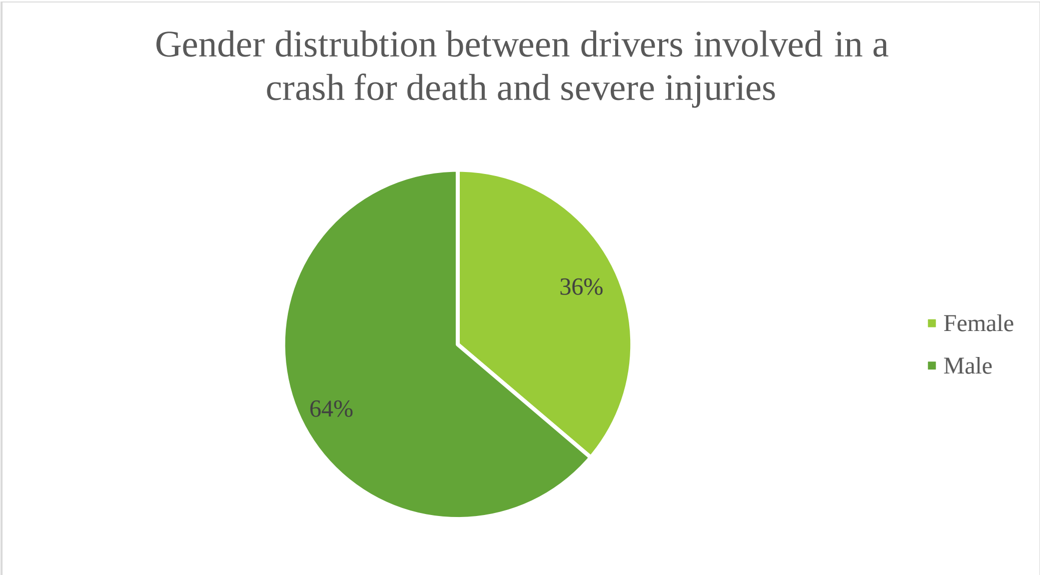


Figure 23 Gender distribution for severe and death injuries from STRADA

5 Discussion

The project has included both literature studies and data analyse from STRADA and IGLAD. Data has been extracted by text search algorithms to identify correct crashes with e-PMVs. The few crashes extracted from IGLAD evolved in a decision to not include it in the result subsections. Only the total number of crashes was presented. The result was considered reliable and not surprising since IGLAD is mainly focused on car crashes. The possibility to have more information from IGLAD in the future is considered possible since the development and the focus on e-PMVs collisions is raising.

The results from STRADA was enough to present results for each topic. However, because of the restriction regarding personal data the extraction was limited. This resulted in a few topics which was consider important to understand and evaluate the crashes. Since this could not be evaluated in this report they were marked and is addressed to include in the future projects.

An interesting possibility to restrict the speed of e-scooters in certain areas to avoid fast driving in areas where the scooters is sharing driving space with walking people was read in the literature review (TT, 2019). This is done with geofencing but since no data could be extracted about the speed for the vehicle for the collision made the possibility to conclude any outcome from STRADA impossible.

The possibilities to evaluate whether a driver was experienced of handling the e-PMV was hard and can only be made of conclusions from combining variables such as age, accident source, main reason for accidents and possibly speed. Despite the difficulties this was still considered as an important parameter for evaluation of crashes since an experienced driver could possibly avoid and predict crashes more efficient than an unexperienced driver.

The distraction is another key element to understand why the e-PMVs crashed. The description variable includes a brief description of the crash and if it's containing any information about distortion it could be distinguished and presented. No technique to address the distortion in the description with algorithms was found. The possibility to manually read and evaluate was an option but not enough time was available to complete the operation.

The use of helmet was vital to understand how the driver thought about using the e-PMV in a safe way. The parameter was possible to extract from IGLAD but not from STRADA which made the evaluation not vital for this project but considered important for future work

E-scooter is the largest category for crashes and constitutes the majority of the discussion topics and results. The results in section *4.2 Number of cases* indicates that a major growth in collisions with e-scooters represents for the years 2019 and 2020. This is in line with the literature review in section *0* where the amount of collisions' were reported to rapidly increase during 2019. A possibility to get a ratio between number of collisions over the total number of trips would had been to compare the e-PMVs with other vehicles, this to understand whether the ratio for collisions and injuries are higher than for example e-bikes or bicycles. This was not done since no method or reliable source was found to get the information about the total number of trips made.

