TALLINN UNIVERSITY OF TECHNOLOGY

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AFTERMARKET AUTOMOTIVE HEAD-UP DISPLAY FOR REDUCING DIVER'S DISTRACTION WHILE ENHANCING COMFORT AND SAFETY

"HEAD-UP DISPLAY" PÕHINE LISASEADE AUTOLE, MIS TÕSTAB SÕITJATE TURVALISUST JA VÄHENDAB JUHTI SEGAVAID FAKTOREID

MASTER THESIS

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Tallinn,
2019

AUTHOR'S DECLARATION

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

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Thesis is in accordance with terms and requirements

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Accepted for defence

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THESIS TASK

Student: Lebedeva Ksenia, 111492MADM
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Thesis topic:

(in English) Aftermarket automotive Heads-Up display for reducing driver distraction while enhancing comfort and safety
(in Estonian) "Head-Up Display" põhine lisaseade autole, mis tõstab sõitjate turvalisust ja vähendab juhti segavaid faktoreid.

Thesis main objectives:
1. Identification of inappropriate drivers' behavior that causes car accidents.
2. Analyze the reasons for the distracted driving and the role of the smartphone in it.
3. Propose a solution against the distracted driving caused by using a smartphone

Thesis tasks and time schedule:

No.	Task Description	Completion date
1	Research the problem, literature review, problem justification	11.03.2019
2	Problem delimitation, feedback analysis, user/ market research.	29.03.2019
3	Design brief, generating and developing concepts	22.04.2019
4	Concept elaboration, prototyping, testing, iteration.	20.05.2019

Language: English **Deadline for submission of thesis:** 27.05.2019

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ABSTRACT

The objectives of this graduation thesis entitled “Aftermarket automotive Heads-Up display for reducing diver’s distraction while enhancing comfort and safety” are to identify the inappropriate drivers’ behavior, particularly distracted driving, that causes car accidents, review and illustrate the reasons for this behavior pattern, define the role of the smartphone use in it and propose the alternative way of driver interaction with the smartphone behind the wheel. This thesis concerns the conceptual development of the aftermarket automotive device and related to its App for car owners from different segments. The problem research and conceptual design development were carried out in cooperation with the California-based company HUDWAY LLC that creates ADAS (Advanced driver-assistance systems) solutions.

Theoretical studies allowed focusing on and delimiting the problem. During the literature review and problem research, the smartphone proves to be the main reason for distracted driving. The practical work dealt with the further development of the company’s product line. Based on field research and theoretical study, the comprehensive head-up display solutions have been developed to overcome a pattern of distracted behavior of the driver, to meet users’ and projected stakeholders’ demands.

CONTENTS

ABBREVIATIONS

ABS - Antilocks brackes

ABS - Acrylonitrile Butadiene Styrene

ADAS - Advanced driver-assistance systems

AEB - Automatic emergency braking

APP - Application

AR - Augmented reality

CAGR - Compound Annual Growth Rate

GDP - Gross Domestic Product

GPS - Global Positioning System

GRSP- Global Road Safety Partnership

GRP - Gaze retention period

HUD - Head-Up display

IQ - intelligence quotient

OEM - Original equipment manufacturer

OBD - On-board diagnostics

PMMA - Poly(methyl methacrylate)

POS - Point of sales

PC - Polycarbonate

ROI - Return on Investment

SBR - Styrene-butadiene rubber

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CHAPTER 1. INTRODUCTION

1.1 Background

The area of work has been selected for being personally appealing to the author. The project writer has experience in the subject caused by prior working background and interest in the field of augmented reality, driving culture, driving safety. More than a few decades countries and nations try to reduce road deaths. People want to drive safer cars on safer roads. The least populated countries are particularly interested in this topic, as they want by all means reduce the population mortality rate attributed to road traffic accidents. A lot of studies have been conducted in this area, based on them, speed limits were set, introduced urban planning regulations, adopted vehicle surface standards, and some basic car safety gears like airbags, seatbelts or antilock brakes (ABS). However, much remains to be done as it is a very challenging task. In recent years scientists began more and more pay attention to the driver and drivers' behavior or so-called human factors. Human factors are how humans behave physically and psychologically in relation to a particular environment. In the last 10 years, a lot of driver assistance systems have been developed to eliminate the effect of the human factor in road traffic accidents. The most vivid example is, of course, self-driving cars, wherein an attempt to reduce the opportunity to make a mistake the man was completely excluded from handling a vehicle. While self-driving cars are still the future, a lot of companies are looking for a solution, that can be implemented now to make the driving process safer.

The acknowledgment of interest in research in the selected area has been found in communication with one of the market players in the industry - the company HUDWAY LLC, that develops ADAS software/hardware products, bringing advanced options found mostly in hi-end vehicles to almost any modern car. An interview and discussion were made during a meeting with the co-founders and investors of the company who are currently working on a company development strategy, defining the long- term goals and developing business growth strategies for creating competitive advantage. The interview has contributed with confirmation and validation of the initially found problem area.

1.2 Strategy and research methods.

The following table provides an overview of the selected strategy and research methods. The most common and widely accepted product development stages have been taken as a basis. The methodology used to research the topic and develop the concept includes: Overviewing the main scientific findings in this field, market, and user research, observation, end-user field work, feedback analysis, conducting the questionnaire, eye tracking test, Iterative design process, prototyping and testing, including beta-testers.

	Idea generation	Research	Concept development	Concept detailing	Evaluation	Deployment
goal/ pur-pose	identify a relevant context, define the project framing,	define the main problems of drivers and main distracting factors problems and values clarify the market context	Primary research, using research findings develop the concept that solves the main problem	iterate and clarify concept details highlight any flaws or defects in the design	evaluate final prototype create a final concept that can be put into the mass production	develop a marketing strategy develop a marketing plan future development
activi ties	preliminary research	user research, conduct market research, real user feedback analysis questioner analysis	Idea generation Idea screening concept sketching concept elaboration and evaluation concept selection	analysis creating a product mock-up building a prototype 3D modeling	put the prototype into use get a feedback from a focus group evaluate changes and make improvements	
out-put	initial problem area delimitation and prerequisite schedule	defining of the main problems target groups	concept for detailing	create a prototypes	create a gold prototype	

Table 1: Project Strategy

1.3 Initial problem description

With the advent of automobile, people are trying to make its driving safer. As using a car become a daily routine for most of the car owners, they usually more afraid of flying on the plane or being bitten by the dog than have a car accident. However, vehicle accidents causing death are on the third place in Mortality risks table "Odds Of Death In The United States By Selected Cause Of Injury, 2017" [1]

Cause of death	Number of deaths, 2017	One-year odds	Lifetime odds
Accidental poisoning by and exposure to noxious substances	64,795	5,027	64
Drug poisoning	61,311	5,313	68
All motor vehicle accidents	40,231	8,096	103
Car occupants	7,248	44,939	572
Motorcycle riders	4,832	67,409	858
Pedestrians	7,450	43,721	556
Assault by firearm	14,542	22,399	285
Exposure to smoke, fire and flames	2,812	115,832	1,474
Fall on and from stairs and steps	2,493	130,654	1,662
Drowning and submersion while in or falling into swimming pool	723	450,511	5,732
Fall on and from ladder or scaffolding	569	572,441	7,283
Air and space transport accidents	385	846,024	10,764
Firearms discharge (accidental)	486	670,204	8,527
Cataclysmic storm (3)	132	2,467,570	31,394
Flood	27	12,063,673	153,482
Lightning	19	17,143,115	218,106
Earthquake and other earth movements	13	25,055,321	318,770
Bitten or struck by dog	36	9,047,755	115,111

Table 2: Odds Of Death In The United States By Selected Cause Of Injury, 2017

A lot of systems and products that are related to the problem of safe driving have been invented. Airbags, On/Off Switches for airbags, Passenger Sensing System (can tell the size of the person in the

seat), Children car seats (although, there is a research that such seats provoke more injuries, so they exacerbate the situation rather than help), Energy-Absorbing Steering System, Back-Up Sensing System, Electrochromatic Mirror/Auto-Dimming Mirrors, Head Restraints, Heads Up Display, the night vision cameras, eye trackers, stop sleep gadget, driver assistance systems, Antilock brakes (ABS), Traction control, Electronic stability control, accident avoidance systems like Automatic emergency braking (AEB) or pedestrian detection. Even though every day on average 3,287 people die in road crashes. That is, one person is killed every 25 seconds. Moreover, road traffic crashes cost most countries 3% of their gross domestic product.[2], [3], [4]

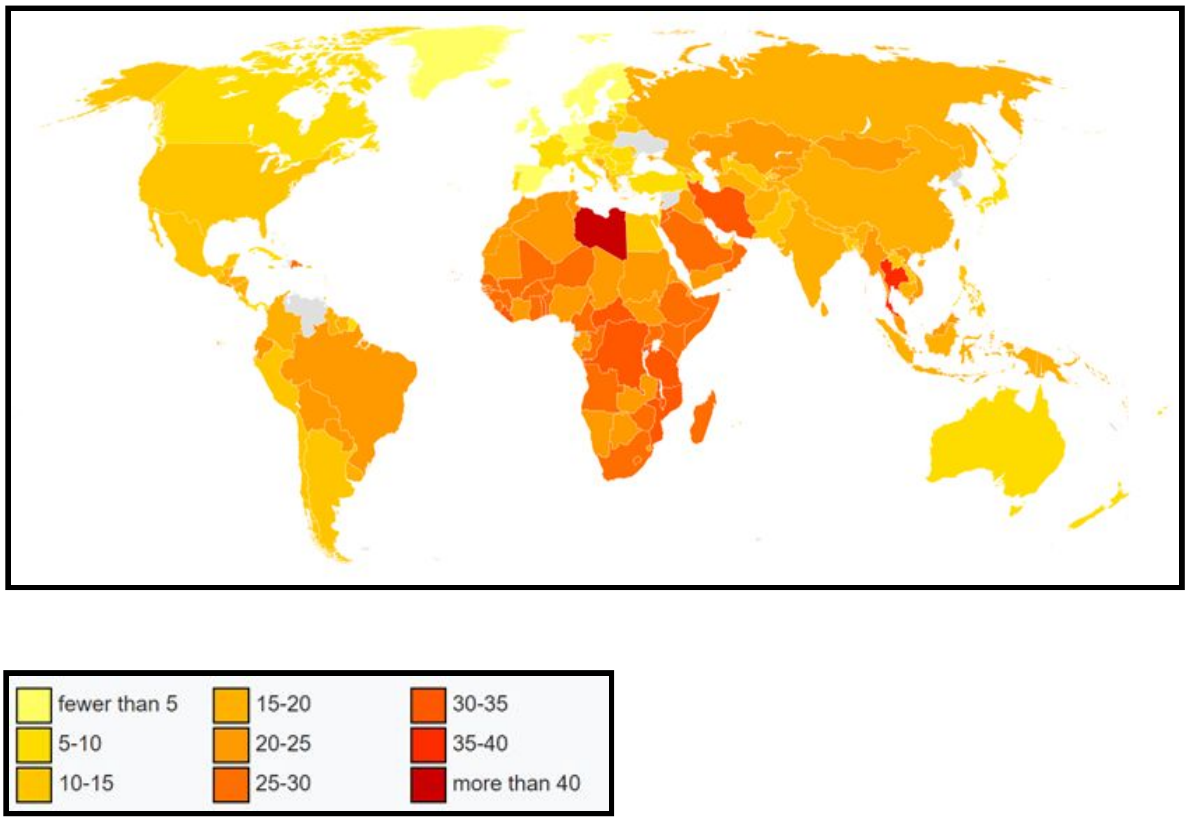


Figure 1: Death rates from road traffic accidents by country, per 100.0000 inhabitants, world map

Despite the fact that over a third of road traffic deaths in low- and middle-income countries, this problem is still acute and relevant for all countries in the World. And if the reasons for such high death rates in low- and middle-income countries more or less clear, the causes of accidents in developed countries should be studied more deeply. What triggers the accidents? Undue powerful cars? Weak legislation? Wrong design of the cities? Urbanistic mistakes? Lack of driving culture? According to the Safer America Car Accident Statistics for 2019 the majority of these road crashes are caused by human error. [5] [6]

Top 10 Causes of Car Accidents [7]

	Name	Description
1	Distracted Driving	Distracted drivers are the top cause of car accidents in the U.S. today. A distracted driver is a motorist that diverts his or her attention from the road, usually to talk on a cell phone, send a text message or eat food.
2	Speeding	Many drivers ignore the speed limit and drive 10, 20 and sometimes 30 mph over the limit. Speed kills, and traveling above the speed limit is an easy way to cause a car accident.
3	Drunk Driving	Drunk person lose the ability to focus and function properly and its very dangerous when operating a vehicle.
4	Reckless Driving	Reckless drivers are often impatient in traffic they are very aggressive, they speed, change lanes too quickly or tailgate before causing a car accident.,
5	Rain	Car accidents happen very often in the rain because water creates slick and dangerous surfaces for cars, trucks, and motorcycles and often causes automobiles to spin out of control or skid while braking.
6	Running Red Lights	Drivers that run red lights, run the risk of causing wrongful death because they often cause side-impact collisions at high speeds.
7	Running Stop Signs	Many rollover accidents and side-impact car accidents result from drivers that run stop signs.
8	Teenage Drivers	The risk of motor vehicle crashes is higher among 16-19-year-olds than among any other age group, the car accident fatality rate for male occupants aged 16-19 was twice the rate of their female counterparts.
9	Night Driving	Car accident statistics are jarring at night. Despite 60 percent less traffic on the roads, more than 40 percent of all fatal car accidents occur at night. Since your ability to perceive and judge distance is severely impaired at night — the human eye requires light to see. An estimated 90 percent of all driver decisions are made based on what they see. While your eyes are capable of seeing in limited light, the combination of headlights and road lights, with the darkness beyond them, can cause several problems for your vision. Therefore, car drivers must take extra precaution to avoid an auto accident during the night.
10	Design Defects	Manufacturing defects can lead to very serious auto accidents. Car manufacturers are usually faced with only two choices after discovering a poorly designed auto component: Recall the defective part or car and fix it. or Pay off accident-related lawsuits as they arise. Manufacturers are required by law to design and engineer cars that meet a minimum safety standard. However, problems with the design and functionality of the cars themselves — sometimes referred to as product liability — is one of the top causes of car accidents on the road.

Table 3: Top 10 Causes of Car Accidents

While some of these car accident causes may seem obvious, it is worth noting that **Distracted Driving** ranked first on the list and the most common distraction for the driver has become a smartphone. [7] The graphic made by the National Highway Traffic Safety Administration, Executive Branch of the U.S. government, part of the Department of Transportation shows that there has been done a lot since 1925, and the number of deaths per one million people (orange line) has been decreased, but it's still pretty high. [8]

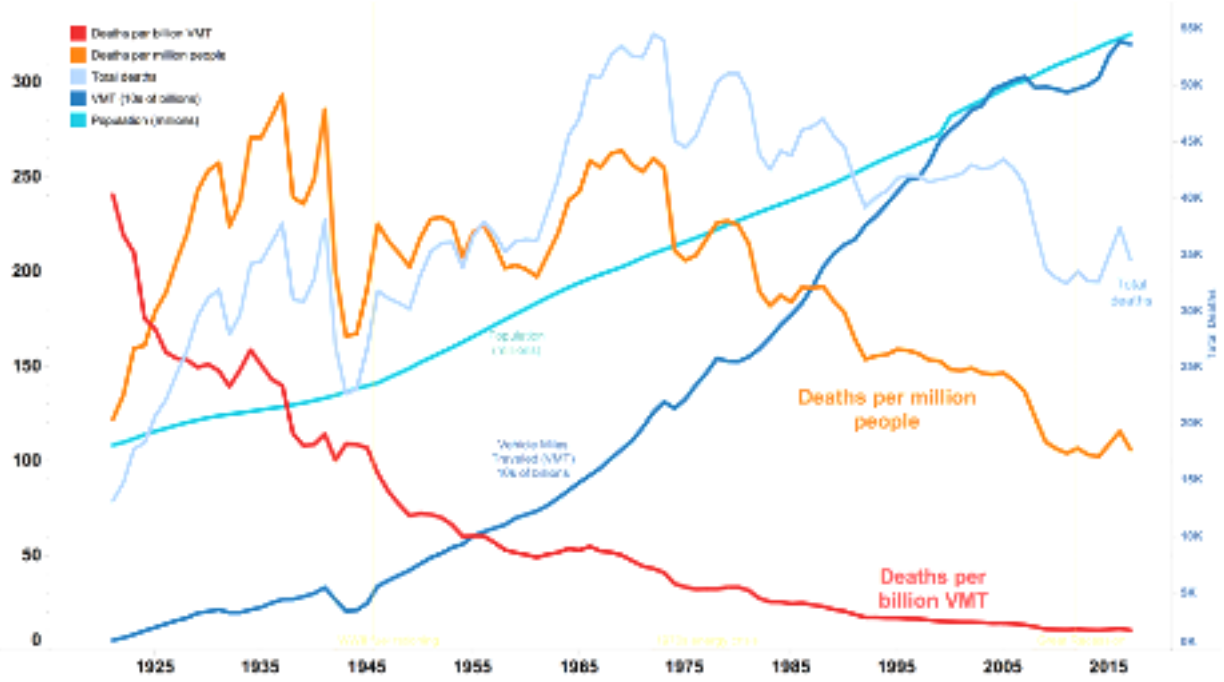


Figure 2: Deaths relative to the total US population

NPR (National Public Radio – non-profit organisation) reports that **94 percent of deadly car crashes are caused by some type of human error** or so-called Human factor (an action or inaction) - it is how humans behave physically and psychologically in relation to particular environments. The human factors contribution to accidents is very high. Human error is a generic term that involves all those instances where a planned activity fails to achieve its intended outcome. In fact, research suggests that regardless of the activity or task being conducted, humans make between 3-6 errors per hour. One study in aviation maintenance conducted by my former Australian Transport Safety Bureau (ATSB) colleague Dr. Alan Hobbs, found that aviation maintenance engineers made on average 50 observable errors per work shift. The good news is that most of the time, these errors are self-corrected and they have little consequence. [9]

