# Tram bottlenecks in Amsterdam after implementation of the Noord-Zuidlijn

BSc-Thesis

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# Tram bottlenecks in Amsterdam after implementation of the Noord-Zuidlijn

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In partial fulfillment of the requirements for the degree of

**Bachelor of science**
in Civil Engineering
at the Delft University of Technology (TU Delft)

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|---|---|
| **Academic year** | 2019-2020 |
| **Supervisors** | Yufei Yuan<br>Rolf Koster<br>Jaap Vleugel |
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Frontpage image [1]

# Preface

This Bachelor of science thesis has been carried out at the faculty of Civil Engineering at the Delft University of Technology in the Netherlands, which is part of obtaining the BSc degree of science. This research has been done at the Department of Transport & Planning (T&P). Through a conversation with Niels van Oort, who is a researcher at TU Delft, he came up with this research topic, which is to do the after analysis. This after analysis holds that the tram network of Amsterdam after the implementation of the Noord-Zuidlijn had to be researched concerning bottlenecks.

Doing the analysis was hard work, but with the help of both external supervisors, Niels van Oort and Ties Brands, I could get the job done. Also almost every week there was a meeting with the supervisors, who were critical on the work that was submitted in that specific week. That helped to improve the work that was already done. Also, the criticism of fellow students helped to improve the work.

I hereby want to thank everyone that was involved in this thesis. Special thanks to Rolf Koster, Yufei Yuan, Jaap Vleugel, Ties Brands, and Niels van Oort.

Bobby Kartoidjojo

# Summary

After the implementation of the Noord-Zuidlijn in Amsterdam, a lot has changed in the tram network of Amsterdam such as dropping of lines and changed routes, focus shift, and also mode split changes. Before the Noord-Zuidlijn, 47% took the tram and after the Noord-Zuidlijn 40% took the tram [4]. The trams were focused on the Central Station of Amsterdam before the Noord-Zuidlijn and after the Noord-Zuidlijn the trams are more focused on the Noord-Zuidlijn and so they function as feeders. All these changes have also caused changes in the number of bottlenecks of the tram lines. These changes in the number of bottlenecks have been analyzed in this research. Furthermore, this research is a continuation of the previous research “Automatic bottleneck detection using AVL data: a case study in Amsterdam” conducted by Ties Brands, Niels van Oort and Menno Yap in 2018 [6]. The goal of this thesis has been to find the number of bottlenecks after the implementation of the Noord-Zuidlijn and finding explanations for the differences between the situation before the implementation of the Noord-Zuidlijn and the situation after the implementation of the NZ-lijn.

The data that has been used for this research is AVL (automatic vehicle location) data. Initially, the AVL-data had been processed. In this stage, the dwell time, punctuality, run time, and speed was computed. To specify this further, the 15th, 50th, and 85th percentiles and average of each of these four variables (dwell time, punctuality, run time and speed) were determined for six different periods (AM peak, interpeak, PM peak, evening, Saturdays, and Sundays) for every tram line, direction, stop, run, and period. After processing the data, the aggregated data that came out were then being tested on eight bottleneck criteria that define whether there is a bottleneck or not. From the testing, the number of bottlenecks was obtained for the whole network and each tramline.

Overal seen, the number of bottlenecks of the whole tram network has decreased after the implementation of the Noord-Zuidlijn. Also on the level of the tramlines, the number of bottlenecks has decreased. However, an increase of bottlenecks is noted at a large part of the tram lines 4, 12, and 13. At these tram lines, the trams have left too early at the tram stops. Furthermore, the largest number of bottlenecks has occurred at the PM peak. In particular early departure cases have occurred a lot. Also, a large cluster of bottlenecks due to low speeds at the locations Leidesplein, Dam, and Central Station, which are located in the center of Amsterdam has been noted. The most unstable period concerning service reliability is the period Saturdays where an average of 13 bottlenecks per day increase and 20 bottlenecks per day decrease has been noted. With unstable is meant that there are large changes compared to the before situation.

Concerning the service reliability aspects dwell time, punctuality, run time and speed between the before and after situation of the whole network, the punctuality has improved in the after situation with approximately 14 seconds, whereas the other aspects, dwell time, run time, and speed, have stayed approximately the same. The same holds for the tram lines. However, tram lines 4 and 14 show an increase in the punctuality of respectively 7 and 10 seconds.

To obtain better numbers concerning the number of bottlenecks, a bigger model has to be build in which a lot more variables can be the input. This means that other factors are taken into consideration when analyzing the tram network of Amsterdam concerning bottlenecks.

So overall seen, the service reliability of the tram network has increased after the implementation of the Noord-Zuidlijn because the number of bottlenecks of the whole network and the tram lines has gone down and also the punctuality has improved. Also, the costumers rating which has gone up from 7.5 in 2017 to 7.7 in 2018 is a confirmation that the service reliability of the tram network has increased [11].

# Contents

# 1 Introduction

## 1.1 Motive

In 2018 the NZ-lijn (figure 1 blue) [2], metro line 52, has finally opened in Amsterdam after years of construction and many delays [3]. With the Noord-Zuidlijn now functional, which means the other transport modes such as bus and tram operate differently compared to before the NZ-lijn. So the other modes, which are bus and tram have adapted their routes and schedules to the NZ-lijn. The tram lines have shifted their focus from the central station of Amsterdam towards the NZ-lijn. This is for them to feed the NZ-lijn. Amsterdam is a busy place. Before the implementation of the NZ-lijn, a lot of pressure was on the other transportation mode such as bus, tram, ferry, and other metro lines. The arrival of the NZ-lijn has eased the pressure on the other modes. Before the NZ-lijn, 47% of the travelers traveled with the tram and 32% traveled with the metro. After the NZ-lijn, that mode split is almost equal (40%) for tram and metro nowadays. So that has divided the pressure better and as a result of that, there is more space in the trams.[4]

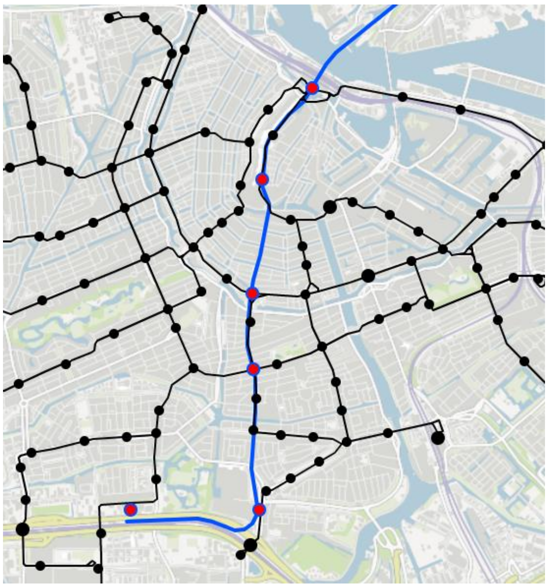

*Figure 1 Tramlines (black) and Noord-Zuidlijn metroline 52 (blue) in Amsterdam [5]*

This research is a continuation of the previous research “Automatic bottleneck detection using AVL data: a case study in Amsterdam” conducted by Ties Brands, Niels van Oort and Menno Yap in 2018 [6]. In this previous research, the service reliability was analyzed of the tram network when the Noord-Zuidlijn was not yet implemented. In that research, a method was developed to automatically detect bottlenecks in Amsterdam using AVL (Automatic Vehicle Location) data. This data was able to be collected, because of the GPS devices that are in the trams. Different variables such as date, tram stops, tram-stop code, departure times, and arrival times are shown. Especially the service reliability aspect travel time and speed were assessed using proposed criteria that define a bottleneck. Other aspects such as weather conditions, crew availability, infrastructure design, etc. were not included in the analysis of the tram network concerning bottlenecks. And so the number of bottlenecks of each tramline was obtained. From now on the Noord-Zuidlijn will be called NZ-lijn. The analysis that has been done in the previous research will be called before analysis and the analysis that has been done of the situation after the implementation of the NZ-lijn will be called after analysis from now on. Analysis in this thesis means, finding the number of bottlenecks of the tramlines in Amsterdam.

## 1.3 Goals and focus

In this Bachelor of Science (BSc) research, the tram network, concerning bottlenecks, has been analyzed of the situation after the implementation of the NZ-lijn. The same method that was developed in the previous research has been applied in this project. To compare the before and after situation of the tram network in Amsterdam concerning bottlenecks, it is handy to apply the same method. In this manner, the same variables (travel time and speed) can be compared to each other and an overview can be obtained of the differences between the two situations. If an own method would be developed or another method would be applied then it would not be consistent for comparing the before and after situation. The reason that it would not be consistent is that the outcomes of the two different methods will not give a good comparison concerning the situation of the number of bottlenecks before and after the implementation of the NZ-lijn. Thus to be consistent the same developed method has been applied to analyze the after situation. So the final goal of this research is "**Obtaining the number of bottlenecks before and after the implementation of the Noord-Zuidlijn in terms of service reliability of the tram network and finding explanations for the differences**"

The focus of this research is the tram network of Amsterdam and especially the service reliability aspects travel time and speed. With this focus, the number of bottlenecks has been analyzed. This means the number of times that service unreliability occurs, which is the number of times the schedule deviates from the original schedule. More on service reliability in chapter 2.1.

