technische universiteit eindhoven

0LAUK0: Autonomous Bus Scheduling System (ABSS)

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1 Executive summary

1.1 background

Public transportation has been around for a couple of decades now. It started with the stagecoach in the nineteenth century. Later on came the steam trains which were capable of carry large capacity of people at the same time. The trains were too big to travel in city themselves, so the tram was invented. However not every city are capable of creating a tram rail network. So with the increasing demands of mobility in the sixties, buses started to be used for public transportation in cities around the Netherlands and the rest of Europe. Bus stops were created around cities and a static scheduling system was implemented. This static scheduling system uses a fixed time table around the city. The buses follow fixed routes each time and do not take into account if there are any people waiting at a bus stop or not. Meaning that the buses do not take a shorter route when nobody is willing to stop of is waiting a certain bus stop. This means it is time for a dynamic system. Therefore the main focus of this report is the Autonomous Bus Scheduling System (ABSS). The new scheduling system for buses aims to create a more efficient passenger flow. It will be able to send extra buses to bus stops that are or are getting too crowded and also the system will choose a shorter route to it is destination when no passengers are waiting at the coming bus stops. Users can check in at the bus stop or with their mobile phone apps. The scheduling system will then optimize the routes by taking this information into account. A small part of the report will discusses the possibility of using autonomous buses in the new dynamic scheduling system, analyzing the impact of user, society and enterprise. Different approaches can be used to optimize this schedule. Those will be analyzed and take feedback data from a survey. This data will be inputted in a simulation in order to analyze the consequence of the different needs of the users. The simulation will also be used to validate the new dynamic scheduling system. The validation will have different requirements like waiting time and crowdedness but also with happiness. This is a design report for dynamic scheduling bus system, incorporating the needs of the User, Society and Enterprise.

1.2 Objectives

Objective	Short description
1.2.1	A potential maximum waiting time of 20 % longer than it currently is.
1.2.2	An average decrease in travel time of 10 % (not including during rush hours)
1.2.3	An increase in happiness of the travelers
1.2.4	Communication to (inactive) buses when every seat is taken

1.2.1

When a bus skips a few bus stops, it will arrive sooner than expected at the next stops, which means that people might have to wait longer than usual for next bus if that one does not skip any. This will lead to potential longer waiting times. However, this also means that there are also potential shorter waiting times between buses, if the first bus does not skip any stops, but the second one does.

1.2.2

When there are stops that can be skipped, more efficient bus routes can be used to reduce the travel time. This will not be possible during rush hours, because the bus stops will be too crowded, which means that there will barely be any stops the bus can skip. Figure 1.1 shows a fragment of the bus route between Eindhoven and Veldhoven.

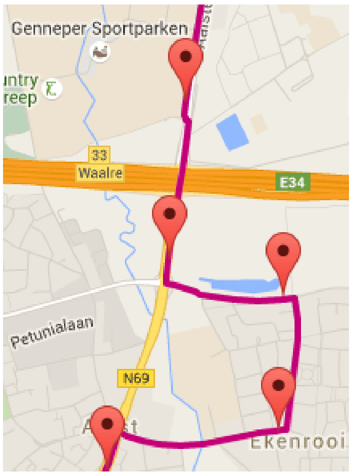

Figure 1.1: *Fragment of a bus route between Eindhoven and Veldhoven.*

In the figure is seen that the bus has to take a pretty large detour just for 2 stops. if there is no one who want the enter/leave the bus at one of these two stops, the bus can take the N69 instead and save a lot of time.

1.2.3

Happiness will be "quantified" in the simulation, and the decrease in travel time should be weighing more heavily than the potential increase in waiting time, and perhaps the troubles caused by the use of the app to sign up for bus rides. Other factors may be included later on.

1.2.4

When a bus is full, an extra bus will come on the same route to pick up travelers that had to miss a bus because it was full. This will also decrease the waiting time.

1.3 Requirements

Requirement	Short Description
1.3.1	Automatically optimize the bus routes by skipping several stops according to check-in info from bus stops and web interface.
1.3.2	Arrange more buses to certain routes to make sure every passenger has a seat when passenger flow increases (determined by check-in info).
1.3.3	Keep the schedule static during heavy load hours. This schedule is predetermined by adapting from the traditional scheduling system.
1.3.4	The scheduling system must be able to switch to manual control mode.
1.3.5	The scheduling system must be able to collect feedback data from user through various methods(web interface, phone apps, etc...).
1.3.6	The system must be able to track locations of each bus and this info will be provided to user through various ways (sms notifications, web interface mail, phone apps, etc).
1.3.7	ABSS only validates request after the ride has been paid for.
1.3.8	Buses should be equipped with GPS.

1.3.1

When there is no one checked in in the coming bus stops, the scheduling system should try to search for a shortcut to skip them by taking current traffic loads into account. The system should only search within the available routes (without disturbing the neighborhoods) and send the new route to the bus.

1.3.2

The scheduling system will arrange more buses to certain routes to control the crowdedness. By crowdedness we mean outside the heavy load hours every passenger should have a seat.

1.3.3

The scheduling system should not optimize the routes dynamically during heavy load hour. When doing so the system won't be conflict with other transport systems.

1.3.4

The scheduling system provides the interface to manually control the routes and schedule for special situations (fire, natural disasters, etc)

1.3.5

The scheduling system provides the interface for collecting user feedback like "too late" "too earlier and missed it" "5 min later than expected". This data can be used to further optimize the system's optimization algorithm.

1.3.6

The system will send notifications to user who has pre checked-in for route changing, reminds and other info. User will be able to choose the way of how this notification sent to them. User who have not pre checked-in can found these data on web interface/phone apps.

1.3.7

As stated, a requirement to prevent people from purposely requesting buses if not necessary, is introduced. Paying for bus ride is enabled by the current way of purchasing items online, namely, after the wanted route of a person is entered into the application, a screen pops up which allows the person to choose a paying option e.g. iDeal, PayPal, Credit card, etc.. These paying options are secured and in several cases allow people to purchase anonymously, for example by purchasing via PayPal. By using this way of paying for requesting buses before buses actually respond to the request, we expect the amount of people to misuse the ABSS will be lower than if the paying option did not exist. Misusing the ABSS could cause the bus to ride to bus stops where no one is waiting, what conflicts with our goal to skip bus stops with no waiting passengers.

1.3.8

When the ABSS is introduced the arriving time at bus stops is not fixed anymore. Therefore, people should be able to track the bus to prevent arrivals at the bus stop after the bus has already departed. First, after the request of a person is accepted the expected arrival time to a certain bus stop is shown to that person. Secondly, a GPS equipment in the bus allows the control center to notices changes in expected arrival times. If the control center detects changes it sends an arrival update notification to the concerning people. At last, a tracking system could let people who requested a bus instantly show where a bus is at the moment.

1.4 Proposed plan of action

As can be seen, the background,objectives and the requirements regarding the autonomous bus scheduling system are already clarified. Now, there will be explained how to investigate whether such a system could replace the current scheduling system.
There are three cases that should be distinguished:

1) Will the ABSS increase the overall happiness?