The following represents a summary of agreed views about human error from experts on the subject:

- Errors do not usually occur randomly - there are generally reasons for them.
- An active hazard must be present for errors to become consequential - not paying attention when working at height is more of a problem that not paying attention when watching a movie.
- Even a relatively small error can trigger a very serious accident, if the system is vulnerable and has poor defences or risk controls.
- Human error knows no boundaries. Regardless of experience level, professionalism, gender or national culture - everybody makes errors. However, the silver lining is that experts at particular tasks are often better than novices at anticipating errors, and taking action to prevent them becoming serious. [9]

The diagram below illustrates the difference between unintentional and intentional actions which is covered in the Incident Cause Analysis Method (ICAM) training session on human error. [10]

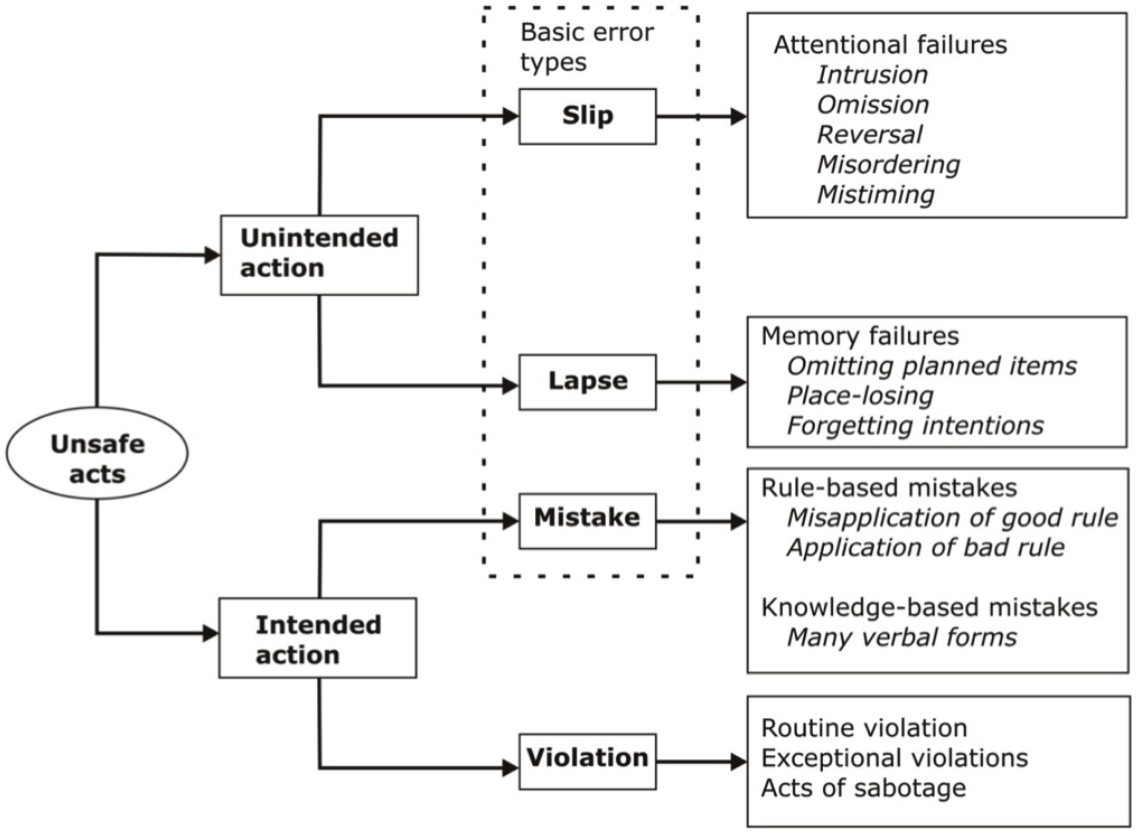


Figure 3: James Reason, Human Error, Cambridge University Press, 1991

In relation to car driving the Unintended error as Slip should be considered. These Attentional failures associated with familiar/ routine tasks, like driving the vehicle. Drivers carried it out without much conscious attention and thus become vulnerable to slips and lapses. Additionally, the different factors

that influence driver behavior created by Global Road Safety Partnership (GRSP) should be listed. [11], [12]

Figure 4: Factors that influence driver behavior, Global Road Safety Partnership

As seen, the driving culture, associated with Media/ Pop Culture, Marketing, Commercial advertising, Broad Social concerns, is implanted and created by the social environment. It gives reason to believe, that by proposing and popularisation the alternative driving patterns and making them attractive for the current road user by adding a new value, fill with meaning and give the opportunity to try something new this destructive behavior could be eliminated.

Unless and until there are fully autonomous cars that drive themselves, the unintended peoples' Slip errors like **distracted driving** must be carried over for consideration. [13]

1.4 Importance of topic

Road Crash Statistics.

Nearly 1.3 million people die in road crashes each year, on average 3,287 deaths a day. An additional 20-50 million are injured or disabled. More than half of all road traffic deaths occur among young adults ages 15-44. It's a global problem. [14]

Increased of mobilization in the future.

Meanwhile, the number of cars worldwide is set to double by 2040 The global number of cars on the road and kilometers flown in planes will nearly double by 2040, according to a report released on Monday by research house Bernstein. Cars are projected to reach the two billion mark by 2040, while air travel kilometers are set to hit 20 trillion in the same period. Bernstein said it expects most of this transport growth to happen in emerging markets like China and India, as global populations are set to rise by another two billion over the next 25 years to 9.2 billion. Growing GDP in those regions will increase demand for items once seen as luxuries, including automobiles and flights. The fastest growth will be in air travel, according to the report, which is particularly sensitive to per capita GDP growth. Here's a visual of projected global transport growth over the next 25 years: [15]

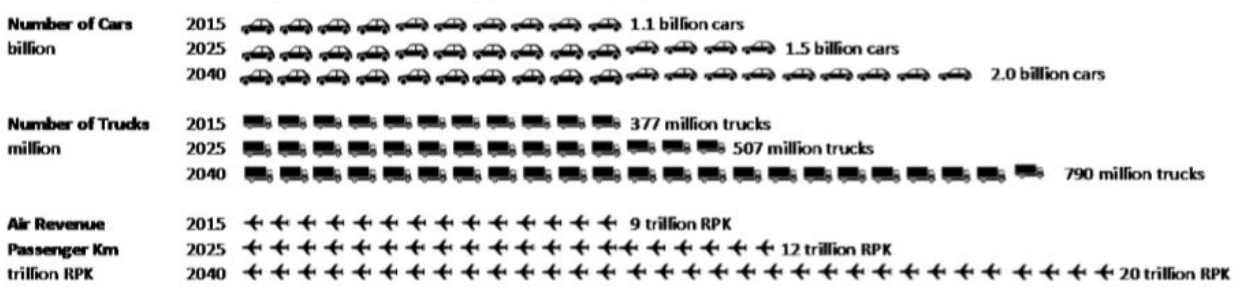


Figure 5: visual of projected global transport growth over the next 25 years, Business Insider

This transport growth will keep the level of the deaths in road crashes. This means that the immediacy of the problem will be increased.

Phone Addicts are the new drunk drivers.

According to the third annual Distracted Driving Study conducted by zendrive a new dangerous category of distracted drivers has been uncovered: Phone Addicts. This growing category of hyper-connected individuals exhibit a pattern of distracted behavior unlike any other group of risky drivers. Phone Addicts spend 28 % of their driving time actively ignoring the road. 'Phone Addicts' doubled in the last year. The survey found that people know distracted driving is a problem, but aren't concerned enough to change their behavior. According to the survey most of them said that they are pretty safe behind the wheel. [16]

The survey shows that people often do not realize the danger to that they expose themselves and other road users. In conjunction with fact that driving the car is a daily routine for them and their

1.5 Mental workload of the driver and HUD devices.

There are 600 million people in the world who get behind the wheel of a car every single day. According to the researches, approximately 75% of them get distracted while driving — it could be just drinking coffee, talking to a child in the back seat, reaching for the glove compartment, changing a radio station, but the worst and most frequent distraction is the smartphone. People are always on the phone. They talk, read, type, tweet, check and search... They do selfies and share pictures. They even do video conference calls while driving! They are nearly driving blind while trying to multitask. Indeed, based on official reports, 22% of all auto accidents happen because of a driver multitasking.[17]

Psychologists said that multitasking doesn't work. Multitasking leads to as much as a 40% drop in productivity, increased stress, and a 10% drop in IQ. Which is why driving while distracted (being on the phone or texting) is actually more dangerous than driving drunk. [18]

Whenever the driver is steering his car, he is faced a certain mental workload. While the driver accomplishes several tasks, inattention, distraction and irritation can occur as a consequence of the high workload resulting from superposition. [19] The authors of the article "Eye Gaze studies comparing head-up and head-down displays in vehicles". Munich University of Technology propose the following taxonomy of driving tasks:

Taxonomy of Driving - Tasks:

- **Primary tasks** - steering, navigation, acceleration and break pedals, changing line
- **Secondary tasks** – turn signal, honking, turning the headlights up and down.
- **Tertiary tasks** – adjusting the temperature, turn off/on air condition, communication and entertainment features. [19]

This classification can help to categorized the information that has to be delivered to the driver. In fact, the phone acts as a source of information that becomes unavailable or hardly/dangerous available to the user behind the wheel. Impossibility, inability or unwillingness to abandon the habitual way of obtaining this info leads to the multitasking, mantel overloading, and distraction.

Head-Up display.

The idea to project the information directly into the driver's' visual field arose in the early 70s. For pilots, for whom information overload was a significant issue, and any distraction could be fatal it was a matter of life and death. [38] Nowadays this technology widely used in the automotive industry to solve the same problems of distracted driving. One aspect of drivers' visual behavior that keeps widespread

attention is the visual distraction caused by the use of in-car devices such as radios, phones or climate control systems. The studies conducted by Munich University of Technology used the eye tracking system. measures visual behavior by recording the frequency and duration of eye gazes at particular objects in the driver's visual field. When drivers perform a secondary or tertiary task while driving, they usually complete this task through a series of brief gazes (1 to 2 seconds) at the object interspersed with gazes at the roadway. [19]

Figure 5: Eye tracking system. Source HUDWAY youtube video and EYE GAZE STUDIES, Munich

The test car was equipped with head- down displays (HDD),and contained a commercial HUD that projects the virtual image in a distance of 2 meters to the driver. For information capture on a display the gaze retention period (GRP) is defined as eye fixation period plus eye movement period. 85% of the test persons pointed out that they accept and desire the HUD while driving. The HUD is an important completion of the information supply. According to the analysis of the GRP in all conditions the HUD showed the best performance. In uncritical situations like driving on interstates, the GRP of all users was between 15 and 20% less on average. In complex scenarios with much traffic like city roads, the averaged GRPs were even reduced up to 25%, which means that a HUD has a high potential for efficient information capturing in complex situations. Between 86% and 90% stated that information regarding speed and active cruise control should, by all means, be displayed in the HUD. The subjects stated the following reasons for preferring the HUD: GRP reduction, comfort and safety. [19]

1.5 Delimitation and prerequisite.

The driver distraction from the road and from the driving of the vehicle while interacting with the smartphone has been chosen as a research area for the master topic. All other distracting factors and possible solutions to increase driving safety are not considered. The distraction itself can be caused by a huge amount of factors, moreover, lack of attention or non-focused driving does not affect all drivers

the same. The ways how to improve concentration while driving also was not considered. This factor was not under control nor was it measured or defined. The main focus of the work is on the smartphone as the drastic human attention diverting object and at the same time great assistant while driving.

1.6 Research purpose and question identification.

The purpose of this project is to improve driving safety by offering a new way of interaction of the driver with the smartphone inside the car while driving. Eliminate the driver attention distracting factors related to the smartphone and at the same time giving the opportunity still to get access to its most important features.

CHAPTER 2. LITERATURE REVIEW

Mobile phone use while driving is common, but it is widely considered dangerous due to its potential for causing distracted driving and crashes. Due to the number of crashes that are related to conducting calls on a phone and texting while driving, some jurisdictions have made the use of calling on a phone while driving illegal. Many jurisdictions have enacted laws to ban handheld mobile phone use. Nevertheless, many jurisdictions allow use of a hands-free device. [20] Driving while using a hands-free device is not safer than using a handheld phone to conduct calls, as concluded by case-crossover studies, epidemiological, simulation and meta-analysis. In addition to voice calling, activities such as texting while driving, web browsing, playing video games, or phone use in general can also increase the risk of a crash.[21]

In 2015, six hundred and sixty thousand drivers in the United States were estimated to use cell phones each day, while driving behind the wheel during daylight hours. Cell phone use while driving has become a leading cause of vehicle crashes over the last two decades. Drivers are distracted, decreasing the driver's awareness on the road, leading to more car crashes. When drivers talk on cell phones the risk of an automobile crash resulting in hospitalization is four times higher when not talking on a cell phone. Drivers who text when behind the wheel, are twenty-three times more likely to have an automobile crash. [20]

How seriously is the problem perceived in the world can be illustrated by the world map which shows the restrictions and legality of phone use while driving.

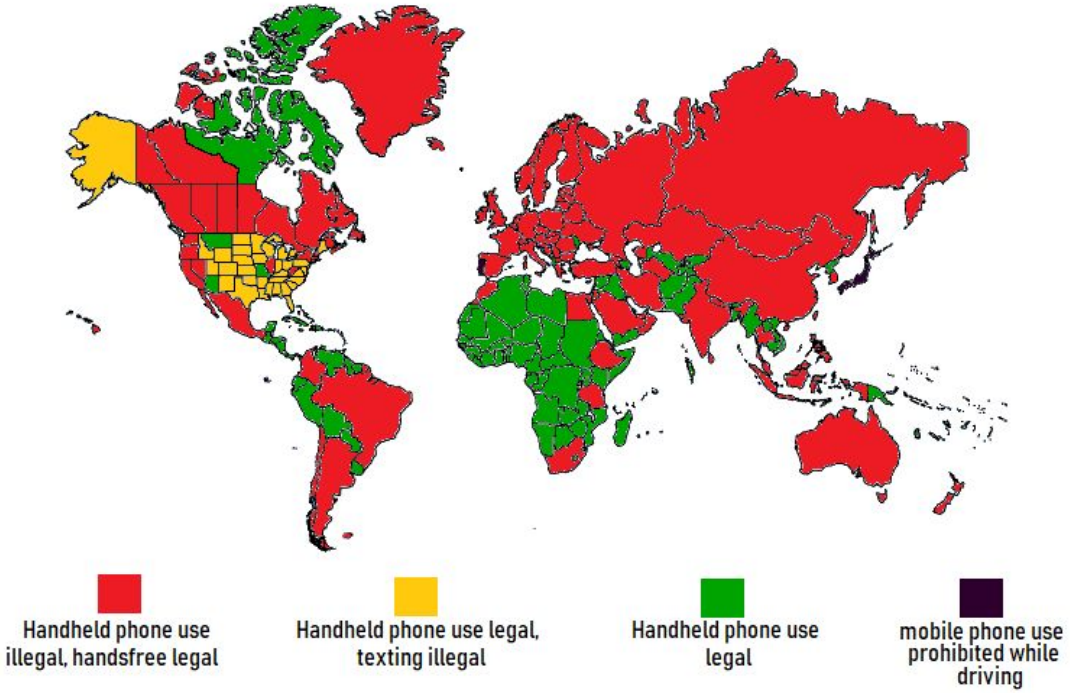


Figure 6: Various laws/regulations in relation to mobile phone use whilst driving 2019 worldwide