To break down the research goal, the following sub-goals have to be tackled:

1) Finding the number of bottlenecks of the after-situation based on the AVL-data.
2) Comparing the before analysis and the after analysis.

In chapter 2 (methodology), these sub-goals will be elaborated further on.

## 1.4 Beneficial's

The after analysis may be of great importance for GVB, the transport company in Amsterdam that provides bus, tram, ferry, and metro services. GVB has said that because of the NZ-lijn, more air has been created so that extra growth can be accommodated there in the coming years [7]. And so by looking into the after analysis, they can add improvements to the tram work. Also for the municipality of Amsterdam, the findings are important, because, in that sense, the municipality can improve their transportation services and also their infrastructure. For public transport researchers, mainly for researchers that engage in traffic and transport of Amsterdam, the findings of the after analysis might be interesting, to see what impact the implementation of the NZ-lijn has had on the whole tram network of Amsterdam and may be a good starting point to carry out further research concerning this topic.

## 1.5 Structure

Since the goal and sub-goals are clear, the following structure has been followed. First, the methodology, which is how to tackle the problem has been elaborated on. In the methodology also the method is mentioned that has been used for the analysis. After this, the findings of the previous research has been mentioned, and also the findings of the after analysis has been mentioned. With the after analysis done, the results of the after analysis have been compared with the findings of the previous research and explanations, and further confirmation about the results has been given. In the end, conclusions have been drawn including findings, discussions, and a further research recommendation.

# 2 Methodology

Since the final goal is known, which is to find the number of bottlenecks of the tram network of Amsterdam after the implementation of the NZ-lijn and afterwards comparing it to the situation before the implementation of the NZ-lijn, the steps to achieve this is explained in this chapter. The following is addressed in this chapter:

- Explaining the terms: service reliability and bottleneck. These terms in this thesis might be abstract. So before analyzing the before and after situation, it is important to have the terms service reliability and bottleneck clarified.
- Explaining what AVL-data is. This is data that has been used for the analyses.
- Showing the method that has been applied for the analysis. The method is based on the developed method of the previous research as mentioned in chapter 1 (Introduction).

## 2.1 Service reliability and bottleneck

Service reliability has been extensively researched by Niels van Oort in his Ph.D. thesis. Here he said that "We define service reliability as the certainty of service aspects compared to the schedule (such as travel time (including waiting), arrival time and seat availability) as perceived by the user".[8] The service reliability aspect is important to keep the quality of service high. Many causes can have an impact on the level of service reliability aspects such as the variables from Trip time variability (figure 2). In figure 2, both the internal and external causes are shown that can have an impact on Trip time variability aspects such as driving time, dwell time, and stopping time.

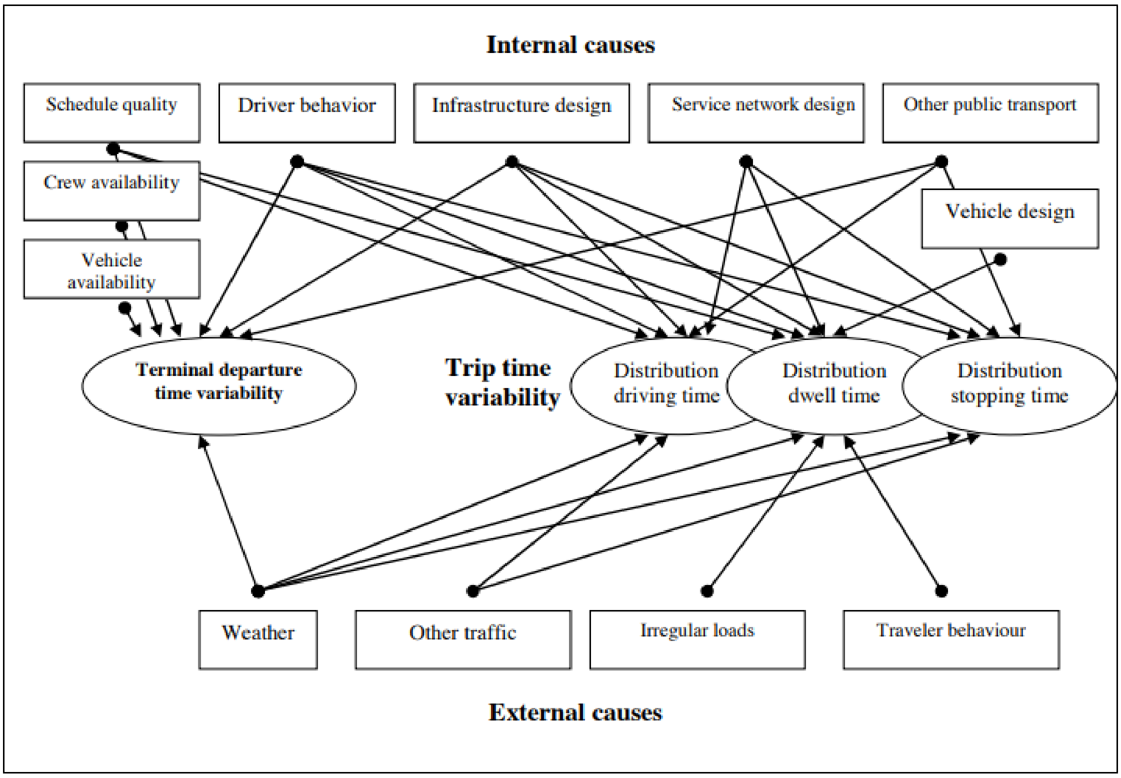


*Figure 2 Causes of service variability and unreliability*

In this research, the focus is on the trip time variability and not on the internal and external causes. For this research, the service aspects time and speed has been assessed, because in the AVL data, times are given and with an external dataset, which contains the distances between stops, the speeds can be calculated. To specify this further, the aspects, dwell time, run time, punctuality, and vehicle speed has been assessed which has further been specified into six different periods. Bottleneck is another term that needs to be clarified as well. Bottleneck is when difficulties occur such as delays, departing too early, etc.  If the service reliability is high, this means that the number of bottlenecks is low. So the number of bottlenecks is an indicator of service reliability. To define whether there is a bottleneck, there have to be conditions. These conditions are presented in chapter 2.3 where the method is covered.

## 2.2 AVL-data

This is data that has been used for the analyses. As was mentioned in the introduction, this is data that could be gathered, because of the GPS devices that are in the trams. Table 1 shows how AVL-data looks like. The data set has approximately six million rows of information. In table A, which is in the appendix, is how the dataset with all the columns look like for five of these rows. The dataset has information on fourteen tramlines. Furthermore, it has data of 41 days. From the 10th of September 2018 till the 30th of September 2018 and from the 1st of October 2018 till the 21st of October 2018. In the dataset that was made available for the analysis, only data of these 41 days was included. So with only this dataset the analysis had to be carried out. The computer tools that has been used for processing the AVL-data are the programming language Python and Microsoft office program Excel.

*Table 1 Part of the AVL data*

| Date | Line number | Direction | Stop Sequence number | Stop name | Arrival time planned | Departure time planned | Arrival time realized | Departure time realized |
|---|---|---|---|---|---|---|---|---|
| 1/10/2018 | 1 | H | 1 | Matterhorn | 12:01:00 AM | 12:01:00 AM | 12:01:09 AM | 12:01:09 AM |
| 1/10/2018 | 1 | H | 2 | Pilatus | 12:01:42 AM | 12:01:43 AM | 12:02:16 AM | 12:02:16 AM |
| 1/10/2018 | 1 | H | 3 | Inaristraat | 12:02:37 AM | 12:02:55 AM | 12:03:13 AM | 12:03:28 AM |
| 1/10/2018 | 1 | H | 4 | Ecuplein | 12:03:49 AM | 12:04:07 AM | 12:04:34 AM | 12:04:34 AM |
| 1/10/2018 | 1 | H | 5 | Baden Powellweg | 12:05:02 AM | 12:05:20 AM | 12:05:22 AM | 12:05:22 AM |

## 2.3 Method for the analysis

The method that is covered in this sub-chapter has already been developed in the previous research “Automatic bottleneck detection using AVL data: a case study in Amsterdam” by the researcher's Ties Brands, Niels van Oort and Menno Yap in 2018 [6]. For the after analysis, it is handy to apply the same method, because eventually the before and after situation should be compared. The method is shortly covered in this chapter. First, the steps to process the data are covered and after that, the different criteria are shown, which define whether there is a bottleneck or not.