2) What does the ABSS change regarding the USE-aspects?

3) Is it already feasible to use autonomous buses in the new ABSS system?

In order to investigate whether or not the ABSS will decrease the average waiting and traveling time, there is made a simulation with as well as possible real life features. With real life features a Poisson Process for passenger arriving time for example is meant. We use DiscreteEventSimulator to make this simulation.

For the second case there is conducted a survey and upload it to the internet (See Appendix A. In the survey is asked what people do and do not like about the current system, what they find important and what they want for changes they would like to see in the future. Besides the survey we will study research that already has been done in scientific journals or informative magazines, analyze those findings and apply them in our own investigation.

The third case is analyzed in section 6, which analyzes the feasibility according to: the expectancy of the public, current laws, ethics, economic impact and the threat of other autonomous vehicles.

2 Past and current attempts

2.1 Past attempts

We have collected a number of papers about the scheduling of a bus system, in this chapter we will attempt to describe every paper to show how their approaches have evolved and what results they have found.

The papers are the following:

- 1967: *Lampkin, W. and Saalmans, P. D. (1967). The Design of Routes, Service Frequencies and Schedules for a Municipal Bus Undertaking: A Case Study, Operation Research Quarterly 18, pp 375 - 397.*
- 1972: *Rea, J. C. (1972).Designing Urban Transit Systems: An Approach to the Route Technology Selection Problem, Highway Research Record 417, Highway Research Board, Washington, D. C., pp 48 - 58.*
- 1974: *Silman, L. A., Barzily,Z. and Passy, U. (1974).Planning the Route System for Urban Buses, Computers and Operations Research, Vol. 1, pp 201 - 211.*
- 1977: *Hsu, J. and Surti, V. H. (1977). Decomposition Approach to Bus Network Design, ASCE Journal of Transportation Engineering, Vol. 103, pp 447-459.*
- 1977: *Scheele, S. (1977). A Mathematical Programming Algorithm for Optimal Bus Frequencies, Ph.D. thesis, Department of Mathematics, Linkoping University, Linkoping, Sweden*
- 1979: *Dubois, D., Bell, G. and Llibre, M. (1979). A Set of Methods in Transportation Network Synthesis and Analysis, Journal of Operations Research Society, Vol. 30, No.9, pp 797-808.*
- 1979: *Mandl, C. E. (1979). Evaluation and Optimization of Urban Public Transportation Networks, Presented at the Third European Congress on Operations Research, Amsterdam, Netherlands.*
- 1980: *Dhingra, S. L. (1980). Simulation of Routing and Scheduling of City Bus Transit Network, Ph.D. thesis, Department of Civil Engineering, lIT Kanpur, INDIA.*
- 1981: *Furth, P. G. and Wilson, N. M. H.(1981). Setting Frequencies on B-us Routes: Theory and Practice, Transportation Research Record 818, Transportation Research Board, Washington, D. C., pp 1 - 7.*
- 1982: *Han, A. F and Wilson, N. M. H (1982). The Allocation of Buses in Heavily Utilized Networks With Overlapping Routes, Transportation Research B, Vol. 16, No.3, pp 221 -232.*
- 1990: *Baaj, M. H. (1990). The Transit Network Design Problem: An AI-Based Approach, Ph.D. thesis, Department of Civil Engineering, University of Texas, Austin, Texas.*
- 1994: *Shih, M. and Mahmassani, H. S. (1994). A Design Methodology for Bus Transit Networks with Coordinated Operations, Research Report 60016-1,Center for Transportation Research, University of Texas at Austin, Austin, Texas.*
- 1994: *Dashora, M. (1994). Development of an Expert System for Routing and Scheduling of Urban Bus Services, Ph.D. thesis, Department of Civil Engineering, lIT Bombay, INDIA*

In 1967 the scheduling problem is approached by Lampkin and Saalmans as a constrained optimization problem for frequency determination, their objective was to minimize the total travel time for a system. Later in 1972 Rea has created a model that searches for an optimum bus network by adjusting the frequencies and type of buses on each link iteratively, such that on some links the service is enhanced while on others it is depleted. The model has reached its optimum when the model has been stabilized, which occurs when no further chance in link levels has been detected. Then in 1974 Silman, Barzily and Passy have proposed a system that can determine optimum frequencies for a set of bus routes and fleet size by a gradient method procedure. Their system also attempted to minimize the total travel time and discomfort, where the latter is mainly characterized by traveling without a seat. In 1977 first Hsu and Surti have introduced the concept of marginal ridership (ridership provided by an additional unit of service frequency) to determine the frequencies for a given fleet size, then later in 1977 Scheele has approached the problem by attempting to provide a solution in the form of a mathematical programming algorithm. In 1979 Dubois, Bell and Llibre have tried to find a way to reschedule a transportation network based on existing demand and later in 1979 Mandl wanted to optimize existing bus schedules using heuristics and realized that none of the bus companies really had algorithms for their schedules, they only worked with trial and error. More interesting advances started to be made from 1980 onwards, in 1980 Dhingra developed a detailed simulation model for studying the effect of different frequencies on various routes and networks, then in 1981 Furth and Wilson also started to look at economic efficiency, taking the downtime of the buses and the level of vehicle loading into account. In 1982 Han and Wilson extended the previous model by also modeling the passenger choice behavior and attempts to find a minimum passenger wait time. In 1990 Baaj published a research based on generating a route using an artificial intelligence hybrid approach. In 1994 Shih and Mahmassani have built on the model of Han and Wilson from 1982 by extending their model, now it has improved passenger choice logic and also uses the concept of optimal vehicle size and tries to link multiple routes together, such that the transition from one line to next line for a single bus is more efficient. Another research in 1994 suggests an expert-based system which allocates the buses to different routes based on criteria that would demand for an extra bus at a route. Every route would then get a specific factor for wanting a new bus and the system would give that bus to the route with the highest factor. The buses are allocated this way until the fleet is exhausted.

2.2 Current attempts

At the moment, buses follow a predetermined route on a fixed time schedule to enable the transport for over 40 travelers. Albert Y.S. Lam stated that this current system can be replaced by a new more dynamic transportation system [1]. The system they address can accommodate transportation requests, and offers point-to-point services with ride-sharing (carpooling). So they also address the scheduling as one of the problems that should be tackled. As a second important problem this article presents us with admission control, it faces the requests suitable for scheduling. "Scheduling involves determining the following: the assignment of AV's (autonomous vehicles) to the request, the routes of AV's to accomplish the assigned requests and the times by which the AV's should reach particular locations" [1] Assumed is that all AV's can communicate with a control center back and forth with almost no delay. The system that the control center uses creates the route, using requests of travelers, to achieve minimum total operation costs (fuel costs) by using a shortest path algorithm. They also take the arrival time into account. The original scheduling problem they have already addressed is composed out of different parameters: costs, travel times and the set of transportation requests. To solve the scheduling problem, they defined several variables. Then, they set up a mixed-integer linear programming problem to minimize the cost function and subject that function to several constraints, consisting of a combination of the variables they defined before. In the admission control part, they added a set of all available requests. Those are added to the computations, the outcome now indicates which request combination is the most profitable (because of minimization of the cost function) and feasible.