It is also worth mentioning about the Accident Analysis and Prevention article named “Impact of mobile phone use on car-following behaviour of young drivers” where a simulator experiment was designed. There a participant drove a simulator vehicle in three different phone conditions: baseline (no-phone conversation), hands-free phone conversation and handheld phone conversation. Various traffic events were programmed to occur in the course of the simulated driving such as car-following, overtaking, pedestrian crossing and sudden breaking of a lead vehicle. Types of phone conversation (hands-free or handheld) affect the car following behaviour differently. When driving with handsfree phone conversation the car-following performance did not deteriorate significantly from the baseline. The findings were different for drivers engaged in handheld phone conversations, with the additional physical constraint of holding the phone. This multitasking configuration increased the workload to the highest level among the three phone conditions. The handheld condition placed an additional manual load on the driver, which together with the mental demand, leads to a greater distraction effect on drivers. As a result, the car-following performance was significantly deteriorated. [22]

Another paper from Transportation Research Part F “Mobile phone use while driving-literary review” analyses the results of studies which were published in 60 papers from 1994 to 2013. Generally, it can be said that the analysis of the research studies results have proved the negative influence of mobile phone use while driving. Studies and research conducted in the field confirmed that mobile phone use while driving reduces driving performance in the way that driver’s reaction time increases, vehicle speed becomes lower, while appropriate lane position is lost. When it comes to future research, it should be focused on identifying the factors which determine mobile phone use while driving, that is to say, the intention to use a mobile phone while driving.[23]

Driver-assistance systems

Many scientists, car manufacturer, and engineers work hard on the problem of distracted driving. Currently on the market there are a lot of driver-assistance systems. It could be sophisticated electronic systems that aid a vehicle driver while driving - when system includes automatic emergency braking, blind spot monitors, backup cameras, lane keep assist - virtually the system in critical situations takes control, thereby not allowing the driver to make a mistake. Such system usually built-in, less often they can be used as an aftermarket solution. Another way to solve the problem is turning your smartphone into the driver assistant device like Zendrive [40] when sensors of the smartphone can to measure driving behavior, including detecting collisions, risky phone use, aggressive driving, distracted driving, and more. [40]

In reality, the first systems are very expensive and it will take a long time until all the cars will be equipped with it, provided that self-driving cars will not capture the market faster. As to the second solution whether or no the way of interaction with the phone remains the same, even if it vibrates when the driver tries to use or touch it while driving. The trend of today's world is to stay connected wherever you are, which is why it's obvious that people tend to use all smartphone features behind the wheel. As to the legislative way to address the problem - the bans always work poorly, especially when it's hard to monitor the execution of a prescription. Due to all these limitations, HUD systems seem to be the most promising and affordable solution in the question of distracted driving.

CHAPTER 3. MARKET RESEARCH

2.1 Overview of the global HUD market

According to the Global Automotive Head-up Display Market Research Report 2017, the global automotive head-up display market is projected to grow at an impressive double-digit CAGR of 22.4% over the next five years to reach US$ 1.75 billion in 2022. Rising demand for high-end luxury and mid-size cars with advanced safety features including head-up displays, increasing use of smartphones and navigation systems, introduction of more stringent government regulations regarding safety, continuous reduction in the price of head-up displays, advancement in the technology, and an organic growth in the automobile production are major growth drivers of the global head-up display market in the automotive industry.[24]

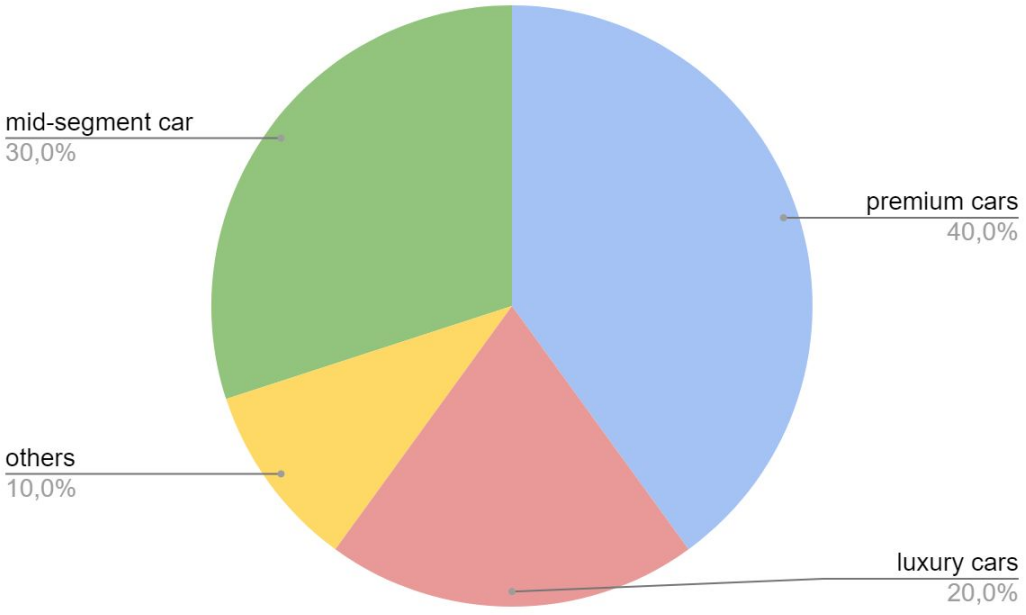


Figure 7: Automotive Head-up Display Consumption Market Share,
Source: QYR Machinery & Equipment Research Center, Apr 2017

Another reason for HUD market growth is the emergence of Augmented Reality which is used as an assistant between drivers and vehicle that leads to safer driving. Thus, with the invention of new driver-centric innovative products, HUD market has gained traction over the forecast period. In terms of volume, the number of shipments in automotive segment of HUD is expected to increase significantly

over the forecast period. The combination of Head-Up Displays with the driver assistance systems which has implemented by large number of manufacturers has propelled the growth of the HUD market. [24]

The global automotive head-up display market is segmented based on vehicle type: luxury cars, sports cars, mid-segment cars, and basic-segment cars. Luxury car is projected to remain the largest segment in the global automotive head-up display market during the forecast period of 2017 to 2022. All major luxury car manufacturers, such as BMW, Mercedes-Benz, and Audi are incorporating the head-up display into some of their models. These luxury car manufacturers are also working with the head-up display manufacturers to introduce these systems into their mid-segment cars. This will drive the demand for head-up displays in the mid-segment cars in the coming five years.[24]

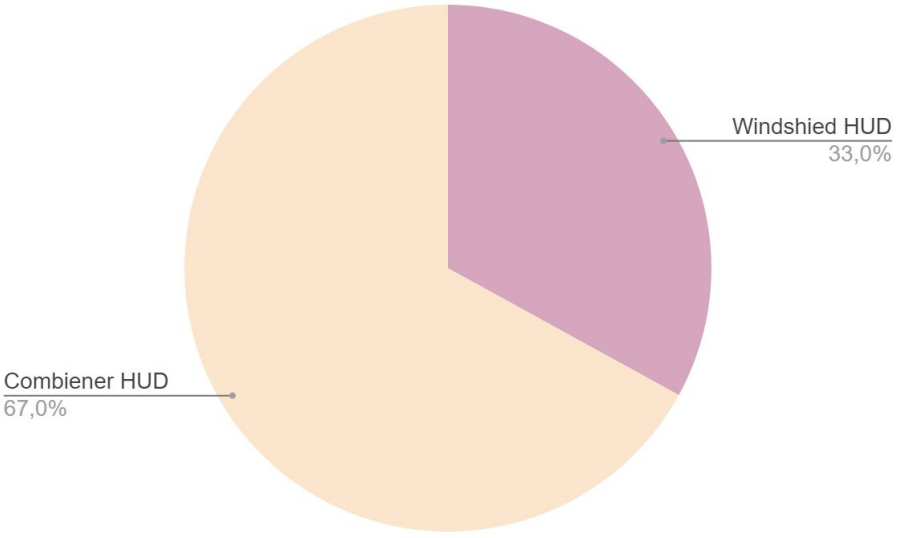


Figure 8: Global Production Market Share of Automotive Head-up Display byTypes

Source: QYR Machinery & Equipment Research Center, Apr 2017

The global automotive head-up display market is further segmented based on product type as windshield and combiner. Windshield projector is expected to remain the largest product type in the global automotive head-up display market during the forecast period, driven by higher use in the luxury vehicles. Both projector types (windshield and combiner) are likely to witness the double-digit growth rates over the next five years, however, combiner projector based head-up display is expected to grow at a much higher rate in the same period, propelled by its low cost and smaller in size. [24]

OEM is expected to remain the largest end-user type in the global automotive head-up display market over the next five years, driven by increasing adoption from luxury to mid-segment carmakers. There is also a good growth expected in the aftermarket in the same period. [24]

Figure 9: Figure Global Automotive Head-up Display Revenue (Million USD) and Growth Rate (2012-2022), Source: QYR Machinery & Equipment Research Center, Apr 2017

North America is expected to remain the most dominant market in the global automotive head-up display during the forecast period, driven by increasing adoption of HUDs in the new models. There are more than 40 vehicle models available in the United States with standard or optional head-up displays, up from 10 models seven years ago. [24]

Asia–Pacific is projected to register the highest growth in the global automotive head-up display market in the same period. China, Japan, South Korea, and India are the largest producers of automobiles in this region. These countries are expected to drive the demand for head-up displays in the region over the next five years.[24]

Nippon Seiki Co., Ltd., Continental AG, Denso Corporation, Visteon Corporation, Yazaki Corporation, Pioneer Corporation, Panasonic Corporation, Robert Bosch GmbH, Delphi Automotive Plc, and MicroVision Inc. are the well-known manufacturers of head-up displays for the automotive industry. An excellent growth in the market is attracting other players to enter the market. Advancement in technology, development of cost-effective solutions, and collaboration with OEMs are some of the key strategies adopted by major companies to gain a competitive edge over others.[24]

The market is driven by factors such as increasing demand for in-vehicle safety features, a rising number of connected cars, and progress toward developing semi-autonomous and autonomous vehicles.[24]

The head-up display ecosystem comprises many entities, from component manufacturers to technology providers, which include Nippon Seiki (Japan), Continental (Germany), DENSO (Japan), BAE Systems

(UK), Visteon (US), Pioneer Corporation (Japan), MicroVision (US), Thales (France), Garmin (Switzerland), and Panasonic (Japan).[24]

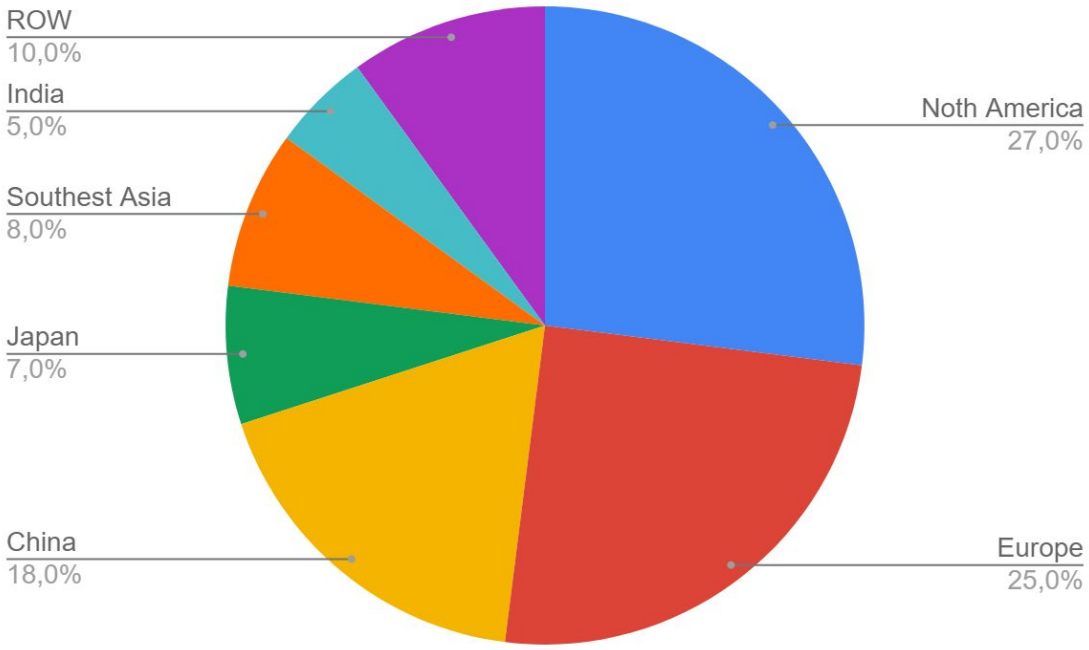


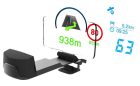
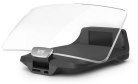
Figure 10: 2016 Global Automotive Head-up Display Production Market Share by Regions

Major Market Developments

- In November 2017, Continental (Germany) signed a contract with automotive manufacturer Lincoln Motor Company, a division of Ford Motor Company (US), to install HUD with digital micro mirror device (DMD) technology to show all relevant information in the driver's field of vision, reducing driver distraction, and therefore making a significant contribution to enhanced comfort and safety.
- In October 2017, DENSO (Japan) has developed a thin-film transistor (TFT), liquid-crystal HUD to project critical driving information on the windshield for drivers.
- In January 2017, BAE Systems (UK) signed a contract with Lockheed Martin to modernize the F-22 Raptor's head-up display (HUD) for the US Air Force, replacing it with a completely digital version.
- Porsche has invested in the Swiss start-up WayRay. The technology company develops and produces holographic augmented reality head-up display technologies.[25]

The HUD market analysis shows that this is a worldwide growing market, it is now far away from market saturation, on the contrary, a lot of market players faced the product awareness problem. This should be taken into account while developing a marketing strategy

2.2 Market research - Existing solutions - Case studies

name	HUD description	price, USD	country	display / where the image is projected	connection to the car	software	hardware	picture
In build solution	in-build Heads-Up Display	starting from $ 2000	-	Windscreen or Dedicated Screen	in-build	own software		BMW X5, AUDI SQ5 ...
Navdy (customer choice)	Portable Heads-Up Display	$ 399,99	FR	Dedicated Screen	OBD-II port	3rd-party app compatibility		
Kivik	Portable Heads-Up Display	$ 204,54	KR	Dedicated Screen	USD port, 5V DC	3rd-party app compatibility	Miracast, BLE	
HUDWAY Cast	Portable Heads-Up Display	$ 299,99	US-RU CN	Dedicated Screen	OBD-II port, cigarette lighter cable	HUDWAY Cast app + 3rd-party app compatibility	Miracast	
HUDWAY Glass	passive smartphone based projection HUD display	$ 49.90	US RU	Phone display/ Dedicated Screen	no electronic components	HUDWAY Go, 3rd-party apps with HUD mode	reflection	
Garmin (customer choice)	Aftermarket HUD	$ 140,00	US	Film Projection or Vacuum Fluorescent Display/ Dedicated Screen or Windscreen	cigarette lighter cable	own software		
iScout	Portable Heads-Up Display	$ 299,99	US	Dedicated Screen	OBD-II port	iSCOUT app	Bluetooth 4.0/LE technology / simcard	
HUDIFY	Passive smartphone based projection HUD display	$ 45.00	CA	Phone display/ Dedicated Screen	no electronic components	no own application, 3rd-party apps with HUD mode	reflection	
Exploride	Portable Heads-Up Display	$ 299,99	US	Display / Dedicated Screen	OBD-II port	no info	no info	
Carloudy	Portable Heads-Up Display	$ 259,00	US	E-Ink Display / windscreen	Micro-USB port	Integrates Apps (Google Maps,Yelp, ParkWhiz)	Bluetooth architecture	

Arpenkin X5 (customer choice)	Universal Multi-Function Vehicle-Mounted Heads up Display for Cars Windshield Compatible with OBD II EOBD System Model Cars	$ 32,99	CN	3 Inch LCD display / windscreen with Reflecting Film	OBD-II port	own software	no connection to the phone	
ZXLine A8	Head Up Colorful Multifunction Display with OBD2	$42.99	CN	5.5 inches HD screen	OBD-II port	own software	no connection to the phone	
Echoman EM03B	Head Up Colorful Multifunction Display	$79.00	CN	LED display / Dedicated Screen	cigarette lighter port	own software	no connection to the phone	
HUDWAY Drive	Portable Heads-Up Display	$ 299,99	US RU, KR			Own app + 3rd-party app compatibility	2 modes -with phone and without	

Table 4: Comparison of existing automotive HUD solutions on the market.

Overall the market of HUD devices is still growing and the actual level of saturation is still low, however the consumer purchasing power is not so high, this conclusion can be done based on the fact that all expensive market players like Navdi has gone into liquidation, as the demand on the market was not so high as they were expected that. This is unknown field and people are not ready to spend a lot money for something that has unclear value for them, for something that they don't know how it works and how to interact with it. In this circumstances the passive non electronic device play the role of affordable unit in the HUD market, that can in certain conditions de-risk the driving process, introduce the HUD and provide HUD product experience to the user.