**Data processing**

The available AVL-data was processed to find the following aspects: dwell time, run time, punctuality, and speed.

- Dwell time is the time when a tram is at a station for passengers to get in or out.
- Run time is the time that indicates how long it takes for a tram to go from one station to the next.

- Punctuality is how much the realized departure time deviates from the planned departure time.
- And speed is based on the run time and also on the distance between tram stops.

So the following four formulas are to show how dwell time, run time, punctuality, and speed is computed using the formulas of the previous research.

**1) Realized dwell time**

$$t_{l,d,k,r,s}^{dwell} = \theta_{l,d,k,r,s}^{real} - \tau_{l,d,k,r,s}^{real} \; (1)$$

$t_{l,d,k,r,s}^{dwell} = realised\ dwell\ time\ for\ l,d,k,r,s$
$\theta_{l,d,k,r,s}^{real} = realised\ departure\ time\ for\ l,d,k,r,s$
$\tau_{l,d,k,r,s}^{real} = realised\ arrival\ time\ for\ l,d,k,r,s$
$l,d,k,r,s,p = line\ l, direction\ d, day\ k, run\ r, stop\ s, period\ p$

If this has been done also the following have to be found:
$t_{l,d,s,p}^{dwell,p15}, t_{l,d,s,p}^{dwell,p50}\ and\ t_{l,d,s,p}^{dwell,p85}$ , which are respectively the 15th, 50th and 85th percentiles. The 15th and 85th percentiles are needed to see how large the variation is of the dwell time. The set has to be ordered first before going on to find the percentiles. The 50th percentile is the median of the ordered dataset. Besides the percentiles, also the average value has to be calculated for each period P, stop s, direction d, run r, and line l. The periods P are mentioned at the beginning of page 11. The average is computed as follows:

$$t_{l,d,s,p}^{dwell,av} = \frac{\sum_{k \in K_p, r \in R_{l,p}} t_{l,d,k,r,s}^{dwell}}{|k \in K_p| * |r \in R_{l,p}|} \quad (2)$$

$t_{l,d,s,p}^{dwell,av} = average\ dwell\ time\ for\ l,d,s,p$
$k \in K_p = number\ of\ days\ in\ period\ p$
$r \in R_{l,p} = number\ of\ runs\ in\ period\ p$

**2) Realized punctuality**

$$\pi_{l,d,k,r,s}^{real} = \theta_{l,d,k,r,s}^{real} - \theta_{l,d,k,r,s}^{sched} \; (3)$$

$\pi_{l,d,k,r,s}^{real} = realised\ punctuality\ for\ l,d,k,r,s$
$\theta_{l,d,k,r,s}^{real} = realised\ departure\ time\ for\ l,d,k,r,s$
$\theta_{l,d,k,r,s}^{sched} = scheduled\ departure\ time\ for\ l,d,k,r,s$
$l,d,k,r,s,p = line\ l, direction\ d, day\ k, run\ r, stop\ s, period\ p$

Here also the 15th, 50th and 85th percentiles of the realized punctualities have to be determined which are noted as $\pi_{l,d,s,p}^{p15}, \pi_{l,d,s,p}^{p50}\ and\ \pi_{l,d,s,p}^{p85}$ and also the average realized punctuality $\pi_{l,d,s,p}^{av}$.

**3) Run time**

$$t_{l,d,k,r,s}^{run} = \tau_{l,d,k,r,s}^{real} - \theta_{l,d,k,r,s_l^-}^{real} \; (4)$$

$t_{l,d,k,r,s}^{run} = realised\ run\ time\ for\ l,d,k,r,s$
$\tau_{l,d,k,r,s}^{real} = realised\ arrival\ time\ for\ l,d,k,r,s$
$\theta_{l,d,k,r,s_l^-}^{real} = realised\ departure\ time\ for\ l,d,k,r,s_l^-$
$l,d,k,r,s,s_l^-,p = line\ l, direction\ d, day\ k, run\ r, stop\ s, previous\ stop\ s_l^-, period\ p$

Here also the 15th, 50th and 85th percentiles of the realized run times have to be determined which are noted as $t_{l,d,s,p}^{run,p15}, t_{l,d,s,p}^{run,p50}\ and\ t_{l,d,s,p}^{run,p85}$ and also the average realized run time $t_{l,d,s,p}^{run,av}$.

### 4) Vehicle speed

The vehicle speed $v$ can be computed by using the run times ($t_{l,d,s,p}^{run,p15}$, $t_{l,d,s,p}^{run,p50}$, $t_{l,d,s,p}^{run,p85}$ and $t_{l,d,s,p}^{run,av}$) and the length of each segment $L_{l,d,s}(length\ of\ line\ l, direction\ d\ and\ stop\ s)$. A segment is a part between two stops. Speed is runtime divided by the length of the segment. So the speeds are $v_{l,d,s,p}^{run,p15}$, $v_{l,d,s,p}^{run,p50}$, $v_{l,d,s,p}^{run,p85}$ and also the average speed $v_{l,d,s,p}^{run,av}$.

The 6 different periods P for which the data have to be processed are:

1) AM peak (7 AM-9 AM) on workdays. At this period, there is a lot of movement, because people have to go to work or school or to a other activity and so a lot of people take the trams.
2) Inter peak period (9 AM-4 PM) on workdays. During this period, not a lot of people are on the move, which is kind of an average of the whole day of the number of people. This period is comparable to Saturdays.
3) PM peak (4 PM-6 PM) on workdays. Just as the AM-peak, the PM-peak is interesting, because, at these times, people mostly go back to home and so a lot of people take the trams.
4) Evening period (6 PM-midnight) on workdays. People are mostly at home, so few people make use of the trams. This period is comparable to Sundays.
5) Saturdays. On Saturdays and Sundays, the number of people that take a tram are at the whole day almost the same. More places are open on Saturdays and stay open longer than Sundays. Saturdays attract a lot of tourists.
6) Sundays. Sundays are not that busy because not a lot of places are open and if they are open, they do not stay open for long. But at the opening hours, mainly during the evening a lot of people are in the city.

These periods have also been retrieved from the previous research and also the coming eight criteria have been retrieved from the previous research.

**The eight criteria for bottleneck detection**

In the previous research, the following criteria were developed to define whether there is a bottleneck or not. These are the eight types of bottlenecks:

1) Large dwell time: $t_{l,d,s,p}^{dwell,av} > 60s$ (Average dwell time greater than 60s)
2) Large variation in dwell time: $t_{l,d,s,p}^{dwell,p85} - t_{l,d,s,p}^{dwell,p15} > 120s$ (The 85th percentile dwell time minus the 15th percentile dwell time greater than 120s)
3) Early departure: $\pi_{l,d,s,p}^{p50} < -60s$ (50th percentile punctuality smaller than -60s)
4) Late departure: $\pi_{l,d,s,p}^{p50} > 180s$ (50th percentile punctuality greater than 180s)
5) Large variation in departure time: $\pi_{l,d,s,p}^{p85} - \pi_{l,d,s,p}^{p15} > 300s$ (85th percentile of punctuality minus 15th percentile of punctuality greater than 300s)
6) Punctuality change compared to previous stop: $|\pi_{l,d,s,p}^{p50} - \pi_{l,d,s_l^-,p}^{p50}| > 60s$ (absolute value of 50th percentile punctuality minus 50th percentile punctuality of previous stop greater than 60s)
7) Low speed: $v_{l,d,s,p}^{run,av} < 15\frac{km}{h}$ (average speed smaller than 15 km/h)
8) Large travel time compared to free flow: $t_{l,d,s,p}^{run,av} - t_{l,d,s,p=6}^{run,p15} > 60s$. Free flow is $t_{l,d,s,p=6}^{run,p15}$, which means the 15th percentile of the travel time on P = 6 (Sundays). (average runtime minus 15th percentile runtime on Sunday)

Criteria 1 and 2 are based on the aggregated dwell times with the average and percentiles. Criteria 3, 4, 5, and 6 are based on the aggregated punctualities with the percentiles. Criterion 7 is based on the aggregated speed with the average and criteria 7 and 8 are based on the aggregated run times with the average and percentiles. So if at least one of these eight criteria is met, there is a bottleneck. So for every tram line, the number of bottlenecks can be detected using this method. After the data has been aggregated at the data processing stage, the aggregated data can then be tested on these eight criteria to see whether there is a bottleneck or not.