Another attempt is that of the Anbessa City Bus Service Enterprise (ACBSE) [2]. Here, the bus routes and the scheduling system are fixed. They used Linear Programming in the model and used this to determine the optimal amount of buses per route. In our project, we also want to know what the optimal amount of buses is. They also take into account the demand distribution (see table 2.1). This shows that, for example, 40% of the total bus users, uses the bus in the morning period. The model they made gives better performances on the bus utilization, operating costs and distance.

Table 2.1: *bus demand per period of the day [2]*

Shift	Time Interval	Duration (min.)	Demand Proportion
Morning peak	6:15-9:30	195	40%
First off-peak	9:30-15:30	360	20%
Evening peak	15:30-19:30	240	35%
Second Evening peak	19:30-21:00	90	5%

2.3 Conclusion

The literature study shows that a new, more efficient and dynamic form of public transportation can be realized. Eventually it provides us with ways to compute the optimal route while taking the assignment of requests, the set of routes the bus could take and the arriving times to a particular location into account. Also in some literature they determined the optimal amount of buses per route and take the demand distribution into account. Further on in this report we want try to prove that by using such a dynamic scheduling system for buses, the general happiness will improve.

3 Impact of ABSS

In this chapter, the impact of ABSS on the USE aspects will be explained. This is very important when creating a new system that involves all three parties, (*Users, Society and Enterprise*). The impact has to be positive on all three parties in order to make a system work. First of all, the impact on the users will be analyzed. Then, the society will be looked into and finally the opportunities for enterprises will be explained.

3.1 User

As said before, with the new scheduling system, people are able to let the bus driver know at what bus stop and at what time they want to enter the bus, by using an app on their smartphone. Not only, people are able to check in with the mobile app, the app also shows at what bus stops other people are waiting so they can see the expected arriving time at a certain bus stop. Users of this system can experience more flexibility, because they might suddenly want to take the bus, and notice that some stranger has already checked into a bus, and the bus is already on its way to the bus stop. When this is not the case and the waiting time will take longer than a certain time, for example 20 minutes, the autonomous scheduling system automatically sends another bus to the bus stop to reduce waiting time. Not only will the waiting time be shorter, the average time of the bus rides also decreases. Out of experience, we know that mostly in weekdays between the morning and evening rush and on Sundays there are a lot of bus stops unoccupied, meaning that traveling to each single bus stop then, would be a waste of time. For that reason, the scheduling system can adapt the route, making the ride time to the final destination shorter. This might increase the user's satisfaction instead of being irritated by the fact that the bus is wasting time driving to places it should not have to go. There are however also some problems with the ABSS system, when regarding users. Namely the following three:

- Though, not everyone in the Netherlands or Eindhoven owns a smartphone, what about those [3]?
- What about older people from let's say: '55+', from the people who we do not expect to own a smartphone?
- How do these non smartphone owners know when they should arrive at the bus stop, and what bus stop, when the autonomous scheduling system is introduced?

They are clueless now regarding the times, and places where the bus stops, because due to the scheduling system both arriving time and place are stochastic now. Out of experience we can conclude that a lot of bus passengers are older people, who often travel by bus for groceries and for visiting relatives and friends.

Several studies have been done categorizing the smartphone distribution per age category. These studies contradict with the prejudice we may have with older people not owning a smartphone. For example a study by Deloitte [4], stated that in June 2013 already 37% of the people older than 55 owns a smartphone (see figure 3.1). Though, 29% of them have never downloaded any mobile application. However, this can simply be explained by a relative or by a mobile shop assistant who does understand downloading apps.

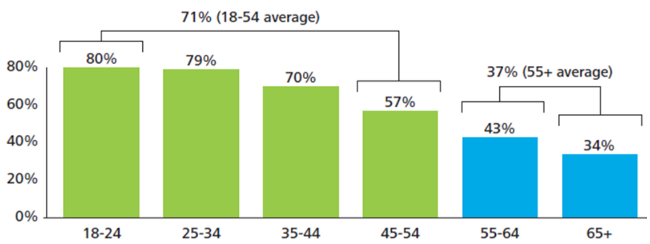

Figure 3.1: *Percentage of people owning a smartphone in The Netherlands [4]*

Also, they predicted that the ownership of smartphone of these 55+ categories will increase to 45-55 percent in 2014.

Out of this information we can conclude that older people are adjusting to the new mobile phone [5], making more and more of them able to use the mobile app which is integrated in the autonomous scheduling system. In order to overcome the problem for those who do not have a smartphone, 'bus call poles' will be introduced. These poles have a display showing where the different buses are in the area and have a 'call' button. Those 'bus call poles' will serve the same purpose as the smart phone application. The 'bus call poles' can also be incorporated inside the bus stop itself. An example of such a bus stop design is illustrated in figure 3.2.

Figure 3.2: *Design example of the future bus stop*

In this design, the elderly rest on a bench, track the buses and call a bus without the need of a smartphone.

3.2 Society

The new automated bus scheduling system should reduce overall traveling time by 10%, and increase overall happiness of the users of the buses. A consequence of this could be that people will start using the bus more often, and refrain from taking the car for everything. This bring some advantages along. For example, less cars on the roads will lead to less carbon-dioxide emissions and an increase in safety in traffic.

Figure 3.3: *deathly traffic accidents around Eindhoven [6]*

Between 2006 and 2014, 6.163 people died in a traffic accident in the Netherlands [6]. figure 3.3 shows the deadly traffic accidents around Eindhoven in this same time frame. In pretty much every single traffic accident, a car was involved. Less cars on the streets would definitely mean less accidents, so an overall increase in safety in traffic. More safety in traffic could also be an incentive for people to take the bicycle more instead of a car for short distances.

Pollution of the environment by carbon-dioxide emissions is still a pretty big problem. Even though electric cars are improving rapidly, they still are heavily overshadowed by "regular cars". A slight decrease in cars on the roads might not be the biggest difference in the world, but every little thing counts. A decrease in cars in the city would also improve the air quality in the central part of Eindhoven, which would be better for the health of the citizens.

Another advantage of having less cars on the road would be that the buses have an easier time passing through, which would improve traveling time of the buses and in turn increase the comfort, etc.

3.3 Enterprise

In this chapter, the investment aspect of a scheduling system will be discussed. To be able to realize the improved scheduling system, an investment will be required. However, no one will be investing in a concept that is not realizable right away, or is not worth it financially. The new dynamic system only requires a way to sign up for bus rides through a mobile phone app and a system that transfers this information towards the busses, so they can choose to take shortcuts. The technology exists already, so the new scheduling system is definitely realizable.

But besides being realizable, the new system should be beneficial for the investing party as well. Why would they invest in it if there is nothing in it for them? It probably will not be possible to apply it to the current bus transport infrastructure, unless the investing party is the owner of the current system. The new scheduling system could create opportunities for competing with the current bus transport system, because it is more efficient. Not only would this be beneficial for the investors, it would also be good for the users. Competition generally drives down the prices for the customers.