Figure 11: Navdy HUD unit

Figure 12: Garmin HUD unit

Figure 13: Kivik HUD unit

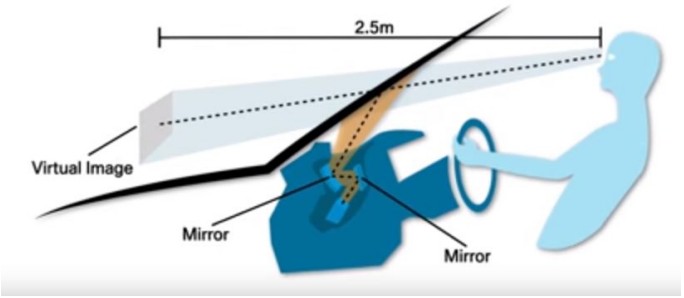


Figure 11: Built-in Head-Up display

2.3 Relevant design comparison of the products from the chosen market segment

The table below illustrates the Pros and the Cons of the proposed models. After a thorough analyse the common disadvantages have been found. Although the existing solutions have certain limitations related to the passivity of the device, several main points have been defined where the enhancement and improvement could be applied to advance the product and boost marketing.

HUDWAY Glass version 1

Pros

1. Curved lens enlarge the image and creates a focal distance about 50cm.
2. Good light absorption rate of the lens provides clear, distinct reflected image.
3. Lens is featured with anti-fingerprint coating
3. Nice design + high quality materials - lens is from optical plastic.
4. Ghost-free HUD reflector (to eliminate double reflection).
4. Fast installation of the cradle to the mount (magnetic fixation)
5. Adjustable mount allow to set the necessary angle for better reflection and according to the user height.
6.Flexible mount allow to mount the accessory on the curved dashboard.
7. Specially created navigation HUD app goes with the device.

Cons

1. Mount magnets unglued in certain conditions.

	2. The reflection rate 65% does not provide a decent reflection in sunny days 3. Curved lens creates image distortions. 4. The cradle mate has not enough friction with the smartphone. 5. The white frame in the reflected image of the white phones is very distracting. 6. The reflective coating is very sensitive. 7. Some phones overheats on the cradle 8. Mount adhesive appeared to be insufficient for some dashboard surfaces 9. Double reflection at night still persist.
 	**HUDWAY Glass version 2** **Pros** 1. Darker lens ensure the good reflected quality during the daytime and sunny hours. 2. Curved lens enlarge the image and creates a focal distance about 50cm 3. Pink glass (Reflected rate has been changed) disturbed some users 4. Nice design + high quality materials - lens is from optical plastic. 5. Ghost-free HUD reflector (to eliminate double reflection). 6. Adjustable mount allow to set the necessary angle for better reflection and according to the user height. 7. Good light absorption rate of the lens provides clear, distinct reflected image. 8.Flexible mount allow to mount the accessory on the curved dashboard. 9. The specially created navigation HUD app goes with the device. **Cons** 1. Hard to install the cradle to the mount. (can't be done with one hand) 2. Double reflection at night still persist. 3. Mount adhesive appeared to be insufficient for some dashboard surfaces 4. Some phones overheats on the cradle 5. The white frame in the reflected image of the white phones is very distracting. 6. Curved lens creates image distortions. 7. The reflective coating is very sensitive 8.The cradle mate has not enough friction with the smartphone.

VIZR

Pros

1. Dark lens ensure the good reflected quality during the day and sunny hours.
2. Small lens fits any dashboard even where there is not so many space between dashboard and windscreen
3. Flat lens creates no image distortions.

Cons

1. Dark lens does not allow to see through at nighttime hours.
2. Small lens - small reflected image
3. Flat lens - the reflected image is not enlarged
4. Non adjustable mount doesn't suit uneven dashboards.
5. The base is too big and too thick (hinder the view).
6. Bulky design

Hudify

Pros

1. Dark lens ensure the good reflected quality during the day and sunny hours.
2. Small lens fits any dashboard even where there is not so many space between dashboard and windscreen
3. Flat lens creates no image distortions.

Cons

1. Dark lens does not allow to see through at nighttime hours.
2. Small lens - small reflected image
3. Flat lens - the reflected image is not enlarged
4. Non adjustable mount doesn't suit uneven dashboards.
5. Poor reflection visibility during the daytime
6. There is no own Navigation app.

Smart i hud

Pros

1.Ergonomical, compact and streamlined design
2. Ghost-free HUD reflector (key technology)

The HUD reflector is slightly tapered so that the reflected images form the outside and inside. Surface of the HUD reflector are reflected at slightly different angles, chosen so that the images substantially overlap at the viewer's eye. This technology, which are applied on high-end vehicle shows the navigation's image very

clearly.
3. Adjustable mount.

Cons
1.The reflection rate does not provide a decent reflection in sunny days
2. Phone is insecure on the cradle
goo.gl/9KJXQo

No brand chinese versions (aliexress)

Pros
1.Qi wireless charger 10 В т /7,5 В т
2. Translucent screen
3. ABS (Acrylonitrile Butadiene Styrene)
4. Phone holder function

Cons
1.Not all phones supports wireless charging
2. Not battery, it should be all the time connected to the socket.
3. The reflection rate does not provide a decent reflection in sunny days
4. Non Adjustable mount.
5. Some phones overheats on the cradle
goo.gl/3Mwq5X

VJOYCAR

VJDYCAR

Pros
1. Good quality of reflected image
2. Phone holder function
3. Adjustable mount
4. Flat lens creates no image distortions.

Cons
1.The lens works almost like a mirror and therefore the screen is not translucent
2. Flat lens - the reflected image is not enlarged
3. The base is too big and too thick (hinder the view).
4. Some phones overheats on the cradle
5. Middling design

goo.gl/HBTV1B

	**No brand chinese versions (aliexress** **Pros** 1. Flat lens creates no image distortions. 2. Simple and nice design 3. Fix the phone in place **Cons** 1. The reflection rate does not provide a decent reflection in sunny days 2. Flat lens - the reflected image is not enlarged 3. Cheap materials, non optic glass 4. Some phones overheats on the cradle 5. No mounts. Does not fit curved dashboards. goo.gl/8gfpwd
	**No brand chinese versions (aliexress** **Pros** 1. Flat lens creates no image distortions. 2. Simple and nice design 3. Fix the phone in place 4. Phone holder function 5. Wireless charger **Cons** 1. The reflection rate does not provide a decent reflection in sunny days 2. Flat lens - the reflected image is not enlarged 3. The lens works almost like a mirror and therefore the screen is not translucent 4. Some phones overheats on the cradle 5. No mounts. Does not fit curved dashboards. goo.gl/MigAJm

Table 5: Relevant design comparison of the products from the chosen market segment.

After the thorough market research and documentation of the Pros, Cons to define the facts that differentiate the innovation from competing products and specifying market requirements for successful commercialization the following statements could be done: The wireless charger can become one of the strengths of the product and add a value to it. The design should solve the problem with poor reflection visibility and double (ghost) reflection by using, for example, photochromic lens or set of different lenses for day and night. The mount and lens should be adjustable, the form and reflected rate of the glass(lens) should be carefully researched, as well as mount and friction cradle mate.

CHAPTER 3. USER RESEARCH

3.1 Customer research (location, age, gender, income level, etc.)

The gathered information below conducted to identify who are customers or potential customers, where do they from, what, when, where and how they buy, define customer segments, needs, and understand their behaviors, social and lifestyle trends, needs and expectations, attitudes towards the product and product's competitors. The following sources and methods have been used to research customers: Google Analytics, customer behavior observation, questionnaire (survey) for customers, point-of-sale (POS) feedback, focus group, gathering and analyzing of customer feedbacks, personal seller interviews, field trials. All these data have been gathered from the company HUDWAY LLC. Google Analytics based on several marketplaces and social networks (facebook, вконтакте, instagram, twitter) that leads the company. The questionnaire (survey) have been held with the customers or potential customers from the newsletter subscription list of the company HUDWAY LLC. The information relating to customer behavior observation and customers' feedback, complaints or suggestions was gained via HUDWAY customer support center, as well as feedback about POS from the distributors.

Google Analytics

Страна	Код валюты	Пользователи ↓	Сеансы	Доход	Транзакции	Средняя стоимость заказа
		84 626 % от общего количества: 100,00 % (84 626)	109 990 % от общего количества: 100,00 % (109 990)	383 668,43 $ % от общего количества: 100,00 % (383 668,43 $)	1 729 % от общего количества: 100,00 % (1 729)	221,90 $ Средний показатель для представления: 221,90 $ (0,00 %)
1. United States	(not set)	**31 301** (36,03 %)	39 123 (35,57 %)	211 093,27 $ (55,02 %)	891 (51,53 %)	236,92 $
2. Russia	(not set)	**5 398** (6,21 %)	7 110 (6,46 %)	5 067,84 $ (1,32 %)	37 (2,14 %)	136,97 $
3. India	(not set)	**3 612** (4,16 %)	4 232 (3,85 %)	2 111,20 $ (0,55 %)	11 (0,64 %)	191,93 $
4. Germany	(not set)	**3 592** (4,13 %)	5 176 (4,71 %)	14 116,01 $ (3,68 %)	74 (4,28 %)	190,76 $
5. United Kingdom	(not set)	**3 132** (3,60 %)	3 966 (3,61 %)	12 009,22 $ (3,13 %)	64 (3,70 %)	187,64 $
6. Canada	(not set)	**2 662** (3,06 %)	3 684 (3,35 %)	10 226,60 $ (2,67 %)	50 (2,89 %)	204,53 $
7. France	(not set)	**2 317** (2,67 %)	2 813 (2,56 %)	4 453,62 $ (1,16 %)	22 (1,27 %)	202,44 $
8. Brazil	(not set)	**2 140** (2,46 %)	2 401 (2,18 %)	1 115,95 $ (0,29 %)	5 (0,29 %)	223,19 $
9. Australia	(not set)	**1 895** (2,18 %)	2 478 (2,25 %)	9 362,95 $ (2,44 %)	53 (3,07 %)	176,66 $
10. Spain	(not set)	**1 658** (1,91 %)	2 071 (1,88 %)	3 600,51 $ (0,94 %)	21 (1,21 %)	171,45 $

Table 6: Google Analytics, that tracked the Flash, video, and social networking sites and applications and measured advertising ROI

Here is top 10 countries with highest eCommerce rate and traffic. The main revenue-generating countries are USA, Germany, United Kingdom, Australia, Canada, Russia, France, Spain. The potential growth is possible in Russia, India, Brazil, China, Japan, Middle East countries. These are the markets to focus on. Localization of the marketplaces, instructions and Apps strongly required for listed countries. It may also be necessary to adapt the name of the promoted product.

	Тип устройства	Источники трафика			Действия			Конверсии	
		Пользователи	Новые пользователи	Сеансы	Показатель отказов	Страниц/сеанс	Сред. длительность сеанса	Транзакции	Дох
		84 626 % от общего количества: 100,00 % (84 626)	86 921 % от общего количества: 100,05 % (86 875)	109 990 % от общего количества: 100,00 % (109 990)	8,06 % Средний показатель для представления: 8,06 % (0,00 %)	3,41 Средний показатель для представления: 3,41 (0,00 %)	00:01:10 Средний показатель для представления: 00:01:10 (0,00 %)	1 729 % от общего количества: 100,00 % (1 729)	383 количе
1.	mobile	**69 108** (80,84 %)	70 435 (81,03 %)	85 894 (78,09 %)	6,04 %	3,18	00:00:56	680 (39,33 %)	123 288,
2.	desktop	**13 393** (15,67 %)	13 498 (15,53 %)	19 592 (17,81 %)	15,38 %	4,26	00:02:02	873 (50,49 %)	226 873,
3.	tablet	**2 982** (3,49 %)	2 988 (3,44 %)	4 504 (4,09 %)	14,72 %	4,06	00:01:43	176 (10,18 %)	33 506,

Table 7: Google Analytics, Device Category

The largest number of visits to the site is carried out from a smartphone, but more purchases are made through a computer.

The below table illustrated customers interests segments. The Affinity Categories is a broad content categories that identify users in terms of their lifestyles. It is no surprise that the top

			пользователи	Сеансы	отказов		длительность сеанса		Дох
		13 381 % от общего количества: 15,81 % (84 626)	13 067 % от общего количества: 15,04 % (86 875)	18 149 % от общего количества: 16,50 % (109 990)	3,61 % Средний показатель для представления: 8,06 % (-55,26 %)	4,36 Средний показатель для представления: 3,41 (27,76 %)	00:01:42 Средний показатель для представления: 00:01:10 (46,18 %)	565 % от общего количества: 32,68 % (1 729)	100 3 количе
1.	Shoppers/Value Shoppers	**9 528** (3,83 %)	9 245 (3,82 %)	13 082 (3,86 %)	4,24 %	4,39	00:01:44	412 (3,97 %)	71 338,4
2.	Technology/Technophiles	**8 842** (3,55 %)	8 584 (3,55 %)	12 302 (3,63 %)	4,28 %	4,35	00:01:42	372 (3,59 %)	64 334,4
3.	Lifestyles & Hobbies/Business Professionals	**8 370** (3,36 %)	8 174 (3,38 %)	11 700 (3,46 %)	4,48 %	4,29	00:01:43	366 (3,53 %)	66 818,8
4.	Home & Garden/Do-It-Yourselfers	**7 750** (3,11 %)	7 514 (3,10 %)	10 760 (3,18 %)	4,54 %	4,45	00:01:48	348 (3,36 %)	59 421,7
5.	Vehicles & Transportation/Auto Enthusiasts	**7 165** (2,88 %)	7 008 (2,89 %)	9 954 (2,94 %)	4,57 %	4,46	00:01:51	326 (3,14 %)	55 553,8
6.	Media & Entertainment/Movie Lovers	**6 825** (2,74 %)	6 615 (2,73 %)	9 136 (2,70 %)	3,47 %	4,30	00:01:36	263 (2,54 %)	44 635,4
7.	Shoppers/Luxury Shoppers	**6 468** (2,60 %)	6 294 (2,60 %)	8 877 (2,62 %)	3,57 %	4,35	00:01:44	255 (2,46 %)	44 331,8
8.	News & Politics/Avid News Readers	**6 287** (2,52 %)	6 131 (2,53 %)	8 814 (2,60 %)	4,59 %	4,44	00:01:50	305 (2,94 %)	53 454,4
9.	Food & Dining/Fast Food Cravers	**5 762** (2,31 %)	5 604 (2,31 %)	7 705 (2,28 %)	3,04 %	4,23	00:01:35	207 (2,00 %)	35 487,4
10.	Beauty & Wellness/Frequently Visits Salons	**5 732** (2,30 %)	5 569 (2,30 %)	7 681 (2,27 %)	4,26 %	4,14	00:01:38	233 (2,25 %)	42 079,0

Table 8: Google Analytics, customers interests segments.

affinity category is shoppers and value shoppers. Technology and hobbies share the second place, Home and garden/ do it yourself on the third and what was unexpected Auto/ vehicles & transportation are

only on the fifth place followed by Media & Entertainment /Movie Lovers, Luxury shoppers, news readers and Food/ Fast food cravers. this means that the awareness of the HUD devices is low and that only strongly interested in the area or “shopaholics” are able to find out the product.

Different age groups and gender traffic.

A key factor in creating a successful customer experience is to really know who they are - your consumers. This data is gained from the facebook account of the HUDWAY LLC company. According to this information, it can be concluded that 90% of all buyers are men among 18-44 years old. Having statistics from the help center was also noticed that more than the half of women that buy HUD units, buy it as a present for their lovers (husband, son, fathers) and not for their selfs.

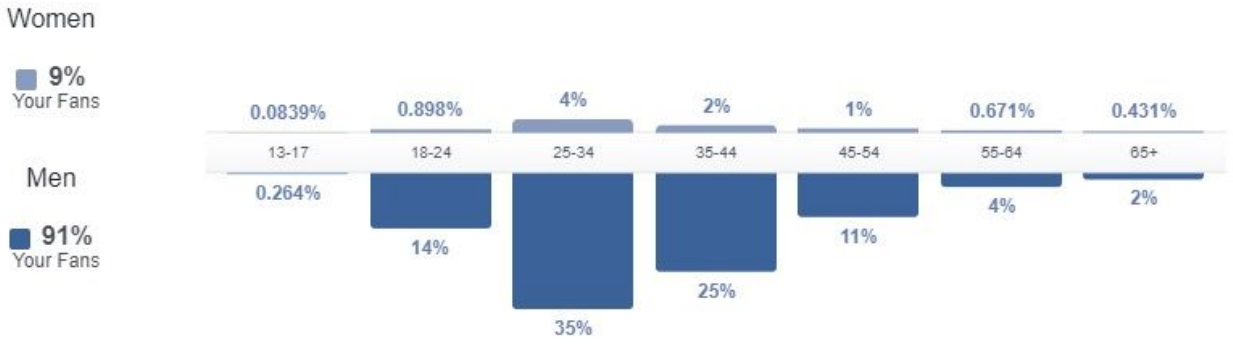


Figure 12: Age and gender traffic.