## 2.4 Analysis and comparison of the tram lines concerning bottlenecks

Firstly the findings of the previous research, as was mentioned in the introduction, have been set out. After the results of the before analysis have been given, the steps, results, and explanation of the after analysis has been given. The comparison part is the interesting part because it shows how the situation of the number of bottlenecks of the trams in Amsterdam has changed after the implementation of the NZ-lijn. In the after analysis, the same method as the before analysis has been applied. The number of bottlenecks is presented. Also, the type of bottleneck is presented on a map with the tram stops and the type of bottleneck. These results has eventually been compared with the result of the before analysis. For the comparison part, explanations have been given of the differences, also additional numbers is provided to confirm the outcomes. Additional numbers such as customer ratings available from klantenbarometer which are a part of CROW [9], who is a knowledge institute for transport and other areas has been provided.

## 2.5 Conclusion

So the number of bottlenecks of the after analysis has been found with the method that has been described in chapter 2.3 by first processing the data to find the 15$^{th}$, 50$^{th,}$ and 85$^{th}$ percentiles and average of the dwell time, punctuality, run time and speed of the six different periods (AM peak, Interpeak, PM peak, Evening period, Saturdays and Sundays). After this the obtained aggregated data has then been tested on the eight bottleneck criteria that define whether there is a bottleneck or not. Then for the comparison, the results have been normalized, which means taking the average. The results have been looked at on the level of the whole network and at the level of the tram lines including the stops.

# 3 Analysis and comparison of the tram lines concerning bottlenecks

In this chapter, both sub-goals are discussed. First, the findings of the before analysis of the previous research will be given. After this, the findings of the after analysis will be shown. Furthermore, the before and after analysis will then be compared.

## 3.1 Before analysis results of the previous research

The before analysis [6] has been carried out in the previous research before the implementation of the NZ-lijn. In the paper that was mentioned in the introduction, a tool was developed to automatically detect bottlenecks. This method is mentioned in the methodology including the steps that should be taken to answer whether there is a bottleneck or not and thus obtaining the number of bottlenecks.

What was done in the previous research first, was processing the data. In this part, the realized dwell time, realized punctuality, run time, and speed was computed. To specify this further, the 15$^{th}$, 50$^{th,}$ and 85$^{th}$ percentiles and average of each of these four variables (dwell time, punctuality, run time and speed) were determined. Besides this, also these variables had to be computed for the six different periods (AM peak, interpeak,  PM peak, evening, Saturdays, and Sundays). This was the data processing part. After this part, the aggregated data that came out of the data processing part were then being tested on the eight criteria that were mentioned earlier in the methodology. From the testing, the number of bottlenecks was the result. These results are shown in Table 2 below. The eight criteria are shown on the top of the table and the six different periods are shown on the uttermost left of the table. As a remark. The last column of Table 2, "At least one criterion", is not a criterion. This is in fact how many times at least one of the eight criteria had been met during the testing.

*Table 2 Number of bottlenecks per period and per criterion*

| Period | Large dwell time | Large variation in dwell time | Early departure | Late departure | Large variation in departure time | Punctuality change compared to the previous stop | Low speed | Large travel time compared to free flow | At least one criterion |
|---|---|---|---|---|---|---|---|---|---|
| AM peak | 4 | 0 | 17 | 0 | 27 | 11 | 87 | 7 | 133 |
| Day period | 4 | 0 | 11 | 0 | 60 | 10 | 87 | 13 | 164 |
| PM peak | 14 | 0 | 29 | 0 | 102 | 17 | 99 | 21 | 219 |
| Evening | 7 | 0 | 20 | 0 | 18 | 7 | 67 | 0 | 109 |
| Saturdays | 10 | 0 | 12 | 0 | 66 | 11 | 76 | 10 | 158 |
| Sundays | 6 | 0 | 29 | 0 | 0 | 9 | 64 | 10 | 104 |

In table 2 the largest number of bottlenecks can be seen at the PM peak due to large variations in departure time. The highest number of bottlenecks can be seen at PM peak, compared to the other periods. PM Peak is defined as 4 PM – 6 PM on workdays. At this period, most people leave work for home and so a lot of people are waiting at the tram stops to take the tram. This contributes to large dwell times. As a consequence of the boarding and getting off the tram, most of the bottleneck criteria are met. Besides the overall number of bottlenecks of the tram network, the type of bottlenecks that occurred at the tram stops was also shown in the paper. In the methodology, the type of bottlenecks is mentioned. In figure 3, the location of the tram stops with the type of bottleneck is shown.

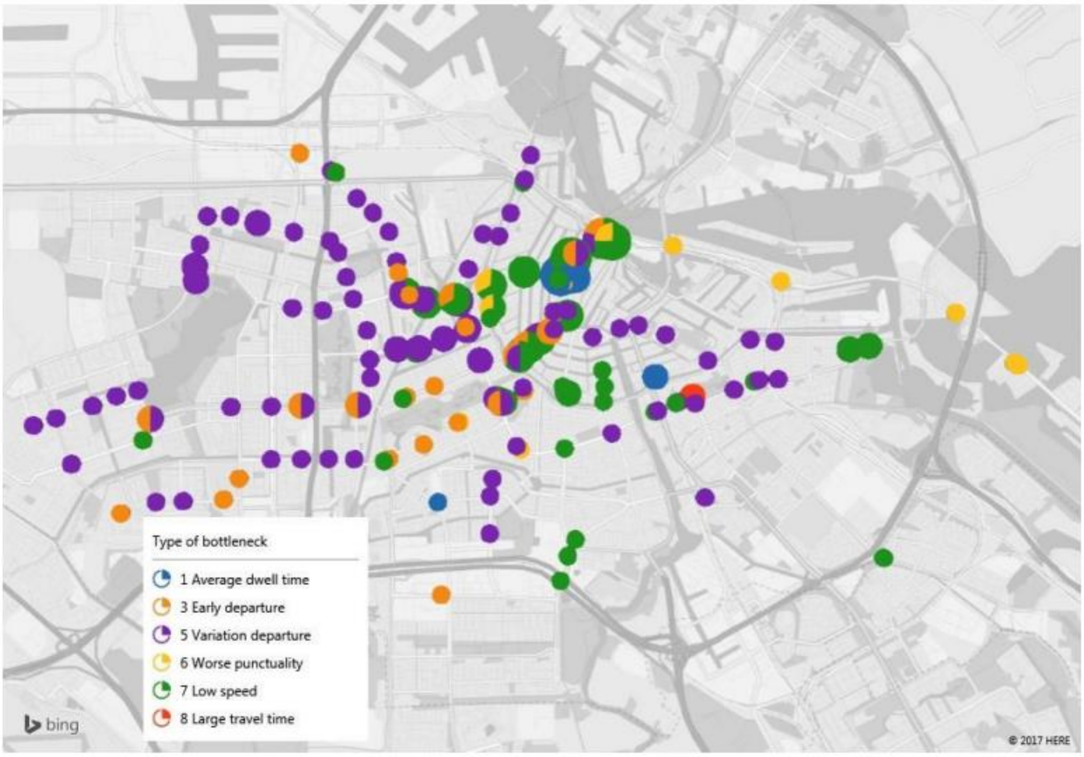


*Figure 3 Type of bottleneck at the tram stops.*

Mostly outside of the center, the variation in departure times is large, this is due to the low occupation at the tram stops and these places are not busy. But more in the center of Amsterdam, the speed of the trams are low, which causes bottlenecks in the center. The low speeds are a result of a lot of people that are in the center, so the tram driver must consider these pedestrians into their driving behavior. This results in delays and low speeds. Also, the occupation at the tram stops is high as well, which causes larger dwell times.

## 3.2 After analysis

The data processing asked for huge computer power because the dataset is large with almost 6 million rows of data. For some speed for the processing, computing in the cloud, google collaboration was used. There are a total of 14 tram lines, 1,2,3,4,5,7,11,12,13,14,17,19,24 and 26 (figure 4). The processing of each tram line took approximately 20 minutes. The data of the after situation consists of 41 days, but for comparison with the before situation 30 days of data out of the 41 days have been taken for consistency. The results of the number of bottlenecks are shown in table 3. The six different periods are on the left side of the table, and the eight criteria are at the top of the table.