For shareholders, the system has to be profitable. Being able to sell stocks during less financially stable times is essential for a company to grow. In order to expand the system from, for example, Eindhoven to the entirety of the Netherlands, additional funds are required. Lending money would be another option, but it does bring required repayments in the future. Selling stocks would, however, will dilute the ownership of the company [7].

3.4 Conclusion

The ABSS system is overall positive when regarding the users, because the waiting and traveling time might decrease with this system. However, as expected, there are some problems regarding users. The ABSS strongly rely on the users owning and knowing how to use a smartphone. This problem can be solved by designing new bus stops with 'bus call poles'. Those poles allow users without smartphones to track and call buses whenever they are at a bus stop. The decrease in travel time brings along better safety in the city, cleaner air and overall less crowded roads. The new system also brings along some business opportunities, which are worth investing in with room for expansion.

4 Survey

4.1 Survey analysis

To get an accurate representation of what the people in Eindhoven think we conducted a survey (Appendix A). The survey has two main goals. First of all it wants to determine the weight of, waiting time, travel time and the Crowdedness of the bus for the simulation. These weights will be used in the simulation to calculate a good overall happiness level for the passengers. Secondly it we want to find out what the social impact could be of a bus scheduling system. We want to know how open people are to the possible change coming. Do they think improvement is needed at all? Are they prepared to use an app? How do people think about bus routes going through their streets? All these questions will help us understand what the public expects from such a system and how open they are towards this change.

The survey that was used can be found in the wiki page called survey. The survey was handed out on the bus station of Eindhoven central station and via Facebook. Because not all questions are about traveling in a bus, and we also wanted participants that took the bus less, we used Facebook and handouts to distribute the surveys. In total there were 102 responses to the survey.

According to the "Centraal Bureau voor de Statistiek"(CBS) 6.7% of the total population of the Netherlands is using the public transport. [8] This means the total of people using public transport in the Netherlands is 1125600. To get a desired margin of error of 5% 387 responses were needed. Since there were only 102 responses to the survey, the margin of error will be 10% with a confidence interval of 95%. This margin of error is pretty high which does not boost well for the validity of this study. However with the lack of time we decided to continue instead of gathering data since the results from this survey will be used for the simulation.

Before we preform statistical tests on the data the outliers had to be removed first. All data entries looked normal except one entry. This entry had all extreme values that deviated from the mean by a large amount (1 versus M=6.1, 6.5, and 6.4). This entry also had non-serious remarks on the open questions. We decided to remove this entry. With this removed the sample consisted of 60 man and 41 women with an average age of 26 (M = 26.26, SD = 12.26).

When we looked closer at the data it became apparent that at question 6-8 there were a lot of answers around 5. When we looked at the survey on a mobile phone it became apprehend why this was the case. If one looked at the survey with a mobile phone the possible answers shown were 1-5 and one had to use the scroll bar to reveal the answers 6-10. This caused a lot of people to view it as a 1-5 scale instead of a 1-10 scale. To resolve this problem we decided to multiply every entry that had all values lower or equal to 5 at questions 6-8 by 2. This is of course not perfect since it is possible that a participant rated the questions this low while using the full scale. However the variables did show normality after this multiplication while this was not the case before this.

With the low margin of error and the changing of the variables for question 6-8 it is no longer possible to get valid conclusions from this survey. However as stated before we will continue with the data analysis while acknowledging that the results from this analysis will not be scientifically valid. We will assume that the changes made and the small sample size will not influence the validity of this analysis.

First let us look at the means for, waiting time (M = 7.84, SD = 1.36), travel time (M = 7.27, SD = 1.61), and Crowdedness (M = 7.55, SD = 1.65). From this we can conclude waiting time is most important for passengers to experience a pleasant journey as this has the highest average of all factors. The means will now be used in the simulation to see how effective our system is. It is interesting to see that all these values are not too far apart, but this is probably due to the multiplying of the low values.

To see whether there is a difference in responses from people traveling often with the bus and people traveling less with the bus, we ran a chi2 test on whether people travel often with the bus and how important they rated waiting time, travel time and Crowdedness. For waiting time and Crowdedness there was a difference, $\chi^2(1, N = 101) = 32$, p = .024 and $\chi^2(1, N = 101) = 33$, p = .05. Travel time did not show a significant difference, $\chi^2(1, N = 101) = 18$, p = .64. From this we conclude, people rate waiting time and the Crowdedness of a bus higher when they travel more often with the bus. To distinguish we diced to split the participants up into two groups, those who take the bus regularly (at least once a week), and those who take the bus less (less than once a week).

For the group traveling often with the bus the values are: waiting time (M = 8.05, SD = 1.18), travel time (M = 7.29, SD = 1.69), and Crowdedness (M = 7.97, SD = 1.54). For people who travel less with the bus the values are: waiting time (M = 7.46, SD = 1.60), travel time (M = 7.23, SD = 1.50), and Crowdedness (M = 6.77, SD = 1.57). Waiting time is still the most important factor for comfort according the participants.

Now let us look at the social impact. Currently the people are neutral about the current system (M = 3.32, SD =.82) for a score between 1 and 5. A chi2 test learned us that there is significant difference in these answers whether people travel often or less often with the bus $\chi^2(1, N = 101) = 9$, p = .42. Although people are not dissatisfied whit the current system there is still a lot of room for improvement. Of all the participants asked 55% would travel more often with the bus if the system would get improved this is again not depend on how often you travel with the bus. The 55% is a substantial amount and could convince investors to invest in this system since it would generate more and happier passengers.

The data shows that 55% of the participants are prepared to use an app to register for a bus stop. This is a low value considering the young average age of the participants (M = 26.26, SD = 12.26). Younger people are easier in using smartphones in day to day life and people should use the app for the system to be most effective. A Wilcoxon Signed-Ranks test was conducted to see if indeed older people would be hesitant to use an app, and this was indeed the case Z=-2.79, p <0.0053. Our system functions best when all people use an app to register for a bus stop and only 55% was willing to use an app. This is something which is not nice and is something that should be resolved otherwise the system won't function as well.

It is good to notice that there is no one that has trouble with a bus route going through their street if the bus route is already there. However there are people that say that they would mind it if there would be a bus route going through their street. This has the implication that a part of the public the public (47%) will not like the idea of bus routes going through their street. However this could change over time since the people with currently bus routes through their street don't mind.

4.2 Conclusion

What did we learn from the survey and the corresponding analysis? First and foremost we saw that there was too little data collected and there were coding errors in the data. These errors made it impossible to say anything decisive about the results from the analysis. However we did continue with the analysis and assumed that the errors made no difference. Assuming this make no difference we can conclude the following: Firstly people are relatively happy with the current system and might not see the need for a new scheduling system. Little more than half of the participants said that an improvement of the current system would make them take the bus more often. Secondly little more than half of the participants would use an app to register their journey. Furthermore the older the participants got the less likely they were to use an app. Finally about half of the participants would mind it if there would drive buses through their street. However of the people that currently have buses driving through their street no one said they minded it. From this we can conclude that the implementation of the scheduling system will be less beneficial for the elderly and people who will live in neighborhoods where buses will drive. Furthermore the attitude towards using an app of the users should be changed for the system to work optimally.