3.2 Questionnaire for the current users or potential customers.

The questionnaire (survey) (Appendix 3) have been held with the customers or potential customers from the newsletter subscription list of the company HUDWAY LLC (that means that they already aware of the topic) and the control group of people (just car owners, not from subscribers, not a former buyers). The objective of the survey was to study the product awareness, find out the most popular or potential use-cases of HUD device, explore priorities in navigation applications, discover the most popular car models and smartphone models of potential customers.

The survey shows that 46 percent of participants are using iPhones, thus this is the smartphone they will use with HUD device. It is interesting that about 14 percent do not want to use smartphone with Head-Up display, rather prefer to have it as a fully separate device or to connect it to Android Auto, Android computer stick, Laptop, or built-in head unit. The results concerned the use-cases are summarized in a spider chart below. As expected the most popular case is using the display for navigation, on the second place are smartphone notifications. OBD data and picture from the cameras share the third place. It should be remembered that it was a multi-choice question.

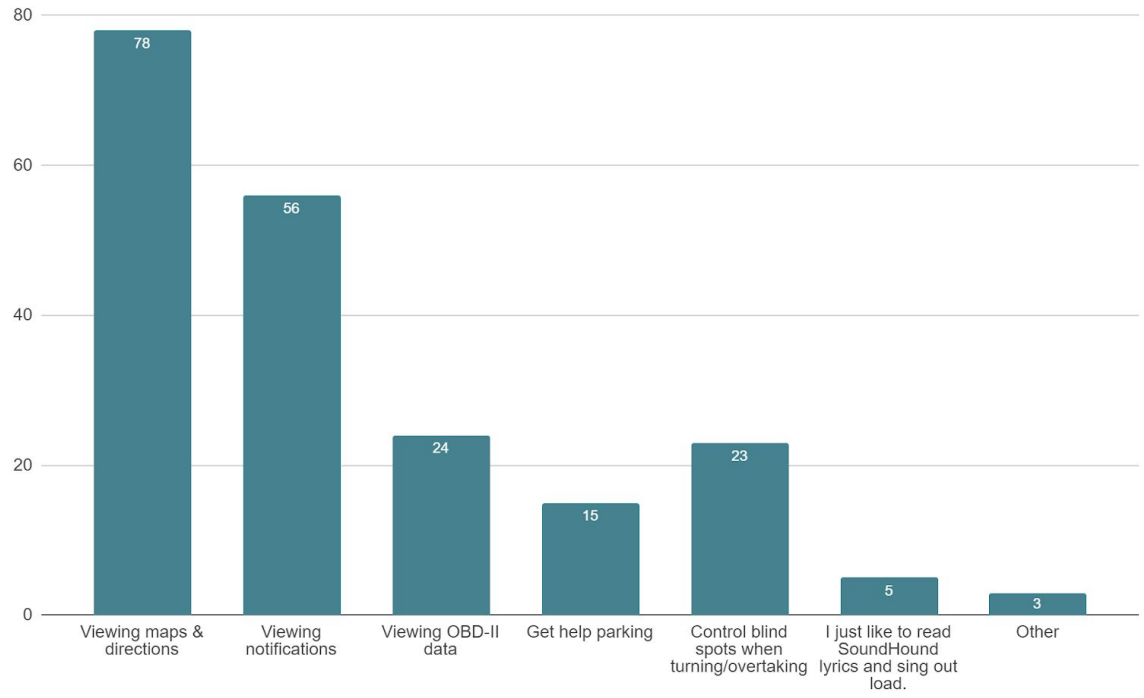


Figure 13: The most important HUD use cases.

However, 37% of respondents from the second group did have any idea or vaguely understood what Head-Up display is about. When talking about Navigation app 61% of those respondents are using Google maps or Waze, 32% using more than one application, 23% non-HUD mode app but would rather use purposely designed for HUD app.

3.3 Identification of the target groups.

Based on previous researches, it is very important to identify the main target groups and effectively raise awareness of the appropriate audience.

Target group	gender	description	what need to be done
Group #1	men	car owner, middle-income or high income, age 25-45, high product awareness, from North America or Europe, Tech-Geek, shopper, ready to try smth new.	increase competitiveness by offering new features. client-oriented approach to increase loyalty.
Group #2	men	car owner, usually an impulse purchase, low product awareness, vaguely understanding of product features and usage, from North America, Europe, Australia, Asia,East.	help to continue to use the purchase, targeted advertising, increasing knowledge about the product.
Group #3	women	car owner or not, age 25-40, more than a half of purchases not for herselt, as a present, faced difficulties with using the product, lose the interest fast if smth is wrong and do not give the second chance.	help to continue to use the purchase, provide immediate customer support, increasing attractiveness and user-friendliness of the product.

Table 9: Main target groups

It goes without saying that the amount of target groups are higher, but the three main ones has been chosen. Based on these largest groups the development vector can be determined.

3.4 End user field work, feedback analysis, demands & wishes determination

The process of the new product development is very expensive and related to the high failure risk. To reduce the consumers' nonacceptance the customer knowledge should be taken into account, so that more beneficial product can be created.

HUDWAY company produces several HUD units. One of the product HUDWAY Glass is located in the chosen market segment. For now, it has 2 versions. More than 1.5k feedbacks have been gathered and analyzed. Here below some examples of the received emails. Each feedback illustrate one of the issue with the existing product.

*- It appears in your demo videos that the phones are black. My iPhone 6S is white. I am concerned that the **white will reflect in the glass along with the display**. Have you tried the Hudway with a white phone?*

- *I just received the hudway glass and wanted to know **to keep the phone from sliding off the mount**. I have a cover on my phone.*

- *I received a Hudway Glass as a gift over the weekend. I've found that my **phone reflects off of the windshield directly in my line of sight, which is distracting**. Do you have any tips on placement so I can see the reflection on the unit with minimal reflection on my windshield?*

- *I am not sure if everyone had this problem: the side of the glass facing the windscreen is a real fingerprint trap, the inside moderately so. Anyway when I tried to clean it with an optical lens cloth,* ***whatever the glass coating was rubbed off*** *with the result that the HUD function no longer works effectively. Also, driving in spring in Australia, my phone became extremely hot behind the glass, even not in GPS mode. I hate to think what would happen in summer!!! Please advise.*

- *Hello, I have just received my hudway glass. When I place my phone on the cradle* ***(motorola Moto G3) it turns the screen off so that it wont display****? This seems only to happen when the cradle is on its stand. Please advise asap. Many thanks (the magnet is in the Glass, so that when the phone touches the cradle the magnet sensor in your phone is activated and the screen is turned off)*

- *Hi On the base stand for my Hudway glass, the* ***magnet that is meant to attach the phone holder to the stand has come out****. This has happened to both the adjustable and compact mount. In the case of the compact mount, the magnet actually broke into a number of small pieces. As far as I can tell, the glue holding the magnet to the mount was not strong enough and removing the glass phone base caused the mount magnet to be removed. I also have a problem with using the glass screen because I get the screen image reflected again above the glass on the windscreen of my car, which is very distracting and obscures my view of the road. Could you let me know if these are problems also reported by other users? Best regards*

Figure 14: Pictures sent by customers to illustrate the issue

- *Hi, I received the glass two days ago. But the **adjustable mount is defective and the ring magnet is detached, which make me unable to install it in my car**. I didn't do anything to the mount, I just assembled the glass and the mount, and left them on my desk during the night. But in the morning of the next day, when I remove the glass from the mount, the ring magnet detached. So now I have no way to install it in my car. Furthermore, my phone is white. The white color reflects on the glass clearly, which effectively blocks my sight. Also, the phone is not fixed. It's a safety hazard in case of an accident. Based on those reasons, I want to return it. Thanks! Best regards,*

Figure 15: Pictures sent by customers to illustrate the issue (HUDWAY LLC)

Lean upon feedback analysis the bar graphs with main product issues have been elaborated. It illustrates not only the frequency of dealing with a certain problem but also presents a comparison of 2 versions. It needs to be emphasized, that these 2 units had a slightly different design which aimed to solve the issues of the first model. It can be seen that not all issues have been addressed. For instance the problem with the dash mount has been resolved by changing the mounting solution, however, at the same time, the new design was not so easy- to use. The coating problem and reflected image issues have been changed relatively small. People continuously reported the concerns regarding phone insecure placement and asked for the built-in phone charger that resulting from the fact that Navi-apps drain the battery.

Figure 16: Evolution. HUDWAY Glass v1 and HUDWAY Glass v2 (HUDWAY)

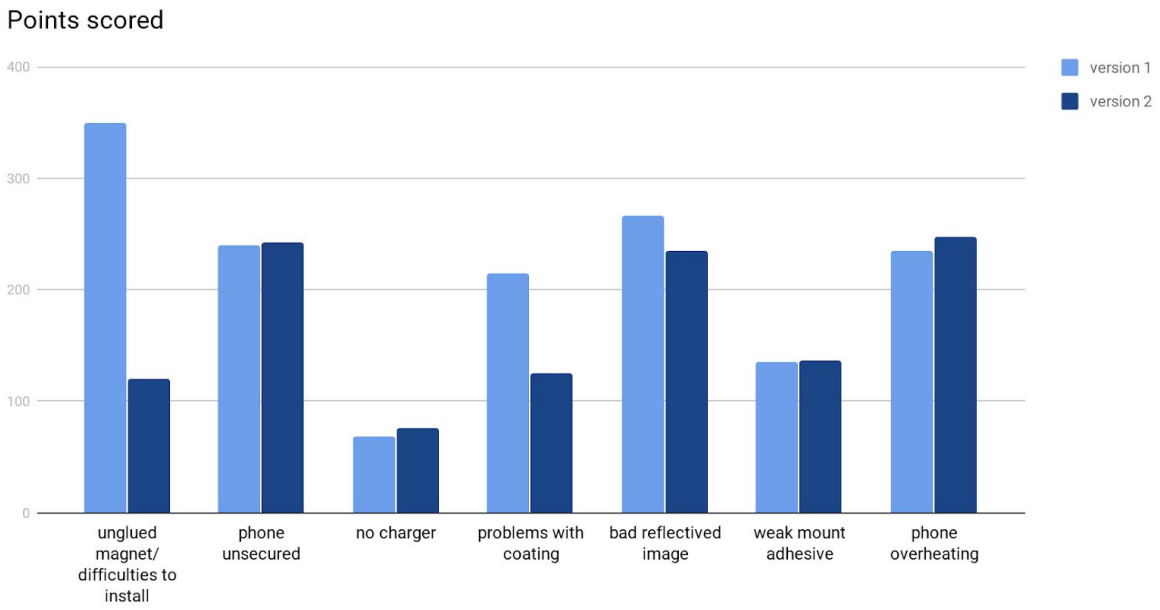


Figure 17: Main issues of HUDWAY Glass HUD unit

The demands and suggestions have been summarized into another chart that afterward will be used for creating the design brief, idea generation, and concept development. Overall the clear upward trend between the two models is not seen. Most of the issues left unsolved and customers unsatisfied. It is clear that the solutions that offer the market currently far from perfect. If it's hard or not easy to use the HUD or the unit doesn't meet all user needs, such a product will not be able to solve the main problem - distracted driving.

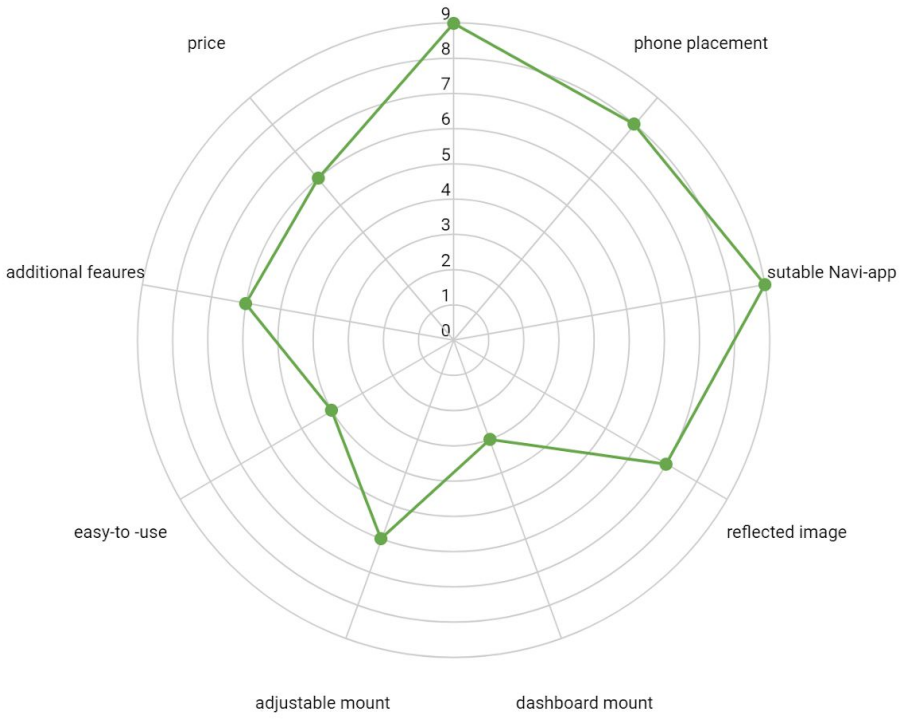


Figure 18: The main criteria that must be considered when developing a design concept.

CHAPTER 4. CONCEPT DEVELOPMENT

4.1 Design Brief

Assignment: *What's our deliverable?*

To develop a car accessory that can turn any smartphone into the Head-Up display to make the driving and the navigation process safer, through elimination of the main distracting factor - smartphone by giving it a new meaning.

Project Background: *What is the history of this project and the objective supporting this assignment?*

The interaction between the driver and the smartphone is the key risk factor while driving. A lot of countries has forbidden the drivers to touch the phone while driving, but still phone plays the main role for many people by driving process by virtue of fact that it acts as a navigator. People are always using their smartphones for navigation with a help of special Navi-Apps and different phone-dash-holders. This way of interacting between the driver and the device can be ameliorated by providing a safer way of navigation process especially in a low visibility conditions.

Objective(s): *What is our purpose? What are we trying to accomplish with this assignment?*

To cope with distracted driving, to provide drivers with safer way of navigation with the help of smartphone, to propose the new way of interaction with the smartphone behind the wheel, to boost the new safer driver behavior pattern.

Regulatory issues: *Regulations which will impact the design.*

CE,FCC,CCC,ROHS - Certificates. Crashing test will affect maybe the shape, size, weigh and the materials. Person can't touch the phone while driving - the interaction with the Navi-app via gestures or voice, managing calls, the projected picture should be less distracting.

Target Audience, Demographics/ Psychographics: *Who are we communicating to? What do we know about the target?*

Primary Target: Middle class men between 18 and 54 car owners. Geeks of all car's staff and gadgets. They are buying it for themself, usually they know already smth about the product, they know what they want and have an idea what they are searching.

Secondary Target: Women/ men - they are buying it as a preset - in this case we do often face a problem of failed expectations or misunderstanding of the product functions.
Thirdly target: Women buying it for themselves. Have high expectations. Do not want to put up with difficulties.

We want that the average, everyday person who uses car for regular every day commuting thinks twice when trying to interact with the phone while driving. The aim is not to sell the HUD Display - but the idea of safe driving, the way of behaving behind the wheel, the safest and easiest way of navigation.

Scope: *Detailed list of everything this project is expected to deliver.*
The project scope is to create a conceptual design of Head-Up display. *Head-up displays (HUD) are partially-transparent displays that render information in a manner that allows the viewer to comprehend it while looking into the forward scene. It is known as Head up display because while using it the operator's head position is UP means forward instead of looking down*.[26] This HUD use the smartphone screen as a source for reflected image. The special Navigation app, that supported HUD mode should be created along. The moto is to follow the navigation while keeping your eyes on the road. The developed mobile app should be able to compete with such market giants as Google maps, Waze, TomTom, Baidu maps, Apple maps, Kakao Talk, Yandex maps. As a conclusion will be the new interaction system performance description with a couple of the use cases.

Not in scope: *Specify design elements that are out of scope.*
Under this master thesis the development of the special smartglass lens will not be considered, as this development requires the involvement of specialists from this area and depends on financial investments.

Purpose and function: *What the product is supposed to be able to do, who will be using it and in what circumstances.*
The product - it is a car accessory that fits any car and can work with any smartphone. The accessory is mounted on the dashboard. The accessory works as a phone mount. The screen of the smartphone can be reflected in the product's lens. The reflected image should be clear, distinguish and legible in different light conditions. The item can wirelessly charge the phone. The cradle position and the angle between the cradle and the glass should be adjustable. The installation/deinstallation of the cradle to the mount and placing phone on the cradle should be fast and easy and can be done with a help of one hand. The product should be safe from vibration created by the car.
Design Project plan: *List the project milestones.*

Ideas generation, Concept exploring, Concept defining, Concept and application approving., Mock-up, 3D- modeling, Prototyping, Validation, testing of the prototypes, Design iterations, Final design, Gold Prototype, Production, Market penetration,Expansion, Profitability.