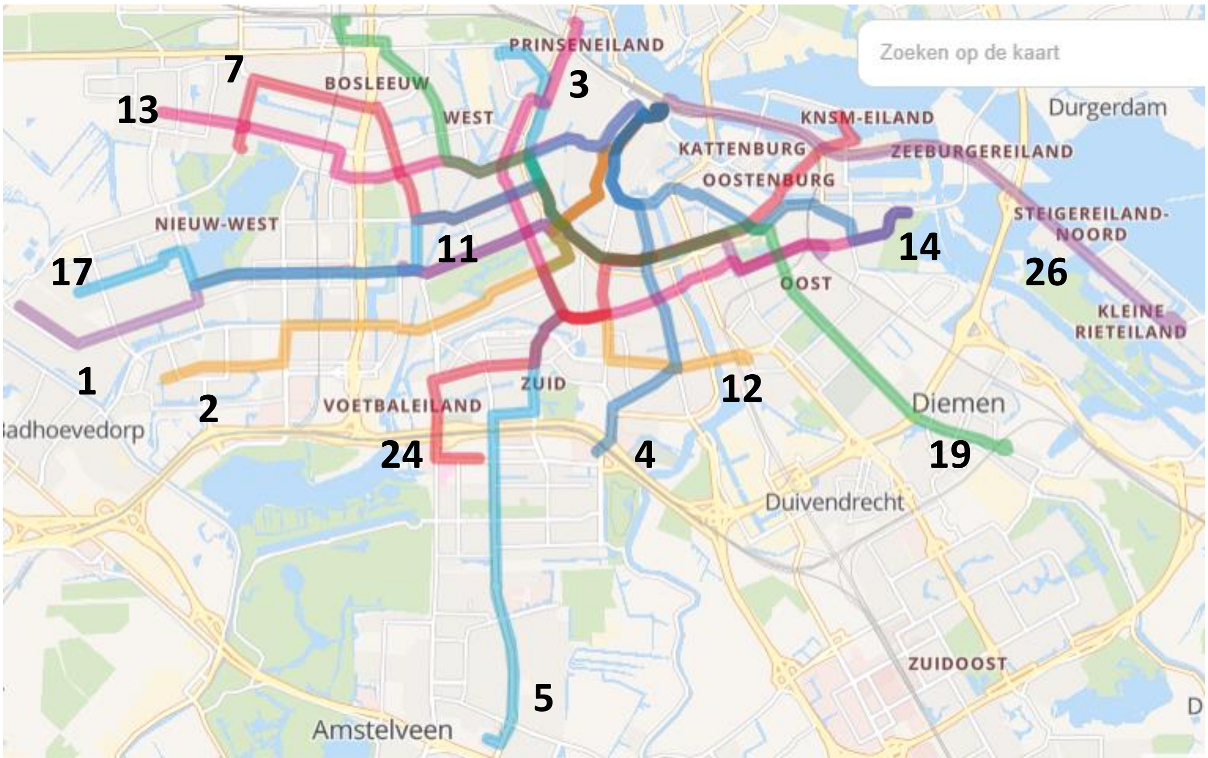


*Figure 4 Tramlines after the implementation of the NZ-lijn. [4]*

As a notice, the tram network of Amsterdam has changed, due to the implementation of the NZ-lijn. This includes dropping of tram lines 9,10 and 16 and the introduction of line 11 in the after situation [11]. But a large part of the tram network has stayed the same. Before the NZ-lijn, the trams were focused on the Central Station. After the NZ-lijn the trams are focused on feeding the NZ-lijn. So this holds that there are changes in the number and type of bottlenecks in the after situation. In the after analysis fourteen tram lines are analyzed with the tram stops as given in the AVL data.

*Table 3 Number of bottlenecks in the after situation*

| Period | Large dwell time | Large variation in dwell time | Early departure | Late departure | Large variation in departure time | Punctuality change compared to the previous stop | Low speed | Large travel time compared to free flow | At least one criterion |
|---|---|---|---|---|---|---|---|---|---|
| AM peak | 3 | 0 | 63 | 0 | 9 | 18 | 85 | 1 | 157 |
| Day period | 4 | 0 | 32 | 0 | 27 | 22 | 99 | 5 | 161 |
| PM peak | 7 | 0 | 109 | 0 | 25 | 27 | 105 | 6 | 225 |
| Evening period | 3 | 1 | 40 | 0 | 25 | 15 | 92 | 0 | 152 |
| Saturdays | 5 | 0 | 38 | 0 | 2 | 17 | 100 | 0 | 150 |
| Sundays | 3 | 0 | 22 | 0 | 20 | 18 | 99 | 0 | 148 |

In table 3, there are no bottlenecks due to late departures at all periods. A lot of bottlenecks are caused due to low speeds and early departures. Due to large variations in dwell time, the least bottlenecks have occurred. The largest number of bottlenecks occur in the PM peak due to early departures. Concerning the periods, Sundays have the least bottlenecks compared to the other periods, this could be caused by a low number of people in the city or that not a lot of people take the tram. So the period where the service of the tram is hight, is on Sundays. The trams perform worse during PM peak times (4 PM-6 PM). During the PM period, a lot of people are waiting at the tram stops and also a lot of people leave work for home, which causes busy streets and busy stops.

By comparing table 2 and table 3 at first sight, it can be concluded that mostly an increase in early departure bottlenecks and a decrease in large variations in departure time bottlenecks can be seen. This has different causes and these are different per stop. In the following, explanations will be given for this and also of other differences between tables 2 and 3.

The type of bottleneck for every tram stop of every tramline of every period together is shown in figure 5. The stops where there are no bottlenecks are not shown on the map. The colors show which type of bottleneck occur(s) at the specific tram stop. As can be seen is that mostly bottlenecks due to early departure (green), low speed (black), and large departure time variation (pink) occur. Especially the bottleneck due to early departure (green) can be seen largely. More in the center of Amsterdam a mixture of low speeds and early departures are the cause of bottlenecks. A large cluster of bottlenecks due to low speeds can be observed at Leidseplein (location A in figure 5), at Centraal Station (location B in figure 5) and Dam (location C in figure 5). At these three stops, a lot of transfer happens. At Centraal Station (location B) also train, metro, and the bus stop there. Furthermore, a lot of pedestrians are at these three locations, A, B, and C. The tram drivers have to take pedestrians into account because a lot of pedestrians cross the path of the rails there and so the tram drivers have to wait for these pedestrians to pass.

Aside from these three locations, most of the tram stops at the beginning of the tram line, so from the first tram stop from a tram line, have low speeds (indicated with black in figure 5). One of the reasons behind this is that it is not busy at these stops and these stops are mostly outside of the center of Amsterdam and so the tram drivers presumably do not keep up to the planned times. As a consequence of these low speeds (black dots), the planned times at the next stops are not met and so the drivers have to leave much earlier (indicated with green dots) to arrive on time at the following stop. Eventually, an accumulation of bottlenecks is the result.

So the main findings of the after situation are:

- A large cluster of trams that have low speeds at the locations Leidesplein (location A in figure 5), Centraal Station (location B in figure 5), and Dam (location C in figure 5).
- Most of the tram lines have low speeds at the beginning of a tram ride.
- The largest number of bottlenecks occur in the PM peak. Especially early departure cases have occurred a lot.

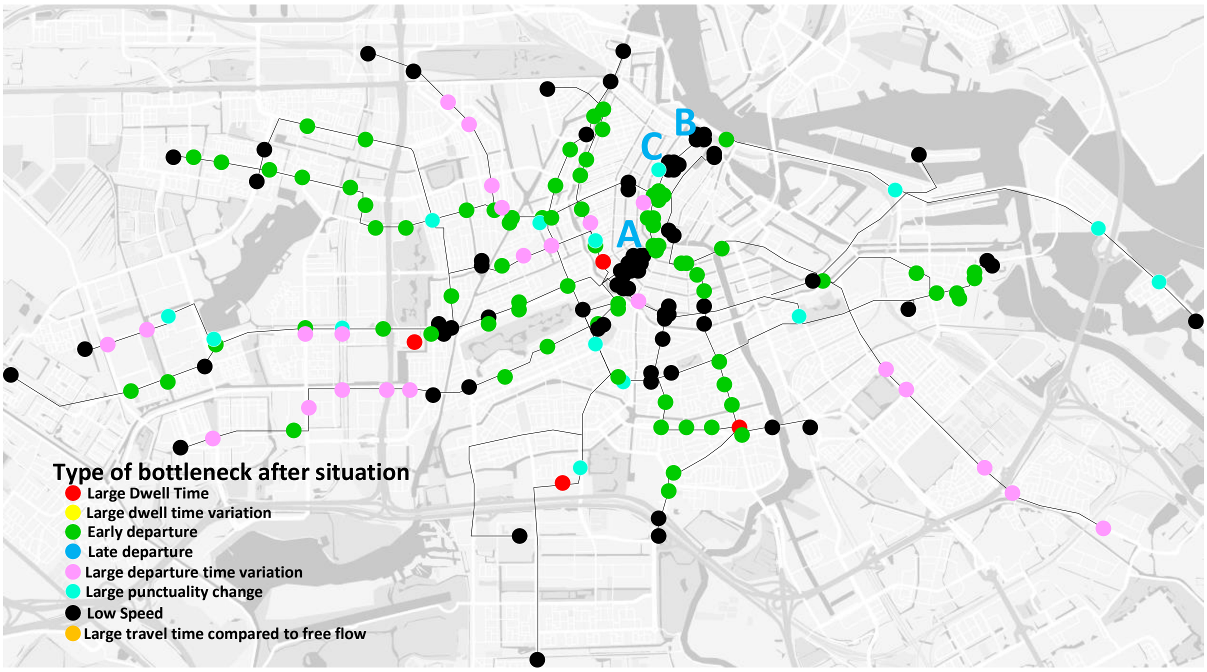

*Figure 5 Map of tramlines with the stops and the type of bottleneck*

## 3.3 Comparison

There are some remarks here. As was said before, 30 days of data out of the 41 days of data of the after situation has been taken for the analysis to have consistency in comparing the before and after situation. For the after analysis, other code is written. If the data of the before situation is analyzed with the same code, not completely the same results are produced as table 2 (results of the before analysis). The results of the before situation with the code of the after analysis is shown in table B, which is in the appendix. Only the tram lines and stops are included in the comparison that is both in the before and after situation.