Since of the wildcard technique for detection of e-PMVs vehicles from the databases was used, an important part of this technique was to investigate what search criterion should be included. The idea was to include all possible collisions with e-PMVs without adding too many irrelevant collisions. After several attempts and different text strings attempts a conclusion developed that the guidelines of how the police and the hospital reported to the databases could have been altered. The classification of e-PMVs has not been united and has been classified irregulary in the vehicle type field. This added complexity to the query and extraction since some of the keywords included not only relevant e-PMV crashes but also several irrelevant crashes.

For crashes matched with “sparkcykel” and “kickbike” a decision was made to include all crashes with a reported driver age older than 15 years. Drivers with an age below 15 was considered using regular scooters and kickbikes while the older drivers was assumed to use electric versions. This statement was not possible to determine in a statistic way and is therefore an important part for future project to evaluate and try to conclude if the assumption is correct.

The age of the drivers is more spread out than expected. By looking at Figure 16 in section 4.7, the age of the e-scooter drivers peaks at mid twenty. When evaluating all the e-PMV categories older drivers are reported. It was expected with younger drivers for e-scooter but not the amount of older drives which could be argued to connect with the e-vehicle category. The e-vehicle category includes keywords which could have an impact on the statistic since those text strings could be argued to include collisions with vehicles out of main focus for this report. The Segway also reports driver age of older people than for e-scooters which is consider reasonable.

The year of 2020 is a special year due to the COVID-19 virus. Because the consequences of the lock downs in multiply countries all over the world have had a considerable impact on the statistics for 2020 and are going to be rather difficult to predict. A possibility to include a mathematical model for the estimation of the total number of collisions based on earlier year was decided to complicated and possible misleading. It’s still possible that the reported crashes will be significantly lower for reports registered after 2020-08-19. The increased uncertainty is based around the discussion and statistic presented by ETSC (2020). The numbers from the report indicates no drastically changes in Sweden which could be related to the less strict restriction applied in Sweden than most of the countries in Europe.

6 Conclusion

Extraction of e-PMVs collisions from IGLAD resulted in few cases which was concluded reasonable since the databases mainly focus on car crashes.

The extraction of e-PMVs vehicles from STRADA resulted around 1300 crashes reported. The project's focus and conclusion relies on the data from STRADA. By the total number of collisions reported the majority are represented by the category E-scooter with 78%. Segway and hoverboard had 14% respectively 6% reported. With the provided data it were not possible to determine reasons behind the collisions nor possible to evaluate if the crashes were single or multiply vehicles involved. Most of the crashes were reported in urban areas. Most injuries from the collisions were reported in the injury category light (ISS 1-3) to medium (ISS 4-8). Very few was reported with no injury and the possible reason with the conclusion that crashes without any injury or other vehicle is not reported to STRADA.

For future studies it would be interesting to compare the experience of the drivers, to investigate further if a pattern could be seen and less collisions is happening when/if the driver gets more skilled at driving. Also, if the environment around the e-PMVs gets more aware of the scooters manoeuvrability and therefore also avoids crashes. For future studies the parameters in section 4.1 would be interesting to evaluate which includes distraction of the drivers, initial speed, alcohol and a few more parameters.

Figure list

Table list

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Appendix

A. Duplicate and applied filter removal results

	Sum of Original	Sum of Collision_AllVehicles	Sum of Collision_OnlyEPMV	Percent removed
e-scooter	**1307**	**1043**	**1026**	**21%**
bird	1	1	1	0%
bolt	2	1	1	50%
bunny	1	1	1	0%
circ	2	1	1	50%
el-scooter	66	58	58	12%
el-scoter	1	1	1	0%
el-skoter	5	5	5	0%
eldriven sparkcykel	10	10	10	0%
elektrisk sparkcykel	1	1	1	0%
elscooter	286	140	136	52%
elscootrar	3	3	3	0%
elscoter	7	7	7	0%
elskooter	6	4	4	33%
Elskoter	23	21	21	9%
elsparkcykel	542	507	503	7%
kickbike	36	36	36	0%
lime	3	2	2	33%
spark cykel	1	1	1	0%
sparkcyckel	3	3	3	0%
sparkcykel	224	206	197	12%
tier	3	2	2	33%
voi	81	32	32	60%
e-skateboard	**12**	**12**	**12**	**0%**
el-skateboard	5	5	5	0%
elskateboard	7	7	7	0%
E-Vehicle	**19**	**17**	**13**	**32%**
el-fordon	3	3	1	67%
eldrivna	12	10	10	17%
elfordon	3	3	1	67%
självbalanserande	1	1	1	0%
hoverboard	**74**	**74**	**74**	**0%**
hoverboard	71	71	71	0%
howerboard	3	3	3	0%
Segway	**191**	**187**	**187**	**2%**
ninebot	2	1	1	50%
Segway	189	186	186	2%

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