Measures of success: *How will you ensure the design is appropriate for your objectives?*
Design solve the problem and provide better solution as before, it address the user needs, the product is better than the former ones, it gets positive feedbacks from users, come at an acceptable prime cost, simplify the production process.

4.2 Mapping the needs

People want to stay connected while driving. This behavior pattern hard to overcome, however, it could be changed if the safer concept of interaction with the smartphone is able to match the following user-requests.

1. A Safer way of interaction with the smartphone.
2. Stay connected while driving.
3. Get access to the main smartphone features.
4. Simultaneous phone charging.

Moreover, based on the relevant design comparison of the existing products on the market and user feedback analysis necessary changes were identified:

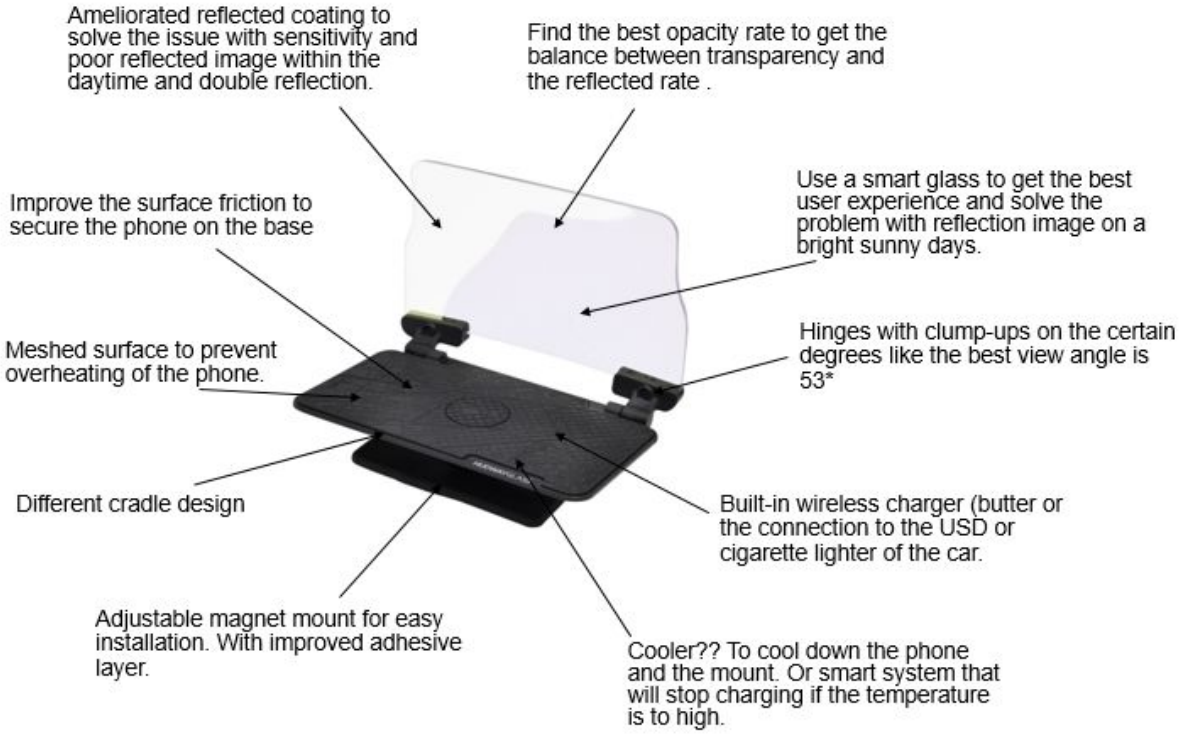


Figure 19: The main issues that have been educed after feedback analyze.

To simplify the process all needs and issues that have to be solved have been divided into main 3 groups: 1. Head-Up display unit 2. HUD mode phone application 3. system performance. The following concept development will involve all these three aspects.

Head-Up display unit

1. **Clear and visible reflected image.**

All HUD units, especially the passive ones, have the same problem of poor visibility of the reflected image during the clear, bright day. The brightness of the projection is limited by the device characteristics and depends on the transparency and reflected the rate of the HUD lens. When the person is driving in the bright sunlight, especially when the sun shines directly in his face, the brightness of the reflection will be poor and the image will be almost invisible for the lens that has low opacity. This problem is usually solved by some manufacturers through obscuring or dimming the lens. Unfortunately obscuring is a two-edged sword, as the darker is the lens, the worse is its transparency. That means that in the night this lens will work almost like a mirror and the driver will hardly be able to see through it. For the nighttime hours, the opacity rate of the lens should be low to ensure that glass doesn't block the view of the driver.

POSSIBLE SOLUTIONS: As the easiest and cheapest way out - using the tint to change the transparency and reflected rate of the lens. On the other hand, 2 different lenses could be provided. The Day lens and the Night lens. This is a typical solution in such cases (like the Snowboard Goggles) but the cost of the lens makes almost the half price of the device. The only way will be is to sell it separately as an add-on. The third idea is to use "Smart glass". The light transmission properties of such glasses are altered when voltage, light or heat is applied. Photochromic Smart glass technologies allow to changes from translucent glass to transparent, changing from blocking some (or all) wavelengths of light to letting light pass through.[27]

Figure 20: Pictures (source internet) illustrating possible ways to solve the issue

2. Double reflection.

As the opacity of the lens is not 100%, the part of the light is going through it and reflects from the windshield. The appearance of the double reflection and its brightness defined by the brightness of the smartphone screen and the windshield tilt angle. Some drivers find this very distracted and are not able to use the HUD because of that. The issue mainly occurs during the nighttime hours as at the daylight the ghost reflection is not visible. This issue highly depends on the people's perception, for some of the users it's very critical and others have never complained about it.

POSSIBLE SOLUTIONS: Reducing the brightness of our phone screen takes care of the double image on the windshield. If that does not work for the drive and he finds driving with the device distracting, it is better to stop using the device immediately as driving safety is the priority. Also tint or properly selected reflection rate of the HUD lens can help about it.

3. Sensitive reflected coating.

The examined HUD lenses were made from Poly(methyl methacrylate) (PMMA), also known as acrylic, acrylic glass, or plexiglass as well as by the trade names Crylux, Plexiglas, Acrylite, Lucite, and Perspex. It is a transparent thermoplastic often used as a lightweight or shatter-resistant alternative to glass. To obtain the necessary properties, the HUD glass is covered with different coatings based on titanium oxide. Overall there are 7 layers, including the anti-fingerprint layer, reflected layer, antiglare layer, firming layer, etc. In terms of production, the connection between the coating and the surface of the glass is non-durable and after 2-3 years it could begin to flake off. Under extreme conditions of use or violation of production technology this period, it could happen faster.[28]

POSSIBLE SOLUTIONS: Make changes in production technology or C hange the material that has been used. Still, it's unclear what exactly causes the flaking. This issue needs further investigation. Do the sudden changes in temperature affect the coating? What were the storage and use conditions? Did the customer use any special solution to clean the glass? Work in this direction requires a lot of time and the involvement of relevant specialists, that's why further these questions will not be considered in the work.

4. Secure placement of the smartphone.

The cradle of the HUD unit should be suitable for smartphones of different models. The screen size of today's phones can vary a lot, that is why using any kind of brackets is not possible as it will limit the usage of the unit. The examined HUD unit has a mat attached to the cradle with high frictional resistance, it is enough to secure the phone on the cradle and ensures that the phone stays in place

even on bumpy curves of the road. However depending on the phone case, road surface condition and the driving style, in some cases the resistance of the mat unable to cope with too sharp a turns or slick phone case.

POSSIBLE SOLUTIONS: Rubber phone case can solve the problem. At the same time Fixate Gel Pads, an anti-slip mat can be used as a separate solution. Also, the material of the cradle mat could be changed. The overall design solution should be reviewed, maybe the best way is to use the magnet to secure the phone on the cradle.

Figure 21: Pictures (source internet) illustrating possible ways to solve the issue

5.Phone overheating.

There are a lot of cases when using the Navigation app, having the GPS chipset enabled, running another app on the background leads to heating the device. Moreover while charging, the device and the charger* may become hot. During wireless charging or fast charging, the device may feel hotter to the touch. Also, the phone heats because of being exposed to direct light when placed onto the accessory cradle. While generally heating the device is a normal working condition, sometimes it can lead to unintended consequences like for example damage of the battery. Phones may heat also when the program is heavy or bad-coded and the device is weak. Currently, we are unable to do something with device heating because of GPS. There are only some external methods that could improve the situation.

POSSIBLE SOLUTIONS: Usually smartphones have their own methods to detect overheating, switch off and cool down. The AC in the car may help as well. The mash surface of the cradle could help with the problem. Some wireless charging devices have built-in fans to cool down the device.

6. The apps and GPS are drastically draining the battery

Feedback analysis showed that a lot of users complaint about too fast battery draining. There are a lot of reasons why the phone battery dies so quickly: inappropriate screen brightness, a constant search for Wi-Fi networks, apps in the background, hardware issues, etc. In case when the phone is used with HUD unit the main issues are usually the Apps that can get stuck and drain the battery or just use a lot of data, especially when the app requires GPS.

POSSIBLE SOLUTIONS: While building the app it should be taken into account that when the data involves location, the phone's GPS chipset is enabled — exacerbating the battery drain problem significantly. Usually using the poor-cooded SDK for building the app doesn't allow to have a power effective app. Enabling GPS uses zero extra power except when location services are actually being used. Turning it on and off all the time use more power than just leaving it on all the time. Having the GPS turned on won't drain your battery if no app is actually using it. If the phone keeps killing the battery too fast even after a reboot, check the battery information in Settings is needed. If an app is using the battery too much the system will show it clearly. It's important to allow access to location Services only when the app or one of its features is visible on the screen, when actually the app is in use. According to the above mentioned it is necessary to built-in the wireless charger inside the cradle of the car. This could solve the issue with the battery and save the driver from the interfering power cord on the dashboard and near the steering wheel. This is also one of the top features that customers asked based on the received feedback and suggestions.[29]

7. HUD unit mount.

How to fix the HUD unit on the car dashboard? The viewing angle of passive HUD units as well as of more sophisticated electronic devices is very small. Basically, there is only one position when the driven can easily see the reflected image. This actually limits the number of options for placing the unit on the dashboard to only one - in front of the driver in his line of sight. Moreover, the idea of HUD is to project information directly into the driver's visual field, therefore left/ right sides are not considered. The second obstacle is the vision line height that could differ up to 20 cm depending on the driver's height. And the last but not the least is car dashboard material. The mount should attach well to any plastic or leather dashboard, and leave no traces when removed.

Figure 22: Pictures (source internet) illustrating different shapes of dashboards

POSSIBLE SOLUTIONS: The mount should be adjustable to correspond to the values of driver eye height. The dashboard mount can be featured either with one-use adhesives like a 3M tape or multi-use gelly glue. The mount should be properly fixed to the dashboard as it's a question of safety. Also some dashboards more vulnerable to vibration, which is why the mount should fit snugly to the surface and if possible absorb these vibrations.

8. Folding the lens of the HUD.

It's obvious that the lens should be foldable. This ensures safe and easy shipping and transportation, makes storage simply and overall delivers the better user experience. It's better if it is possible to open and close the lens, or just adjust its angle with only one hand. Therefore it should not be too tight, but at the same time, it must be stiff enough to keep a certain angle and do not become loose because of vibrations and bumpy roads.

POSSIBLE SOLUTIONS: Hinges should be carefully selected. Moreover, the clamp-ups could be implemented to fix the glass in certain positions, which provide the best quality of the reflected image.

4.3 Initial concept proposal and inspirations

The following section focuses on the HUD unit appearance. Based on previous research, observations, feedback analysis and on findings from tests a number of sketches were drawn, analyzed and compared. Some of them, as the most promising one, were chosen for a more precise comparison.

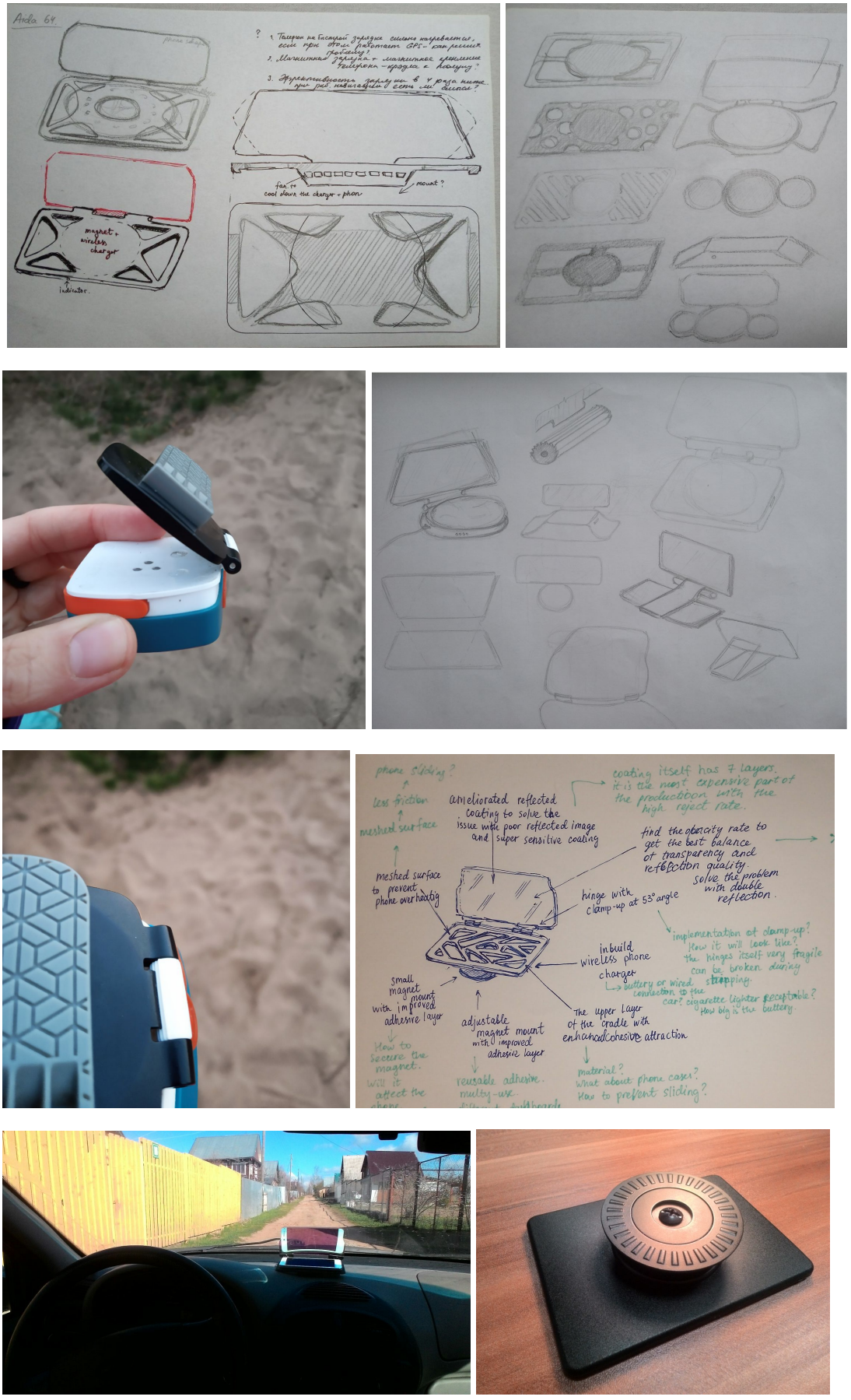
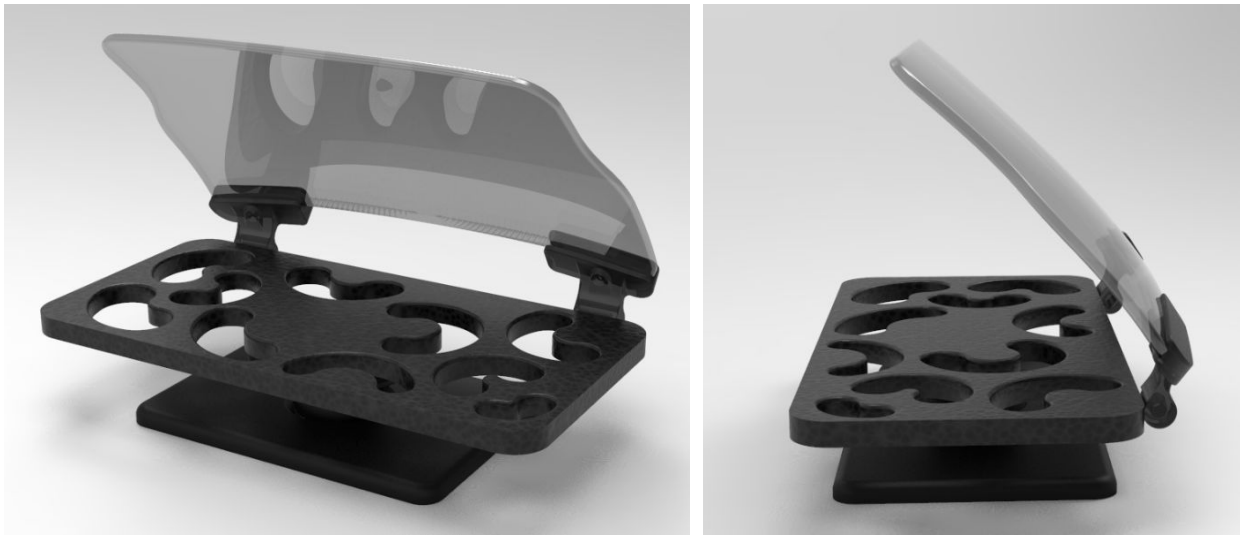