In this chapter, firstly, the four different aspects namely, dwell time, punctuality, run time and speed will be analyzed of the whole tram network and also of the tramlines separately. After that, the bottlenecks will be analyzed of the whole tram network and also of the tram lines separately.

### 3.3.1 Analyzing dwell time, punctuality, runtime, and speed of the whole tram network and tramlines of the before and after situation.

The four service reliability aspects dwell time, punctuality, runtime, and speed are looked at in this chapter. In table 4 the overall performance of the tram network of these four aspects is shown. Especially punctuality has decreased a lot in the after situation. Normally if the tram would strictly follow the scheduled times, the punctuality would be 0. Every other number greater or smaller than 0, means a deviation from the schedule. So the punctuality in the after situation has decreased, which means an improvement in the service reliability aspect punctuality. A reason for punctuality to have improved a lot is because fewer people have taken the trams. Before the NZ-lijn approximately 47% took the tram and after the NZ-lijn approximately 40% took the tram. [4] So this could indicate that trams have left earlier because fewer people have boarded the trams or have gotten off the trams. In the after and before situation, dwell time, runtime, and speed have mostly stayed the same. A reason for this is that a lot of tramlines have stayed the same including the tram stops. Speed is related to the run time (time that it takes to go from one stop to the next) and distance between two stops. Dwell time is the time that a tram is at a station (the difference between arrival and departure at a station). So if most of the tram lines including stops have stayed the same, also run time and speed, and dwell time has stayed approximately the same.

*Table 4 Before and after situation concerning dwell time, punctuality, runtime, and speed.*

| | Before situation | After situation |
|---|---|---|
| Realised dwell time | 23.5 seconds | 22.93 seconds. |
| Realised punctuality | 39.25 seconds | 25.12 seconds |
| Run time | 72.46 seconds | 73.77 seconds |
| Speed | 22.25 km/h | 22.06 km/h |

If the tram lines are looked at separately, figure 6 is obtained for the differences between the before and after situation of the four service reliability aspects. The following can be concluded based on figure 6 and table 4:

- The punctuality has decreased a lot in the after situation. Approximately 14 seconds. So this means an improvement in the service reliability aspect punctuality of the tram lines.
- The other aspects, dwell time, run time, and speed, have stayed approximately the same.
- Tram line 4 and tram line 14 however show an increase in the punctuality of respectively 7 and 10 seconds.
- Dwell time has increased at tram line 2, 12, 13, 14, 17, and 26. But these are small. As can be seen, the increase is approximately 1 second.

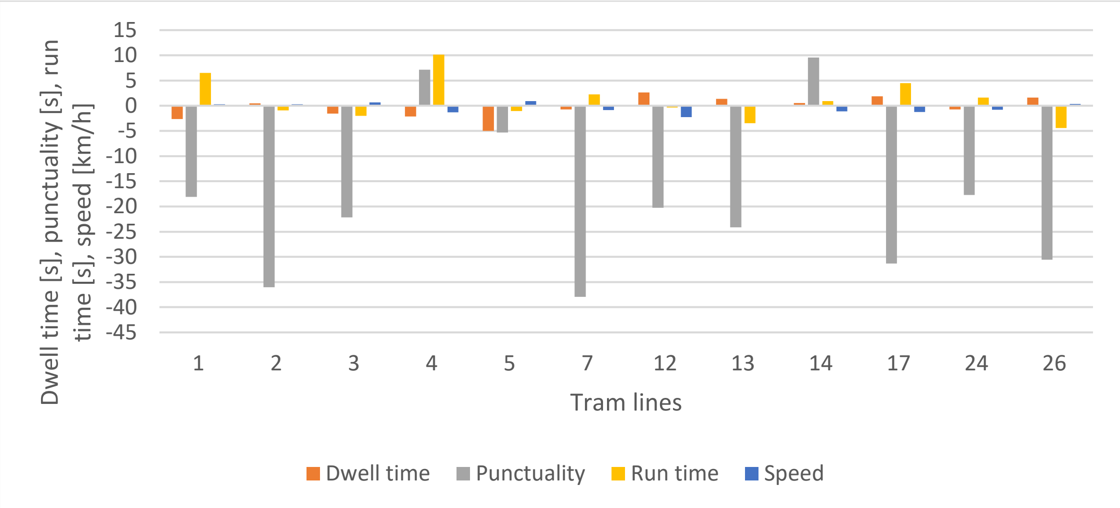


*Figure 6 Difference between after and before situation concerning average dwell time, punctuality, run time, and speed of the tramlines.*

### 3.3.2 Analyzing the number of bottlenecks of the before and after situation of the whole network and tramlines.

For comparison goals, the results of table 2 and table 3 have been normalized, which means the results of the before analysis and the after analysis of every period have been divided by the number of days that are in the dataset, in other words, the average. The numbers that are in the periods AM peak, Day period, PM peak, Evening period have all been divided by 22, because of 22 workdays. And the numbers at the periods Saturdays and Sundays have all been divided by four because of four Saturdays and four Sundays in the timespan of the 30 days of data. The normalized values of the before and after results are shown in Table C and D in the appendix. The difference between the normalization of the before and after analysis results is shown in table 5. So all the values in this table are the average bottlenecks per day and have been rounded to zero decimals.

*Table 5 Normalized difference between after and before results.*

| Period | Large dwell time | Large variation in dwell time | Early departure | Late departure | Large variation in departure time | Punctuality change compared to the previous stop | Low speed | Large travel time compared to free flow | At least one criterion |
|---|---|---|---|---|---|---|---|---|---|
| AM peak | 0 | 0 | 2 | 0 | -1 | 0 | 0 | 0 | 1 |
| Day period | 0 | 0 | 1 | 0 | -2 | 0 | 0 | 0 | -1 |
| PM peak | 0 | 0 | 4 | 0 | -3 | 0 | 0 | -1 | 0 |
| Evening | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| Saturdays | -1 | 0 | 7 | 0 | -16 | 2 | 4 | -3 | -5 |
| Sundays | -1 | 0 | -6 | 0 | 1 | 0 | 3 | -2 | 2 |

As can be seen, is the difference between the average of the after and before analysis results. In this table, we see that the bottlenecks in the after situation have indeed gone down, because a lot of numbers in the table are negative, which indicates that the number of bottlenecks has gone down after the implementation of the NZ- lijn. The bottlenecks due to late departure and large variation in dwell time have zero bottlenecks. In the before situation, this was already the case (table 2). Furthermore at the bottleneck criteria "Large dwell time", and "Large travel time compared to free flow", only decreasing and no change of bottlenecks can be seen. Especially bottlenecks due to large variation in departure time on Saturdays have decreased a lot with an average of 16 bottlenecks per day. But also in this same period, an increase of average 7 bottlenecks per day has occurred due to early departures. The most unstable period concerning service reliability is the period Saturdays where an average of 13 bottlenecks per day increase and 20 bottlenecks per day decrease is noted. With unstable is meant that there are large increasing and decreasing of bottlenecks.

Furthermore, bottleneck occurrences due to early departures, an increase is noted at all periods except on Sundays. An explanation for the increase is that at some tram stops not a lot of people are there and so not many people board the tram, which contributes to shorter times that the tram is at the stop. As a result, the tram driver leaves much earlier and so there are deviations in the schedule. Also on Saturdays and Sundays, an increase of respectively 4 and 3 can be noted of low-speed occurrences. Low speeds bottleneck occurs when the average speed of the tram is lower than 15 km/h according to the criterion mentioned in chapter 2. So an increase of an average of 4 bottlenecks per day on Saturday means, that per Saturday the speed of the trams was on four more occasions smaller than 15 km/h, in other words, low speeds.