5 Simulation

A large part of designing a bus system is simulating how the system is going to work. A simulation is created in order to give a better idea of how the autonomous bus scheduling system works and to analyze how effective ABSS is. Furthermore, it is posible to analyze where the weaknesses are in the ABSS. The simulation tests several different scheduling strategies with different passenger flows and validate the outcome by evaluating the general happiness.

5.1 Concept

The concept of the simulation is to implement different schedulers and different passenger flows first and then by putting them into the simulator, it should be able to give out result containing a list of passenger records including waiting time, traveling time and crowdedness in the bus.

There are three configurable parameters:

1) Bus
   Bus number and interval between each bus.

2) Scheduler
   Different scheduling algorithm.

3) Passenger Flow
   Passenger arrival rate and their destinations.

Results of the simulation:

1) Waiting Time
   The time a passenger spent on waiting for bus.

2) Traveling Time
   The time a passenger spent on bus to reach the destination.

3) Crowdedness on Bus
   Number of passengers on bus.

5.2 Setup

There are three weight factors from the survey we used to calculate the general happiness. In table 5.1 the weight factors are shown.

Table 5.1: *Weight factors from the survey*

n	Factors	Grade from survey	Weight factor (W_n)
1	Waiting Time	8.05	0.345
2	Crowdedness	7.79	0.342
3	Travel Time	7.29	0.313

The weights found in the table are the results of the survey conducted with people who take the bus often. The general happiness is calculated with Equation (5.1) and 5.2.

$$S = \sum_{p=1}^{p}(W1 * \frac{(WaitingTime)_p}{MaxWaitingTime} + W2 * \frac{(PassengerNumber)_p}{MaxPassengerNumber} + W3 * \frac{(TravelTime)_p}{MaxTravelTime}) \quad (5.1)$$

$$H = 100\% - (\frac{S}{p} * 100\%) \quad (5.2)$$

In those equations are $W1, W2$ and $W3$ the weights, p the amount of passengers and $(WaitingTime)_p$, $(PassengerNumber)_p$ and $(TravelTime)_p$ the factors per passenger. The factors are normalizes to 0.0 - 1.0. The max waiting time is 15 minutes. After 15 minutes the passenger feels totally disappointed. The Max travel time is set to one hour. In this way we obtained a normalized general happiness from 0% to 100%. The route which is used in the simulation is bus line 3 [9].

5.3 Implementation

Due to the time limitation only one static scheduler and a simple dynamic scheduler is implemented. Due to the same fact only two passenger flows are implemented.

Dynamic Scheduler
The algorithm makes decisions according to:

1) Check if there is a shortcut available from current bus stop.
2) Iterate over all available shortcuts and check if people on the bus want to go to the skipped bus stops.
3) Iterate over all available shortcuts and check if people from skipped bus stops want to get on the bus.
4) if all conditions are met, choose the shortcut which skips more bus stops.

Passenger flow generation
Currently 2 configuration are implemented:

1) Passenger generated at bus stops are uniformly distributed and time independent, 1 passenger per bus stop per 60 seconds. This done to analyze if the simulation is stable and steady.
2) Passenger generated at bus stop according to time (absolute of a sine wave which simulates the morning and afternoon busy hours). These passengers have higher probability to set their destination to a bus stop far away from the current bus stop, the higher the distance the higher the probability.

5.4 Result

The result shows that with this dynamic scheduling algorithm our system can not improve much when passengers arrive all bus stops uniformly and when the chance a passenger wanting to go to certain destination is equally distributed. The improvement is less than 5% under these situations and sometimes even gives a worse result.

But with a dynamic scheduling algorithm our system can improve the situation when passengers are not arriving uniformly, most of them arrive at the starting bus stop (station eindhoven) and ending at other bus stops. And when the chance of a passenger want to go to certain destination is not equally distributed, most of them want to go to one or two bus stop(station Eindhoven or etc...).
The improvement is more than 10% under these situations but mainly depends on how the passenger flow is configured.(Due to time limitation we only implemented 2 simple algorithm to generate passenger flows)

5.5 Simulator

The Discrete Event Simulation is based on React.NET framework. The source code is available on GitHub under GPL V3 license.(`http://Github.com/npk48/DeSimulator`)
The simulator consists of 2 parts, logic and GUI.

5.5.1 Logic

The logic is implemented upon Discrete Event Simulation Frame by using React.NET and compiled into a dll for later integration. [10] The simulation logic has 3 processes running.

- Simulator
  The simulator process is responsible for spawning all other processes and acts as environment by adding passengers to bus stops.
- Passenger
  The passenger process is responsible for counting the on/off time.
- Bus
  The bus process is responsible to drive alone the destination list provided by the scheduler.

The scheduler is an interface which will be called by the Bus process each iteration for updating the destination list.

5.5.2 GUI

The GUI is written in C# using WPF for fast demonstration purpose. The data is displayed by using Modern UI Charts library. [11] All the simulation results are saved in SimResult class. After the simulation done the GUI will process this result and put it into DataViewer class for visualization.

5.6 Conclusion

Our system is not able to provide a better general happiness than a static scheduler during rush hours, since with large amount of passengers the chance a passenger wants to go to certain destination can be seen as equally distributed and they also arrive uniformly. But during off-peak hours the improvement can be more than 10%. So the dynamic scheduling can improve the general happiness, but it highly depends on how the passenger flow is distributed and of the route configuration. More investigation is needed to test with more passenger flow configurations and probably different route configurations with a better dynamic scheduling algorithm.

6 Feasibility of autonomous buses

The ABSS is able to perform with regular man-driven buses. It would, however, be more beneficial to use autonomous buses in the system, due to the following advantages. It allows for better scheduling as autonomous drivers follow their schedule much more nicely compared to human bus drivers. Bus drivers might for example wait slightly too long at bus stops and then miss the next traffic light, whereas an autonomous drivers could time it exactly. Another example is when a bus driver is taking a minute break at a bus stop, which automated systems obviously do not need. All of this can cause the bus to be a minute late at the next stop, moreover the timetables of bus routes are nowadays often designed to account for those delays, as a result the travel time of a bus could be made shorter if some of these delays are removed. The advantages above are for ABSS itself, however autonomous buses also have benefits for users, society and enterprise. According to CEO Elon Musk, the major advantage for users is that autonomous buses are safer than man-driven buses [12]. Alberto Broggi and Azim Eskandrian of the IEEE intelligent Transportation Systems society both think that 90% of the traffic deaths could be avoided simply by making cars (buses) smarter [13]. Sandeep Kar, global director of automotive & transportation research, says that autonomous vehicles have a higher fuel efficiency and require less maintenance [14]. Also, autonomous buses do not need a driver to drive the buses, together with higher fuel efficiency and less maintenance are three very important benefits for enterprises. In this chapter, we are going analyze if it is already feasible to use autonomous buses in the new ABSS system in 2015. In order to answer this question different aspect the following criteria have to be evaluated:

- The expectancy of the public
- Current laws
- Ethics
- Economic impact autonomous buses.
- The threat of other autonomous vehicles.