Figure 23: Pictures of sketching and idea generators

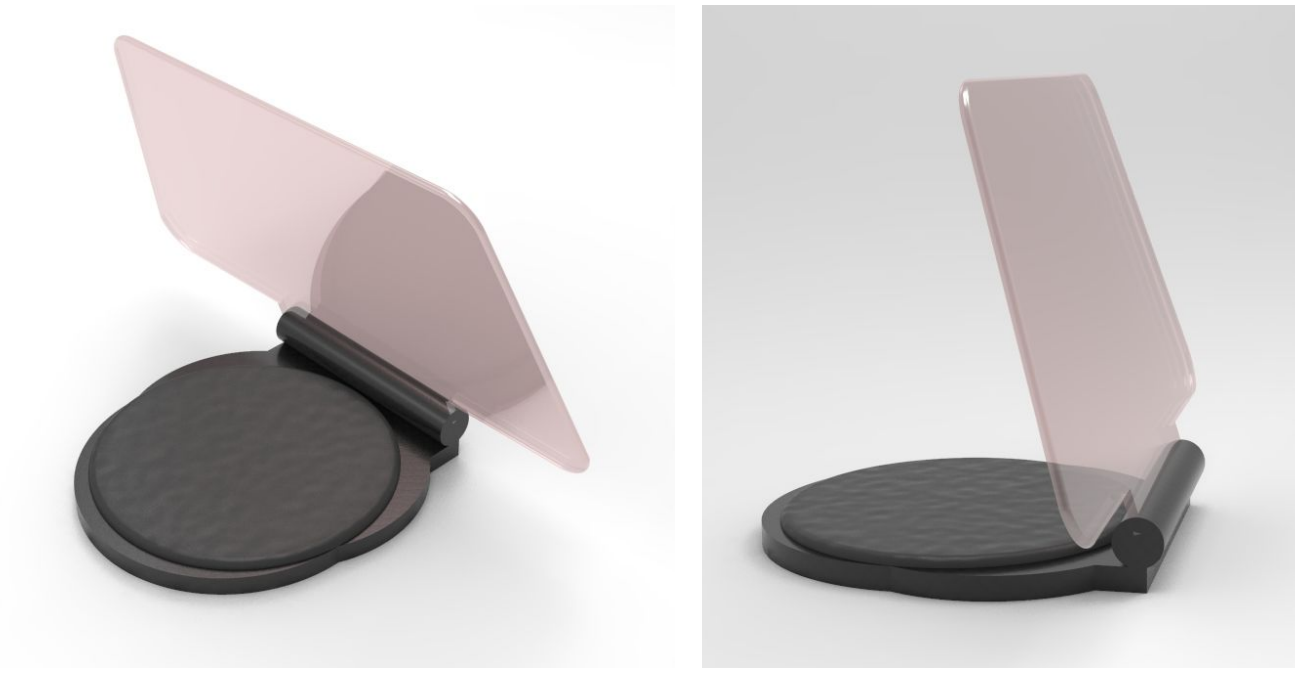
Concept #1 / MESH



The proposed concept aimed to achieve the following results. Meshed surface (probably with the help of built-in fan) protect the smartphone and the induction coil from overheating. The surface of the cradle is made of rubber (or plastic) with a built-in magnet to secure the phone on the cradle. A flexible mount base allows placing the unit on dashboards of various forms. The adjustable mount provides the possibility to tilt the whole unit. This as well as combiner joint-hinges helps to adjust the viewing angle. The combiner is a lens made of optical plastic PMMA, its curvature is about 2 degrees. This enlarges the reflected image. The color of the cradle and mount should be black or as dark as possible, since any other color may be distractive as well as its reflection.

Figure 24: Concept #1 named Mesh 3D rendering

Concept #2 / LIGHT



The idea of the following concept was to make the unit as simple as possible, but keep the most essential functions of it. The surface of the cradle, where the phone will be places is very soft and small. The soft surface protect the phone from the scratches and tears, the built-in magnet keeps the phone in place, and the small size does not result the overheating. This model has a wireless charger as well as previous one, but doesn't include a fun to cool down the phone and induction coil. The small round magnet mount is non-adjustable and non-flexible. It has multi-use jelly glue adhesive that needs to be adjust to almost even, flat surface. The combiner is flat and a little bit smaller than the average. It has additional dark lens for daytime. The combiner holder has stoppers to fix each position of the lens.

Figure 25: Concept #2 named Light 3D rendering with night and day lenses.

Concept #3 / STAFF

The next concept distinguishes oneself with straight lines and regular shapes. Flat, hard magnet cradle, with built-in wireless charger. It is big enough to place there induction coil and the magnets, as well as easily position the phone. The unit has a non-adjustable, but flexible rectangular dashboard mount. Trapezium-shaped slightly curved combiner. As it is reversed curved, the reflected image will be scaled down a bit. The combiner hinge has a smooth and continuous displacement and has no need for lubrication. The dash mount has a locking plug to connect to the cradle. The adhesive is used to attach the mount to the dashboard. As always the unit is black.

Figure 26: Concept #3 named STAFF 3D rendering.

4.4 Design evaluation - decision making matrix.

The following matrix helps to select the best option by prioritizing relevant factors affecting the decision and problem-solving. The rating score has been established to access the value of each alternative/factor. Next, the original ratings have been multiplied by the weighted rankings to get a final score.

Evaluation Criteria	Factor importance (1 to 10)	Concept #1	Concept #2	Concept #3
		score	score	score
Prime Cost	10	4	2	7
Appearance	5	5	7	6
User-friendliness	9	5	6	7
Does overheating issue is addressed?	3	6	0	0
Durability	8	6	6	7
Battery drain	6	9	9	9
Phone is secured on the cradle?	8	7	8	9
Reflected image is better? Double refl/	7	5	7	8
Production simplicity	8	4	8	7
Originality	8	6	8	7
Total		401	361	461

Table 10: Design evaluation - decision making matrix

As seen from the results, the best score was gained by Concept #3. It became obvious that including the cooling fun (Concept #1) into the device could significantly increase the price and make it an unprofitable project. Therefore it was decided to abandon the embedded cooler. Moreover, in terms of cost and profitability, the idea of exchangeable lenses (Concept #2) also inferior to other concepts and can only exist as marketing models with add-on lenses that have to be purchased separately, as the prime cost of the reflected lens is very high. However the idea of small soft cradle (Concept #2) very original and is seen as user- friendly, hence it could be implemented into another concept, but in any case to check it further it has to be prototyped. Using the smart glass currently seen as the most promising idea (Concept #3, Concept #4). Addressing the poor reflection issue was one of the key factors for design development as well as battery issue. Worth noting that despite that, such criterions as

user-friendliness, prime price, production simplicity and the secure placement of the phone affect strongly design development.

4.5 Materials and electronic components.

SMART GLASS

A range of "SmartGlass" technologies has been developed and patented over the last 15 years. "Smartglass" technologies include electrochromic, photochromic, thermochromic, suspended-particle, micro-blind and polymer-dispersed liquid-crystal devices. Preferably to use electrochromic or photochromic, as on the one hand the HUD is always being exposed to the direct sunlight on the dashboard, on the other hand, a built-in wireless charger allows providing the voltage to the glass to change its transparency. There is a number of options for using this technology: a thin film laminate, introduction of photochromic pigments in the mass of the polymer. Imbibing, or the superficial introduction of photochromic pigments, photochromic coating. [30]

WIRELESS CHARGER

Figure 27: Pictures of wireless charger and inductive coil (source www.amazon.co.uk)

Inductive charging is a type of wireless charging that uses an electromagnetic field to transfer energy between two objects through electromagnetic induction. Energy is sent through an inductive coupling to an electrical device, which can then use that energy to charge batteries or run the device. It is the technology that enables smartphone wireless charging, such as the Qi wireless charging standard.[31] Basically, the base has a transmitter coil and the smartphone should have a receiver coil. Usually, fast charging provides the possibility for transmitters to deliver up to 15 Watt power. Before making the prototype several smartphone wireless chargers have been tested to find out the weaknesses and constraints that should have been taken into account in the detailed concept development stage. The first issue that had to be addressed is that the phone has to be placed in the center of the pad, or else it will not work. Even if it off by a little bit, the smartphone will start charging but it will not get the full

charge and the battery will still be drained while sitting on the charger. The second issue is the charging distance, almost all chargers have a distance of about 30 millimeters (in fact the reliable charging were only possible at the gap between 8-11 millimeters).

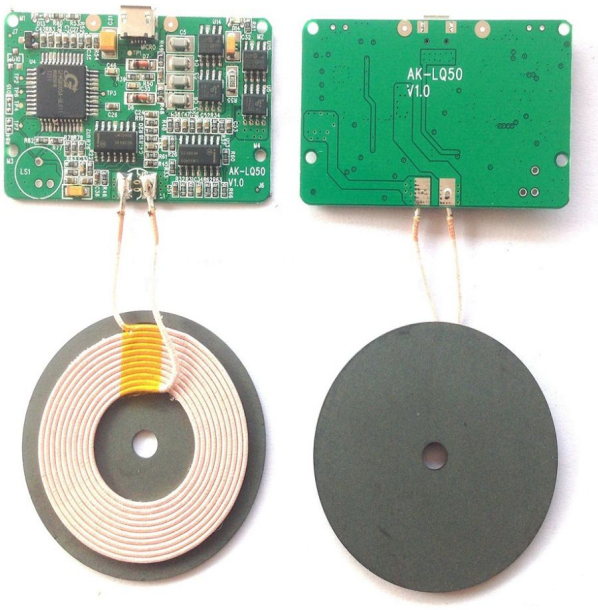


Figure 28: Pictures of transmitter induction coil (source https://www.alibaba.com) [32]

ADHESIVE

In the dashboard mount adhesive gel pad is used. Gel Pads come in a variety of sizes and shapes to manage different jobs and are available in either black or clear. Stikk is made from injection moulded Poly AB glue Plastic to create a material which is strong, flexible, sticky and reusable, without being too hard, gluey or too soft. [33] Although it has very good properties, there are some disadvantages that could be solved by changing the stickiness and the composition. This adhesive doesn't work with the dashboards where wax applied (like BMW) and with some other dashboards from unusual plastic. In some cases, it leaves the traces.

Figure 28: Pictures of jelly glue adhesive pads

4.6 Mocking-up, elaboration and detailed 3D modeling.

The mock-up has been created from the purchased wireless charger, combined with the plastic lens and the dashboard mount. It provides part of functionality of the system and enables testing the idea. Acquired feedback from the test using and test driving helped in further concept elaboration.

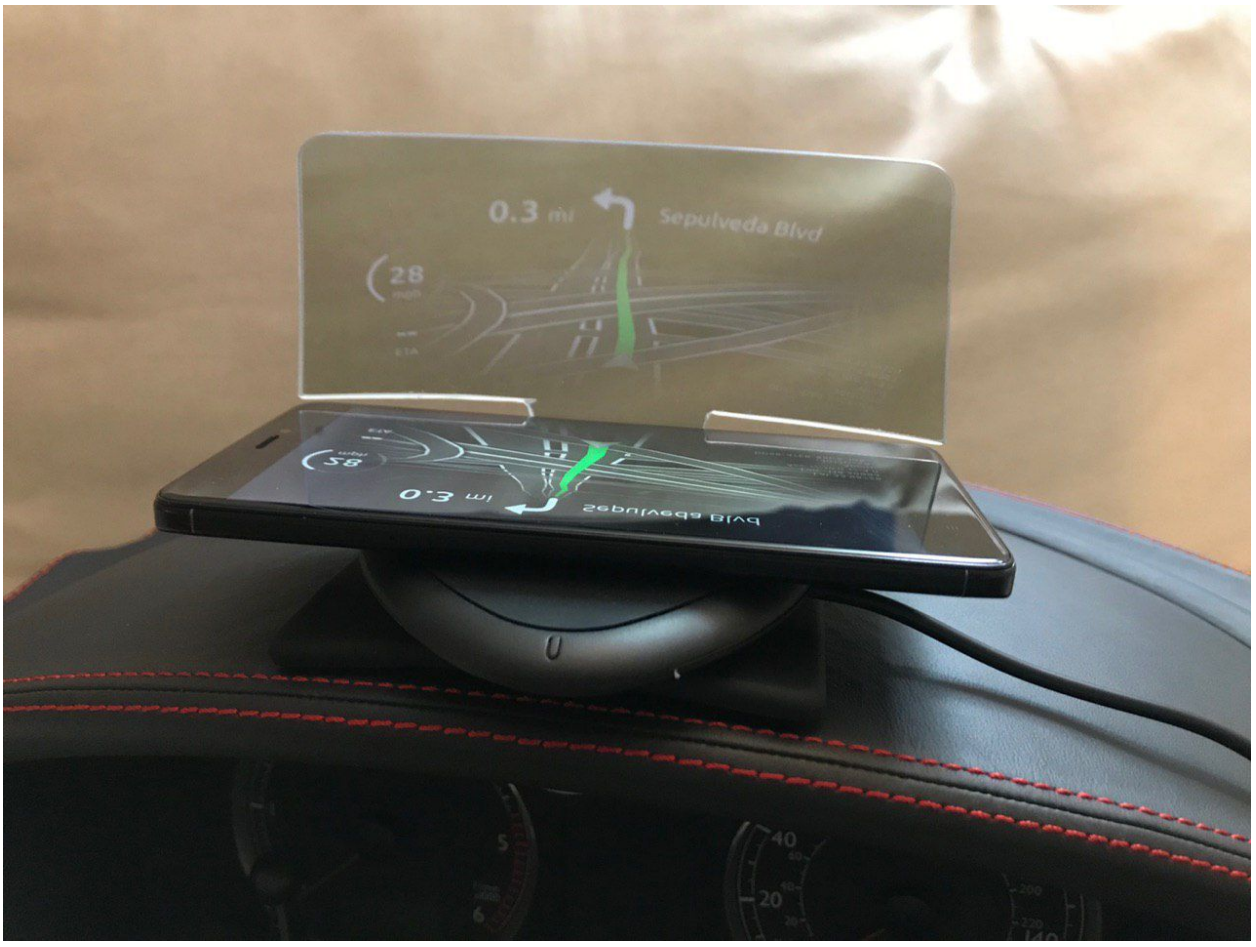


Figure 28: Pic mock-up testing

Once the concept has been defined and the feedback gained from testing the mock-up analyzed, it's time for detailed design development. Mock-up helped to define the overall dimensions, charge input location, the height of the dashboard mount, etc. Complex 3D CAD model allows to specified design characteristics of the chosen concept and makes it suitable for prototyping. During the process of modeling, the idea arose to split the base into two separate parts and make the upper part movable so that it will allow placing the phone not only horizontally, but also put it upright. This allows comfortably set the route, enable the HUD mode in the App and tilt it back to the working position. Furthermore, during the research, it has been found that some users of wireless chargers complain that they are not

able to use the phone when charging. They found it's not gut to constantly interrupt the charging process. This is the way to address their needs.

Figure 29: Pic of detailed 3D CAD prototype

A description of all the structural elements can be found in Attachments (Appendix 1). The model consists of 5 main constructive elements. The dashboard mount - it's flexible mount with the adhesive gel pad glued to the frame from the thin metal which allows to keep the desired shape and follow the curve lines of the dashboard. The covering made from a soft rubber material that is pleasant to the touch. The bottom part of the device body - it plays the role of the central element connecting all the others together. It connects to the dashboard mount, to the combiner holder and the upper cradle. It is the hard-set element with magnets inside to fix the upper part of the cradle firmly. The combiner (lens) holder is a standard hinge with 2 metal pins. The combiner is fixed inside the groove of the holder. The upper part of the cradle is connected to the bottom part on the side opposite the cradle with the similar types of hinges. Its upper surface is flat with the glued thin mat to protect the phone from the tears and scratches and add an additional friction with it. The upper part of the cradle, as well as bottom part and combiner holder, is going to be produced by most typically used in mass-production manufacturing process - injection molding. The upper part of the cradle has a built-in transmitter coil with transmit controller IC, 6 round magnets to hold the phone. The USB micro B input is centered on the right side of the cradle.