As said before, there is a large decrease in bottlenecks due to large variation in departure time on Saturdays of 16. This criterion is defined as $\pi_{l,d,s,p}^{p85} - \pi_{l,d,s,p}^{p15} > 300s$ (85$^{th}$ percentile punctuality minus 15$^{th}$ percentile punctuality larger than 300 s). So the decrease of 16 bottlenecks means that the number of bottlenecks due to large variation in departure time has decreased with an average of 16 per Saturdays. Not an accumulation of 16 for every following Saturday, but per Saturday the decrease is 16. This is a huge improvement in the service for customers because this means that the trams meet the tram schedule more and customers will be more satisfied. Also, a decrease of 6 bottlenecks due to early departure can be seen on Sundays. Also, this is an improvement in the service of the trams. Early departure is the criterion $\pi_{l,d,s,p}^{p50} < -60s$ (50$^{th}$ percentile punctuality smaller than -60 s).

The main findings of the differences based on table 5 are:
- An overall decrease in the number of bottlenecks in the after situation.
- No bottlenecks due to late departure and variation in dwell time.
- Increase in the number of bottlenecks due to early departure except on Sundays were the bottlenecks have decreased with six.
- The number of bottlenecks due to large variation in departure time has decreased with an average of 16 on Saturdays.
- On Saturdays and Sundays, there is an increase of respectively 4 and 3 low speed bottlenecks.
- The most unstable period concerning service reliability is the period Saturdays where an average of 13 bottlenecks per day increase and 20 bottlenecks per day decrease is noted

Now that the performance concerning bottlenecks of the whole tram network is known, the network will now be looked at on the level of the tram lines including tram stops. In figure 7, only the changes of the tram lines and stops are shown which were in 2017 and 2018. The changes are based on the averaged values. The stations where there are no changes in the number of bottlenecks are not shown.

As can be seen, is that there is mostly a decrease in the number of bottlenecks, indicated with green. There are certain places where bottlenecks have increased. These can be seen at lines 4 and 13 (figure 8). At these tram lines, early departures are the causes of bottlenecks. Also, tram line 12 (figure 8) partly has an increase in the number of bottlenecks but also a decrease in the number of bottlenecks. At tram line 12, early departures are also the causes of bottlenecks.

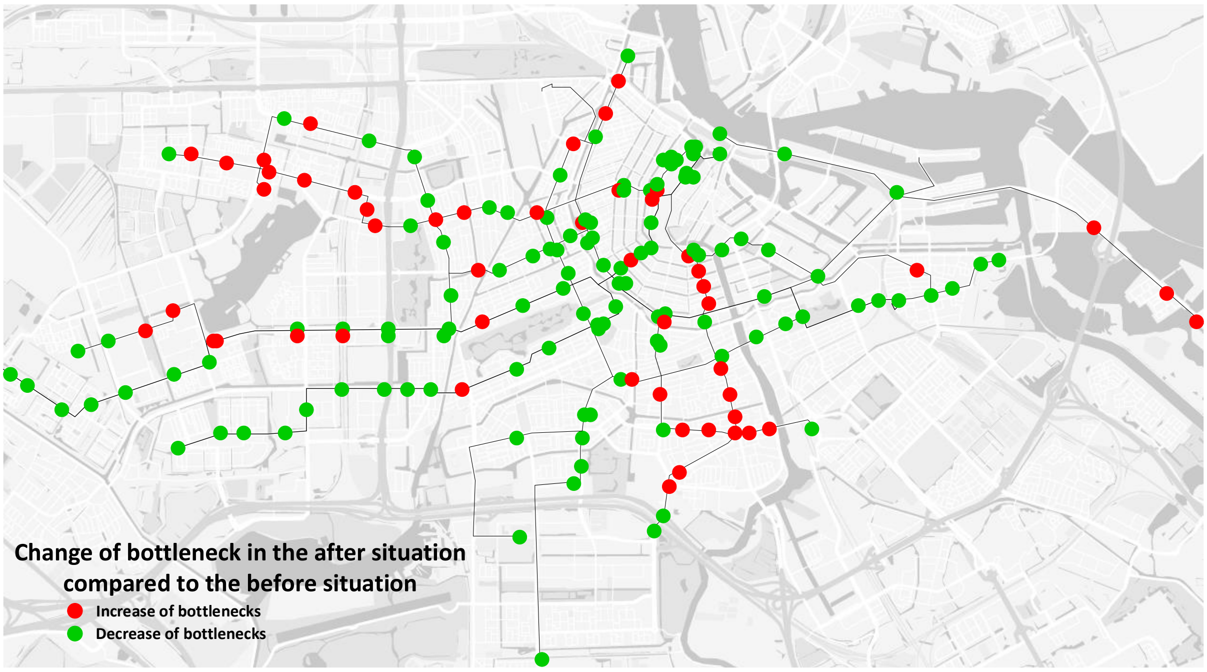

*Figure 7 Changes in the bottlenecks of tram lines compared to the before situation. Increase or decrease.*

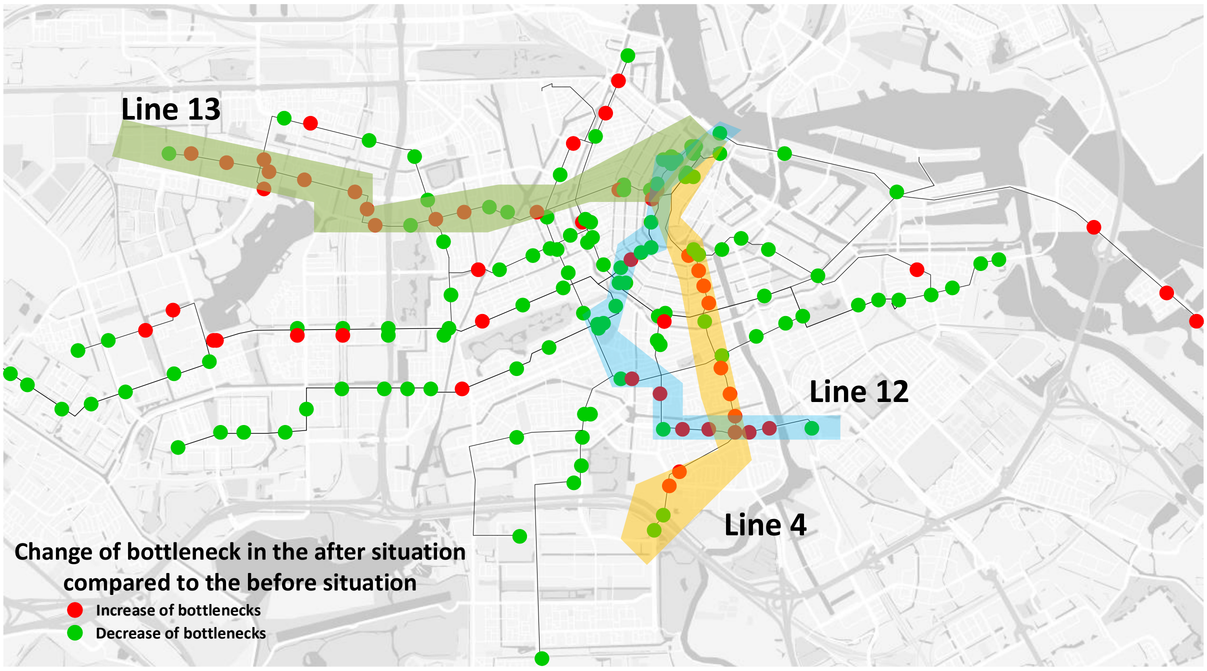


*Figure 8 Line 4, line12 and Line 13*

The main findings of the differences based on figure 7 and 8 are:

- An overall decrease in the number of bottlenecks of the tram lines
- Increase of bottlenecks at a large part of the tram lines 4, 12, and 13. The increase of bottlenecks at these tram stops is mostly, because of early departures.

### 3.3.3 Additional numbers

An indication of whether a service has improved or not is the customer's rating. If the ratings have gone up compared to the previous rating, this means that the service has improved.

According to GVB [11], the rating for the tram, metro, and the ferry has gone up from 7.5 in 2017 to 7.7 in 2018. That is a small increase. That minimal increase could be caused probably because more people use the NZ-lijn and so more space is available inside the trams. Another explanation for the minimal increase is that because of the small increase of the bottlenecks, people still are not heavily satisfied with the tram service. So the increase in rating is a confirmation on the obtained results of this research, whereby the number of bottlenecks has decreased and thus the service of the trams has increased.

## 3.4 Conclusion

In chapter 3, the analysis and comparison of the tram lines concerning bottlenecks have been carried out for the after situation, after which the results were then compared to the before situation. If the overall situation is looked at, then the conclusion is that the number of bottlenecks has decreased in the after situation, so the situation after the implementation of the NZ-lijn. The decrease can also be seen on the level of the tramlines. Furthermore dwell time, runtime and speed have stayed approximately the same in the before and after situation of the overall network and the tram lines. But the punctuality has decreased a lot in the after situation on the overall network and also on the level of the tram lines.