6.1 The expectancy of the public

Information regarding the users of autonomous public transport will be acquired through a survey [15], which has already been conducted. This survey involved 1500 participants divided between the US, the UK and Australia. It is about the public opinion on autonomous driving. There are some problems with this survey, for the case of the report. The first one is, it was conducted in 2014 so opinion might have changed. Secondly it is not conducted in the Netherlands, the opinion is different for different countries, this phenomena can also be seen in this survey. In order to investigate the feasibility of autonomous buses in the pre-described autonomous bus schedule system, the opinions of the public is important and especially the following topic: *Concerns about using self-driving vehicles*. This topic was analyzed in the survey [15]. This resulted in figure 6.1.

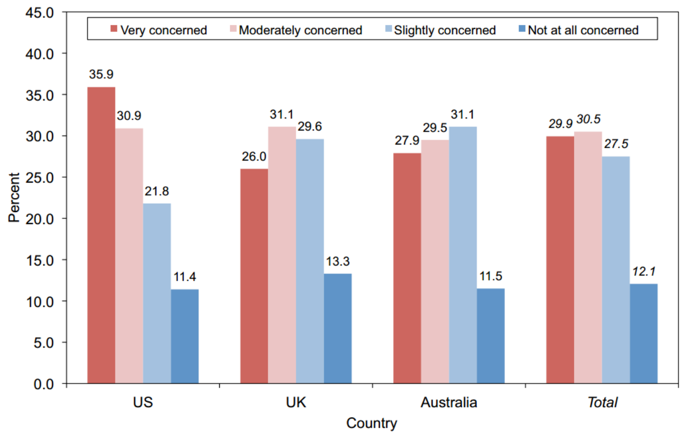

Figure 6.1: *Summary of responses, by country, "How concerned would you be about driving or riding in a vehicle with [Level 4] self-driving technology?" [15]*

The survey was conducted in 2014 so the results might have changed a bit since then. However figure 6.1 shows, that the public is still concerned for using autonomous vehicle. Nearly 30 percent is even very concerned. This means that the public is not ready yet for using autonomous buses. The same results are shown in table 6.1 , which shows the result of the topic: Public transportation such as buses that are completely self-driving.

Table 6.1: *Percentage of responses, by country, "How concerned are you about the following possible scenarios with completely self-driving vehicles (Level 4)?" [15]*

	USA	UK	Australia	Total
Very Concerned	49.7	44.0	44.1	45.9
Moderately concerned	28.1	28.5	26.6	27.7
Slightly concerned	15.4	16.3	19.5	17.1
Not at all concerned	6.8	11.3	9.7	9.3

The willingness of the public for autonomous buses is even lower than just for autonomous vehicles. Nearly one on two person is 'very concerned', this means that it is not viable at this moment to choose for autonomous buses in the public opinion aspect. This state changes of course if passengers gets a 'feel' in autonomous bus. *The university of Twente* conducted an experiment on the acceptance of *traffic jam* aid [16]. The conclusion of that experiment that the acceptance increase after using the product. This might also be the case for autonomous buses, this will however take a lot of time but the juridical part of autonomous vehicle is far from decided. This means it is still not viable at this moment to choose for autonomous buses.

6.2 The current laws in the Netherlands

Important laws such as who is responsible during an accident is still not clear for autonomous vehicles. This is also important in an autonomous public transportation system. For example: when a sensor gets dirty and the autonomous bus cannot read the road marks and crashes. Is it the fault of the bus owner, the programmer or the maker of the sensor? The current law states that a person is not liable for case where there is a defect in the product (the product liability) [17]. This is still vague, because what if a defect occurs after a few years due to wear, is the manufacturer still responsible when an accident happens? The government has not figured out the responsibility yet.

The current law for responsibility does not have to change too much. The Netherlands could use the law that is being used in California right now. This law states that the driver should be able to take control of the vehicle at any time [18]. This means that if an accident occurs, the responsibility still stays with the driver. The driver is able to avoid an accident when needed. This will also solve a lot of the ethical problems. This is, however, not possible in the case of an autonomous bus without a driver. One solution to ease the responsibility in the case of the autonomous bus is to build tracks where only autonomous buses are allowed. This will firstly reduce the accidents that can occur with other vehicle and secondly cameras can be added to the track to investigate any accidents that do occur. The investigation will be done by an independent third party, who will determine who takes the responsibility. Another solution is to give the manufacturer the responsiveness. Car manufacturer Volvo will accept full liability for accidents involving its driver less cars [19]. However, Volvo gives away mixed signals on this matter. ”Volvo also told the BBC it would only accept liability for an accident if it was the result of a flaw in the car's design. ” If the customer used the technology in an inappropriate way then the user is still liable”” [19]. The Volvo proposition is still vague, how is *’inappropriate’* determined? Volvo shows that it is no satisfied by the process by the governments in creating laws for autonomous vehicles, however Volvo protects is self. This means that car manufactures are ready for autonomous vehicles but society is not, ’society presses the brakes’ on process for car manufactures.

6.3 Ethics (Noah J. Goodall)

The ethics behind an autonomous public transportation system and an autonomous vehicle are quite similar in some fields. For example during a crash or avoidance of a crash. This is a known problem, however the solution still needs to be found. Entire papers like that of psychologist Noah Goodall are entirely focused on decision ethics of autonomous vehicles during crashes. Some important conclusions can be found in his paper. One of his first conclusions is that society wrongly assumes that autonomous vehicle are safer than non-autonomous vehicles [20]. Tests [21–23] show that an autonomous vehicle has to drive 725000 miles without an accident to show that it is safer. Not a single autonomous vehicle has driven that far yet. This is very important for an autonomous public transportation system, because the vehicles used in this system will drive a lot of miles each year. The lack of proof means that it will be difficult for companies to convince the public that their system is safe. The first conclusion above is that accidents will occur with autonomous vehicles. This introduces another problem: decision making during a crash or avoidance of a crash. Goodall comes up with a solution, consisting of the three-phased plan [20]. The first phase is a rationalistic moral system for automated vehicles that takes action to minimize the impact of a crash on the basis of the generally agreed-on principles set by the government or an indented third party. The second phase introduces machine learning techniques to study human decisions across a range of real-world and simulated crash scenarios to develop similar circumstances. The rules from the first approach remain in place as behavioral boundaries for the system The final phase requires an automated vehicle to express its decisions with natural language so that its highly complex logic, may be understood and corrected. This is, of course, the ideal solution which does not exist yet, because the progress in AI is far behind making AI self-learning. When the autonomous public transportation system uses separate tracks, the problem becomes less complicated, because of the less interactive surroundings. On the separate tracks, the system can communicate between the different vehicles to reduce the crash chance and to stop the system when a crash happened. Tracks will have a free emergency lane to the right for avoidance and the entire system on a track where the accident happens is completely shut down when a problems occurs. The main conclusion for ethics is: A less extended version of the Goodall three phased system will be used on the tracks provided for the autonomous public transportation system. An example of such separate lanes is illustrated in figure 6.2.