Figure 30: Pic of detailed 3D CAD prototype

4.8 Prototyping

Figure 31: Pic Prototype

The prototype allows to check the ideas and gather feedback in the development stage. Prototyping is a valuable tool that helps to make important decisions, explore new features and refine existing solutions. The created prototype has been checked in close to real conditions (in cars, but not in motion), here below are some findings and conclusions:

1. It's not always possible to adjust the comfortable viewing angle, as the only way to do it is to tilt the combiner, as the mount is firmly stuck to the dashboard. It's subjective and requires more sampling with more people and cars.
2. Overall appearance is not very appealing and uncluttered
3. The position of the USB input is not convenient when the upper part is disposed upwards.
4. Charging begins only in a certain position, maybe this limitation can be solved somehow with the help of the design of the upper cradle so that it will be impossible to place the phone incorrectly.
5. When possible the upper part could be smaller.
6. It's not always easy to operate with the phone attached to the cradle. The solution with a movable upper part is questionable. Is it faster just to take the phone from the cradle and place it back? what will the user prefer?

CHAPTER 5 Software

5.1 HUD mode application.

The glass mirrors the screen image it catches. This means, that the screen image need to be reversed to get the right reflection. This feature is called HUD mode. Currently a lot of customers are asking for HUD mode in existing apps. For example, for now HUD Mode is in the top 10 Waze suggested features https://wiki.waze.com/wiki/Wishlist.

The following pictures illustrate what is HUD mode, the name of the Navigation app is Sygic.

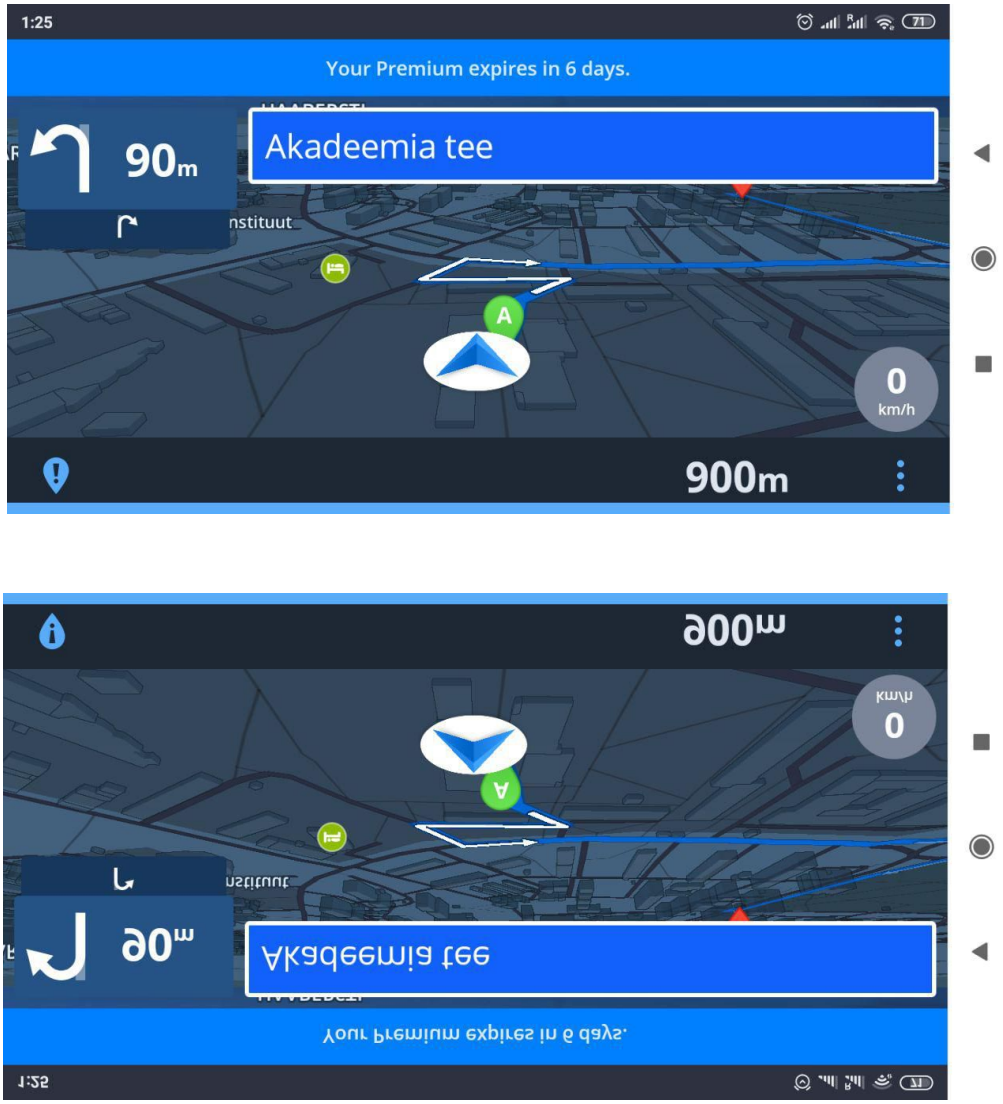


Figure 32: Illustrating of HUD mode feature in application

In fact, HUD mode it's not just inverted image. The common perception that the navigation it's just a map with the street names and highlighted route on it actually not the best solution for HUD devices. To have a right to be a part of an augmented reality, the HUD navigation should fill up the reality, but not substitute it. To be driven by the future technologies that are just around the corner like Way Ray, the way of displaying the info should be reconsidered and changed. that to use the navigation map in HUD mode the background should be completely black (transparent) and moreover the map itself should be simplified, in any other cases, the complexity of the picture will blocks the view and dangerously distracts driver from the road.

	Name	Description	Price	Lifetime Premium
1	**HUDWAY Go**	*Intuitive 3D map, simple navigation, trip info: ETA, speed, distance traveled, choose alternative routes*	free	9,99 €
2	**Navmii GPS World**	*Offline navigation, maps and traffic*	free	6,99 €
3	**Sygic**	*GPS navigation, maps, traffic, speed cameras*	free trial 7 days	16,99 €
4	**NAVIER HUD Navigation**	*GPS navigation, speedometer*	free	4,99 $
5	**aSmart HUD**	*Speed cameras and speedometer*	free	-
6	**Car HUD**	*Auto answering incoming phone call with speaker, speed cameras, speedometer*	free	-
7	**HUD Widgets**	*Trip info, clock, and other handy tools for driving*	-	-
8	**Speedometer**	*Speed cameras and speed limit warnings*	-	-
9	**GPS HUD Speedometer**	*Total distance, trip meter, max and current speed*	-	-
10	**SPEEDOMETER By Nordic Nations**	*Compass, record trip data, speed limits*	-	-
11	**Speed Tracker**	*Speed tracker, GPS speedometer, trip computer support*	-	-
12	**DigiHUD Speedometer**	*Speedometer, odometr, trip distance counter, compass*	-	-
13	**Car HUD**	*GPS speedometer*	-	-

Table 11: Available HUD mode apps on the market

5.2 Concept design for the application to us with Head-up display.

Does the application for the Head-Up display differ from the usual application? Does the smartphone interface suitable to use it with the Head-Up display? The answer is - not it does not. Apart from purely physical reasons, like the color scheme of the interface, when green color works best, white is considerably worse, small elements get completely washed out, or that the background should be black to ensure the transparency of the display, there are a number of objective reasons that do not allow the use of usual applications.

The interface of the smartphone and different applications is usually swamped with various information and notifications. It makes it attractive in normal life compared to the environment but at the same time, it critically increases the amount of information coming to a person and leads to metal overload. In combination with such phenomenon of the human psyche like cognitive tunneling or cognitive capturing all these can lead to adverse effects. First of all the app should increase contextual awareness. Roughly speaking it's when it seems as if the device "knows" where the user is and what he or she needs.[33] However, t's not a standard GPS navigation app, and not an alternative for maps app. It's showing not the map, but the route to follow with upcoming curves, no more overloaded maps. Moreover that app manage the basic functions of the phone and shows when needed special notifications. All info is displayed in a very simplified way, so that the user spend less than a second to identify what it is.

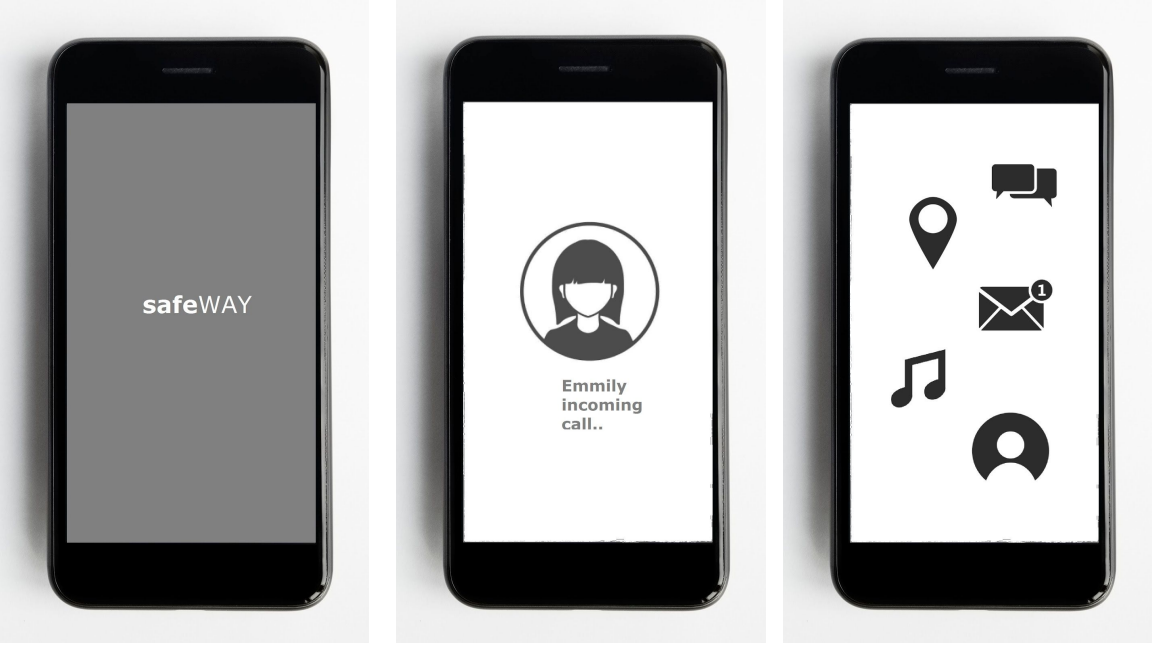


Figure 33: A conceptual model for mobile app

5.3 Use case

The driver places the Head-Up display in front of his line of sight. He adjusts the lens according to his own hight and the dashboard of the car. He places the phone on the cradle of Head-Up display having previously run the application. The cradle has built-in magnets so the phone sits there firmly. The combiner reflects the smartphone screen, so that projects the information directly into the driver's visual field. Driver can simultaneous keep his eyes on the road. From now on there is no need to touch the phone. The safeWAY application provides all necessary information about Navigation, notifications, call or music tracks in the appropriate form for the driver. Navigation inside the app or interaction with the phone could be done with the help of Bluetooth steering wheel button. This is a cost-effective solution integratable to any car model and suitable for any smartphone. The estimated market price is 20$ for button + 45$ for Head-Up device.

5.4 Future anticipation and perspectives

In conclusion, it should be noted that the technology of projecting information on the windshield of a car is only at the beginning of its development. In the future, the Head-Up Displays turned into one of the components of the augmented reality system. Overall passive HUD display with projection on the combiner is a temporary solution until the new technology allows to provide a cheaper and sophisticated one to assist the driver. Like no lens solution AR technology WayRay. If look further into the future, in a broad sense the futurity is in self-driving cars.

Figure 34: Future self-driving cars

Figure 35: AR HUD technology - WayRay (Porshe)

CONCLUSION

The main objective of this master thesis is to help to create a driving culture - crash-free driving culture by reducing diver's distraction behind the wheel via offering a driver assistance system that turns the smartphone that each driver has into Head-Up display that assists, instead of to distracting. Head-Up display used with respective Application and hands-free device can provide an efficient improvement of presented information, reduce distraction and help with driver mental overload. The key benefits of the developed device are providing good reflected image quality adaptable for different lighting conditions (this address the problem of poor visibility and thus information perception troubles increasing eyes-on-the-road time), simultaneous wireless smartphone charging (draining battery issue, otherwise loose wires near the steering wheel and the driver pose a danger), multifunctionality of the device and well-becoming Application improves usability and user experience (this increases the chances of prolonged using the product, what means that the destructive driver behavior pattern will be eliminated), as well as all other changes contribute toward creating positive user experience.

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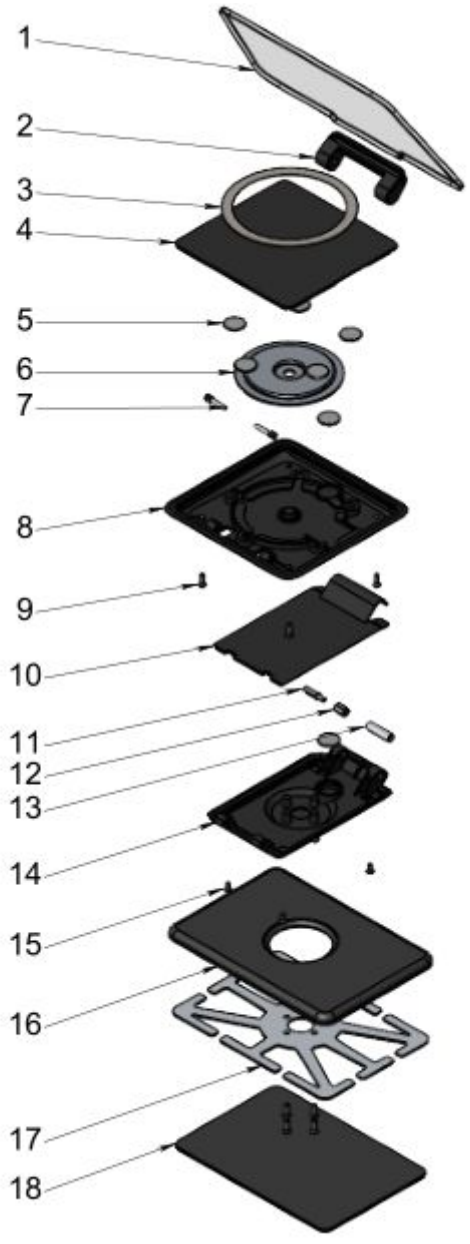
APPENDIX 1 / Drawing



Item No.	NAME	DESCRIPTION	QTY
1	Combiner	"Smartglass"	1
2	Combiner holder	ABS+PC (Polycarbonate/Acrylonitrile Butadiene Styrene) RAL 9017	1
3	Phone holder	Steel plate	1
4	Cradle upper part	ABS+PC (Polycarbonate/Acrylonitrile Butadiene Styrene) RAL 9017	1
5	Magnet	-	7
6	Induction Coil	-	1
7	Torque front	Aluminium	2
8	Cradle bottom part	ABS+PC (Polycarbonate/Acrylonitrile Butadiene Styrene) RAL 9017	1
9	Screw	ISO 7046-1-M2x6-Z -6N	8
10	Base upper part	ABS+PC (Polycarbonate/Acrylonitrile Butadiene Styrene) RAL 9017	1
11	Torque left 2	Aluminium	1
12	Torque left 1	Aluminium	1
13	Torque right	Aluminium	1
14	Base bottom part	ABS+PC (Polycarbonate/Acrylonitrile Butadiene Styrene) RAL 9017	1
15	Screw	ISO 7046-1-M2x4-Z -4N	4
16	Soft mount	SBR (styrene-butadiene rubber)	1
17	Mount frame	Aluminium	1
18	Adhesive	Gel pad	1

APPENDIX 2 / 3D MODELS

APPENDIX 3 / Questionnaire

Survey

1.What is your vehicle model & year?

2.What is your smartphone model and system version?

3.What is your preferred navigation app?

- Waze
- Google Maps
- Sygic
- HUDWAY Go
- Other (you may add it in the comment section).

4. What are the most important HUD use cases for you?

- Viewing maps & directions
- Viewing notifications
- Viewing OBD-II data
- Get help parking
- Control blind spots when turning/overtaking
- I just like to read SoundHound lyrics and sing out loud.
- Other.

5.Any other comments

6.Your name (optional)

7.Your email (optional)

8.Your country (optional)

9.How did you find about us? (optional)