# 4 Conclusion

## 4.1 Findings

In this chapter, the most important findings are mentioned. With “most important findings” is meant, that the findings are present a lot or that differences are large concerning times and bottlenecks. All the findings can also be found in chapter 3.3. The findings of the before analysis are not mentioned here. Only the findings of the after analysis and the findings of the comparison between the before and after analysis are mentioned here.

These are the main findings:

- An overall decrease in the number of bottlenecks in the after situation of the whole tram network and the tram lines separately. But an Increase of bottlenecks due to early departures at a large part of the tram lines 4, 12, and 13 has been noted.
- The largest number of bottlenecks occur in the PM peak. Especially early departure cases have occurred a lot.
- The largest decrease in the number of bottlenecks has been on Saturdays with an average of 16 bottlenecks per day which was caused due to large variation in departure time.
- The most unstable period concerning service reliability is the period Saturdays where an average of 13 bottlenecks per day increase and 20 bottlenecks per day decrease is noted.
- A large cluster of trams that have low speeds has been noted at the locations Leidesplein (location A in figure 5), Centraal Station (location B in figure 5), and Dam (location C in figure 5).
- Punctuality has decreased a lot in the after situation of the whole tram network, approximately 14 seconds, whereas the other aspects, dwell time, run time, and speed, have stayed approximately the same. Tram line 4 and tram line 14 however show an increase in the punctuality of respectively 7 and 10 seconds.

**Overall conclusion**

After the implementation of the NZ-lijn, the service reliability of the tram network of Amsterdam has improved concerning the number of bottlenecks. This can also be seen in the customer ratings that have gone up from 7.5 in 2017 (before the NZ-lijn) to 7.7 in 2018 (after the NZ-lijn) [11].

## 4.2 Discussion

**Remark on the previous research.**

A sensitivity analysis in the previous was carried out to see what impact the numbers in the eight bottlenecks criteria would have if they would be changed. In the previous research, these numbers are called alfa values. And they indeed cause changes. So it is important to have values that would function as a guideline for checking bottlenecks.

**Other factors that can have an impact on the number of bottlenecks.**

In this research, only the times and speed were included for analyzing the number of bottlenecks of the tram network of Amsterdam. Also, other factors can have an impact on the number of bottlenecks such as weather conditions, rail or carriage or stop maintenance, etc. So to obtain much more accurate numbers concerning bottlenecks, other factors have to be included as well.

**Comparison of the before and after situation**

The comparing of the before and after situation was based on AVL-data. For the before situation, the AVL-data of whole November 2017 was used and for the after situation the AVL-data of the 10th September 2018 till the 21st of Oktober 2018 was used. So the dataset is different concerning the number of days that are in the before situation data and in the after situation data respectively 30 and 41 days. Also, the months of the data are different. Furthermore in the before dataset, 1.9 million rows of information is there, and in the after situation dataset approximately 6 million rows of information. So for comparing it would be handier to compare the data of the same month(s) but different years and also the same number of days. In this research 30 days of data were taken from the 41 days of data for the after analysis and afterward the results of the analysis were compared to the before analysis results.

## 4.3 Further research

The model that was built for this research to analyze the tram network of Amsterdam concerning the number of bottlenecks is limited which means that only times and speeds were the input values. But this research can be seen as a starting for further research. For further research, the recommendation would be to build a model in which many more variables are included to have better representative values for the number of bottlenecks for the tram network of Amsterdam.

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# Appendix

*Table A Part of the excel dataset of the after situation.*

| Datum | Volgende_Dag_Indicator | Lijn_Nummer | Richting | %Rit_Id | Rit_Nummer | Deelrit_Indicator | Halte_Volgnummer | Halte_Naam | Halte_Code | Voertuigtype_Id | Grootwagen_Nummer |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/10/2018 | JA | 1 | H | 3535227 | 665 | Nee | 1 | Matterhorn | 4402 | 14 | 2106 |
| 1/10/2018 | JA | 1 | H | 3535227 | 665 | Nee | 2 | Pilatus | 4404 | 14 | 2106 |
| 1/10/2018 | JA | 1 | H | 3535227 | 665 | Nee | 3 | Inaristraat | 4406 | 14 | 2106 |
| 1/10/2018 | JA | 1 | H | 3535227 | 665 | Nee | 4 | Ecuplein | 4408 | 14 | 2106 |
| 1/10/2018 | JA | 1 | H | 3535227 | 665 | Nee | 5 | Baden Powellweg | 4410 | 14 | 2106 |

| Aankomsttijd_Gepland | Vertrektijd_Plan | Aankomsttijd_Gerealiseerd | Vertrektijd_Gerealiseerd | Aantal_Seconden_Aankomsttijd_Cumulatief_Gepland | Aantal_Seconden_Vertrektijd_Cumulatief_Gepland | Aantal_Seconden_Aankomsttijd_Cumulatief_Gerealiseerd | Aantal_Seconden_Vertrektijd_Cumulatief_Gerealiseerd | Geschikt_Voor_Rijtijdanalyse_Halte_Indicator | Geschikt_Voor_Rijtijdanalyse_Rit_Indicator |
|---|---|---|---|---|---|---|---|---|---|
| 0:43:00 | 0:01:00 | 0:37:15 | 0:01:09 | 0 | 0 | 0 | 0 | Ja | Ja |
| 0:43:00 | 0:01:00 | 0:37:15 | 0:01:09 | 42 | 43 | 67 | 67 | Ja | Ja |
| 0:43:00 | 0:01:00 | 0:37:15 | 0:01:09 | 97 | 115 | 124 | 139 | Ja | Ja |
| 0:43:00 | 0:01:00 | 0:37:15 | 0:01:09 | 169 | 187 | 205 | 205 | Ja | Ja |
| 0:43:00 | 0:01:00 | 0:37:15 | 0:01:09 | 242 | 260 | 253 | 253 | Ja | Ja |

*Table B Number of bottlenecks of the before situation, based on the code of the after analysis.*

| Period | Large dwell time | Large variation in dwell time | Early departure | Late departure | Large variation in departure time | Punctuality change compared to the previous stop | Low speed | Large travel time compared to free flow | At least one criterion |
|---|---|---|---|---|---|---|---|---|---|
| AM peak | 4 | 0 | 15 | 0 | 26 | 14 | 91 | 7 | 140 |
| Day period | 4 | 0 | 10 | 0 | 60 | 13 | 102 | 14 | 181 |
| PM peak | 14 | 0 | 29 | 0 | 101 | 17 | 102 | 21 | 231 |
| Evening | 7 | 0 | 19 | 0 | 18 | 8 | 77 | 0 | 122 |
| Saturdays | 10 | 0 | 12 | 0 | 65 | 11 | 83 | 10 | 169 |
| Sundays | 6 | 0 | 44 | 0 | 17 | 19 | 89 | 8 | 142 |

*Table C Normalised before analysis results.*

| Period | Large dwell time | Large variation in dwell time | Early departure | Late departure | Large variation in departure time | Punctuality change compared to the previous stop | Low speed | Large travel time compared to free flow | At least one criterion |
|---|---|---|---|---|---|---|---|---|---|
| AM peak | 0 | 0 | 1 | 0 | 1 | 1 | 4 | 0 | 6 |
| Day period | 0 | 0 | 0 | 0 | 3 | 1 | 5 | 1 | 8 |
| PM peak | 1 | 0 | 1 | 0 | 5 | 1 | 5 | 1 | 11 |
| Evening | 0 | 0 | 1 | 0 | 1 | 0 | 4 | 0 | 6 |
| Saturdays | 3 | 0 | 3 | 0 | 16 | 3 | 21 | 3 | 42 |
| Sundays | 2 | 0 | 11 | 0 | 4 | 5 | 22 | 2 | 36 |

*Table D Normalised after analysis results.*

| Period | Large dwell time | Large variation in dwell time | Early departure | Late departure | Large variation in departure time | Punctuality change compared to the previous stop | Low speed | Large travel time compared to free flow | At least one criterion |
|---|---|---|---|---|---|---|---|---|---|
| AM peak | 0 | 0 | 3 | 0 | 0 | 1 | 4 | 0 | 7 |
| Day period | 0 | 0 | 1 | 0 | 1 | 1 | 5 | 0 | 7 |
| PM peak | 0 | 0 | 5 | 0 | 1 | 1 | 5 | 0 | 10 |
| Evening | 0 | 0 | 2 | 0 | 1 | 1 | 4 | 0 | 7 |
| Saturdays | 1 | 0 | 10 | 0 | 1 | 4 | 25 | 0 | 38 |
| Sundays | 1 | 0 | 6 | 0 | 5 | 5 | 25 | 0 | 37 |