Figure 6.2: *Example Separate lanes for autonomous buses [24]*

6.4 Economic impacts autonomous bus

This chapter is of great importance for the bus scheduling system, for the case that the buses used in this system become autonomous. This will have great impact on different areas and USE-aspects. In this chapter the economic pros and cons will be discussed for the case that the buses become autonomous. First the positive impact will be explained and next the negative impacts.

6.4.1 Pros

1) "Honda Research & Development's has gathered data that states that self-driving vehicles may reduce lost productivity incurred from traffic deaths and injuries" [25]. This results into a gain of $78 billion annually in the U.S. and $75 billion in Japan, based on 2013 data. The above statement rests on the fact that autonomous vehicles make less mistakes than vehicles driven by humans, this might also be the case for autonomous buses.

2) More jobs for lawyers and investigators. When using autonomous vehicles the question of *who is responsible?* is a difficult question to answer. This means that in order to have a fair system, a lot of lawyers and investigators have to be assigned to find answers to that question.

3) KPMG UK thinks that the annual economic benefit of autonomous vehicles will grow to 51 billion pounds by 2030 [26]. The reason for this grows is due to the fact that consumers will see how easy it is to travel. This will lead to economic benefits, for example improved productivity and increased trade [26]. Figure 6.3 shows the Economic benefits accelerated over time. An autonomous bus will ease the travel for users and thus lead to economic benefits.

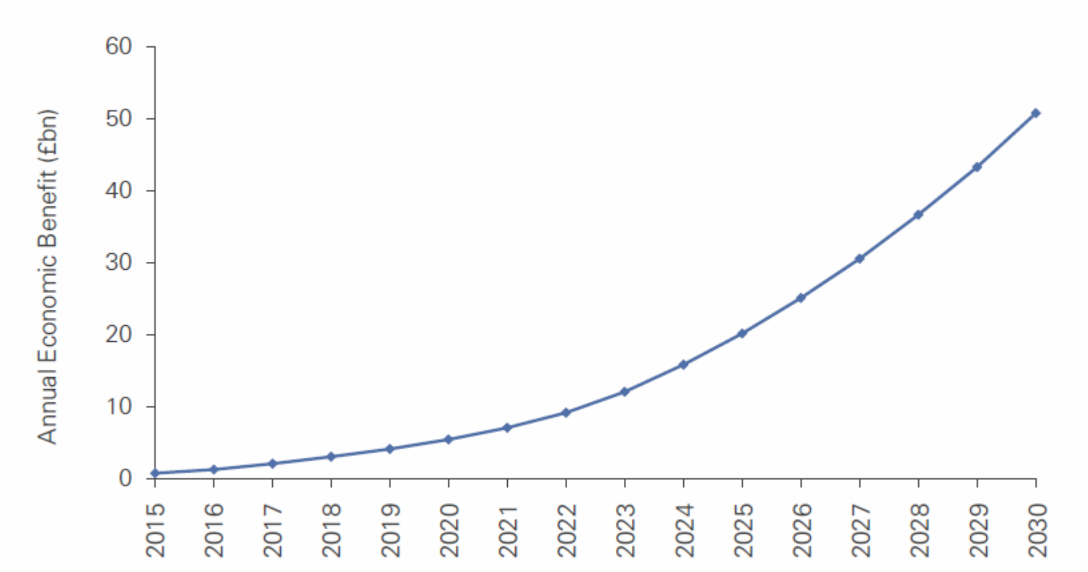

Figure 6.3: *Annual growth of autonomous vehicles calculated by the KPMG UK [26]*

4) "Autonomous buses will lower the cost, resource consumption and ecological footprint of mobility. Because significantly lower costs will prompt many travelers to use buses on medium to long-distance trips instead of cars, these buses will increase the effective capacity of highways when measured in people-miles" [27].

5) Big saves for public transportation providers, due to no need of a driver. In the Boston area there around 5500 people driving buses, with a yearly salary of 29.000 dollar [28]. This results of saving of 159.500.00 dollars each year for the public transportation provider in Boston alone [28].

6) A drop in health care bills. Autonomous vehicles are claimed to be safer than human driving cars. This means less injuries and death due to traffic accidents. This results in a saving of billions of dollars in health care cost [29]. This means that the average household will have a benefit with health insurance. No only health care cost will drop but also the traffic cost and environmental cost will drop, according to 'Kennisinstituut voor Mobiliteitsbeleid(2013)' [30].

6.4.2 Cons

1) The first positive impact also has a negative one hidden inside. "What happens when autonomous vehicles make mistakes? When crashes occur we might need an army of lawyers to tell us who is culpable. And of course, autonomous vehicles need autonomous insurance policies to match" [25]. This can destroy the current insurance market.

2) An autonomous bus transportation system will reduce the 'need' for a car. The car ownership is already decreasing under the youth [31]. If from the simulations it is clear that the new public transportation system has a higher efficiency, this has great negative impact on the car industry. The decrease in cost and increase in time efficiency will alter the discussion of car users to buy another car. This means that fewer cars will be sold each year. Autonomous cars show the same effect. An autonomous car is able to pick up and deposit people without the need of a driver. That means that when two people have to go to different locations there is no need for two different cars [29]. The reduction in car sales will lead to job losses in the car industry. This will lead to higher unemployment.

3) The loss of jobs in the public transportation branch. In case the buses become autonomous the need for a driver will decrease over time [28]. This will result in an increase in unemployment. The bus drivers nowadays will have to find another profession; this might involve re-education [28]. This does not have to result in a negative impact, because the re-education might create new jobs. The re-education will favor newer employees over older employees, meaning older people will get penalized by the autonomous bus [28].

The economic impact of autonomous bus is quite a complex point on this own. All the impacts are based on predication, this means that all states of Pros and Cons may change in future. The economic part can however not by left out in the analysis if autonomous are feasible. So in context of economics it would be feasible to used autonomous buses, autonomous vehicle show more pros than cons in the context of economic impact. However the other factors involving autonomous buses make so difficult to uses autonomous vehicles. This means that the economic gain cannot over throw the barriers mentioned above.

6.5 The threats of autonomous vehicles for public transportation

Autonomous vehicles are making tremendous progress and one day in the future all vehicles might become autonomous. In this scenario car are not 'own' anymore. Autonomous cars can pick up different people without the need of a driver. This means that if a person is at home and does not need to go anywhere the car can be used by somebody else without been a nuance for the other person. This might be a bit of topic but this scenario might become reality in the future. If this scenario becomes reality than, the need for public transportation will decrease. Why used big heavy buses when small light weight autonomous cars can do the job [32]. Small cars can go almost everywhere, while big buses are restricted by their size. Small cars will be kind of Uber taxi that excites today, however instead of regular cars a fleet of autonomous cars. On the other hand buses are however, have a higher passenger flow than cars [33]. Buses have special lanes dedicated for in a lot of cities around the world, meaning buses can bypass a lot of traffic during for example traffic jams. This will slow down the change of buses for autonomous cars. As mentioned above separate lanes already eases the progress of introducing autonomous vehicles in society. In the distant future the bus will become obsolete, we think. The future of public transportation will change from autonomous buses to *'road train'*. An example of such a futuristic *'road train'* is illustrated in figure 6.4.

Figure 6.4: *Future of autonomous public transportation [34]*

Those *'road trains'* will excite of small individual vehicles, which can carry four people. These vehicles can attach to each other when going to the same destination, in order to save space. This system is called *'next'*. This system does not use single-users pods; the next system can be seen as small buses that uses a very advanced ABSS system to regulated the small 4 man buses.

6.6 Conclusion

In this part of the report the feasibility of autonomous buses in the autonomous scheduling system has been analyzed in the following five topics: *The expectancy of the public, Current laws, Ethics, Economic pros and cons of autonomous buses, The threat of other autonomous vehicles.* The conclusion of the first topic is: the public is not yet ready for autonomous buses. Autonomous vehicles are still in their in fancies, the public does not know yet what to expect of autonomous vehicles, even though the acceptance might increase when people experienced the new autonomous vehicles. This will however take time, so for now the public still do not accept autonomous buses. The current laws are still vague, for autonomous vehicles, some propositions have been mentions above. This means that incorporating autonomous buses now would be too difficult legally, however in the future with good new laws regarding autonomous vehicle autonomous buses would be feasible, juridical. The ethics are complex and a solution is still to be found, so for the ethics topic it is not feasible to use autonomous buses yet. The separate lane approach might be a solution, however it would take a lot of time to create those lanes in Eindhoven. On the economic impact of autonomous buses there are more pros and cons for autonomous buses. Those pros however are not able to overrule the first three discussed topics and those pros are predicates that might be wrong only time will tell. The threat of other autonomous vehicles is of course a scenario for the future. At first the autonomous vehicles might make the need for public buses unnecessary due to its benefits, however the buses might overrule those benefits used as they are today. This means that in future the need for buses will still be there, but maybe in a different environment. For example in the *'next'* system. The overall conclusion is: In 2015 it is not feasible to use autonomous buses for the dynamic bus scheduling system.

7 Conclusion

The literature study shows that a new, more efficient and dynamic form of public transportation can be realized. Eventually it provides us with ways to compute the optimal route while taking the assignment of requests, the set of routes the bus could take and the arriving times to a particular location into account.

The ABSS system is overall positive when regarding the users, because the waiting and traveling time might decrease with this system. However, as expected, there are some problems regarding users. The ABSS strongly relies on the users owning and knowing how to use a smartphone. This problem can be solved by designing new bus stops with 'bus call poles'. Those poles allow users without smartphones to track and call buses whenever they are at a bus stop. The decrease in travel time brings along better safety in the city, cleaner air and overall less crowded roads. The new system also brings along some business opportunities, which are worth investing in with room for expansion.

For further research the survey should be redone in its entirety. The sample size was way too small and there were coding errors in an important part of the survey. A sample size of at least 387 should be used to create a viable survey. Furthermore the survey should be tested on mobile and on a computer to see if the layout remains the same and no options disappear, to prevent the same errors to return. Our system is not able to provide a better general happiness compared to a static scheduler during rush hours, since with large amount of passengers, the chance a passenger wants to go to certain destination can be seen as equally distributed and they also arrive uniformly. But during off-peak hours the improvement can be more than 10%. So the dynamic scheduling can improve the general happiness, but it highly depends on how the passenger flow is distributed and of the route configuration. More investigation is needed to test with more passenger flow configurations and probably different route configurations with a better dynamic scheduling algorithm.

In 2015 it is not feasible to use autonomous buses for the dynamic bus scheduling system. We, however, learned a lot doing research on this topic. The main thing we learned is complexity involving autonomous vehicles in general. The technology is making tremendous progress in the automation field. However, the laws and ethics are far behind on that matter.

8 Discussion

This section is discusses what in the future can be done to make more progress regarding research and implementation of the autonomous scheduling system. First let us look at the simulation. The math behind the scheduling system is already done, however there is room for improvement. In combination with a simulation that embraces more real life factors a better prognosis can be done regarding the improvement of overall passenger satisfaction. Furthermore the real passenger flow should be implemented to give an accurate result. Secondly there should be more research done towards the opinion of the users. As described in the survey analysis, the survey should be redone with more samples to make it valid. Furthermore the survey should be tested on mobile and on a computer to see if the layout remains the same and no options disappear, to prevent the same errors to return. For further research a similar survey as was conducted by the University of Michigan in USA, UK and Australia could be conducted in the Netherlands. This will update the results to 2015 and the correct audience will be used to research if the people of the Netherlands are ready for autonomous vehicles and especially autonomous public transportation in the form of buses. Society is not ready for autonomous buses for public transportation. More research can be conducted to maybe give an estimate for when society is ready for autonomous buses to be used in the new dynamic scheduling system. Also, we learned the matters involving autonomous buses changes every day; Volvo says it will take full liability for accidents involving driver-less cars [19]. This means that car manufactures are ready for autonomous vehicles but society is not, 'society presses the brakes' on process for car manufactures. Lastly further research could be done towards the development of the app. The system would work best if everyone uses the app, thus it is important to make the app as user friendly as possible.

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Appendix A

Survey

Geachte meneer/mevrouw, Wij zijn een groep studenten van de Technische universiteit Eindhoven die een klein onderzoek doen naar een nieuwe manier van bus transport. Bij deze nieuwe methode moet u via een app aangeven hoe laat u met welke bus wilt gaan en vanaf welk bu sstation u wilt vertrekken. Met deze informatie kan de bus een efficintere route bepalen. Dit zal vervolgens wachttijd, reistijd, en de drukte moeten verlagen.

Wat is uw geslacht?
o Man
o Vrouw

Wat is uw leeftijd?

Hoe vaak reist u gemiddeld met de bus?
o Nooit/bijna nooit
o Een keer per week
o Meerdere keren per week
o Bijna Elke dag

Hoe tevreden bent u over hoe uw busreis nu gaat?
o Heel tevreden
o Tevreden
o Neutraal
o Niet tevreden
o Totaal niet tevreden

Hoelang zou u maximaal op de volgende bus willen wachten?

Op een schaal van 1 tot 10 hoe belangrijk vindt u de volgende dingen voor uw bus reis.

Wachttijd:	1 2 3 4 5 6 7 8 9 10
Reistijd:	1 2 3 4 5 6 7 8 9 10
De drukte in de bus:	1 2 3 4 5 6 7 8 9 10

Zou een verbetering van de vorige genoemde punten ervoor kunnen zorgen dat u vaker met de bus gaat?

Is er een nog een niet genoemd punt dat uw belangrijk vindt voor het gemak van de busreis?

Gaat er op dit moment een bus route door de straat waar u nu woont?
o Ja
o Nee

(Indien ja) Hebt u last van de bussen die door uw straat rijden?
o Ja
o Nee

(Indien nee) Zou u het erg vinden als er een bus route door uw straat zou komen?
o Ja
o Nee

Zou u er moeite mee hebben als u zich moet aanmelden bij een bushalte via een app als dit wel uw reistijd kan verkorten?
o Ja
o Nee