Improving public-transport access to Eindhoven Airport

Accomodating future public transport demand to the region

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by

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Preface

This thesis is written as the final project at the end of the Civil Engineering bachelor degree. It is part of the domain Transport and Planning and it will cover the problem regarding the accessibility of Eindhoven Airport with public transport. I came up with this topic as I personally experienced multiple times that it is a hassle getting tot the airport with public transport. After some reading up on the topic I discovered that this was a much bigger problem with the growth of the Brainport Industries Campus.

This thesis challenged me especially at the start. Although I had ideas early on, I found it difficult to translate them into a clear research direction and structure. After a few weeks, the ideas started to flow, but even then, putting them into a coherent and concise report remained a challenge. Looking back, this process taught me the value of persistence, feedback, and iterative thinking.

I would like to thank my supervisors, Yufei Yuan and Srinath Mahesh for their feedback every week, as well as my fellow students that reviewed my work every week and gave feedback.

Derk Verhees
Delft, June 2025

Summary

This thesis investigates how public transport to Eindhoven Airport can be improved to accommodate the expected increase in travel demand to the region, which is primarily driven by two developments: The expansion of Eindhoven Airport's terminal and the substantial growth of the Brainport Industries Campus (BIC), where ASML is planning on opening a new office employing approximately 20,000 people. These plans are expected to cause a significant rise in daily passenger and commuter demand, pressuring the current public transport system, which relies primarily on buses and lacks a direct train connection.

This research aims to address this problem by investigating the following research question:

> *"How should the public transport to Eindhoven Airport be improved to accommodate the increasing demand of the region?"*

To answer this question, five sub-questions were formulated, covering reference cases at European airports, regional growth projections, demand estimation, public transport mode evaluation and implementation ideas.

The report combined a stakeholder analysis, literature study, demand analysis, and a Multi-Criteria Analysis (MCA) using the Analytic Hierarchy Process (AHP). The literature review explored three different European Airports to inform about potential costs and implementation time for their train based solutions (Brussels, Schiphol and Stuttgart), as well as the expected expansion plans of ASML at the BIC, and the technical characteristics of five possible public transport solutions: Bus Rapid Transit (BRT) system in the form of the Brainportlijn, Light Rail Transit (LRT) system, Metro system, a train station at Acht (part of Eindhoven nearby), and an underground train station at Eindhoven Airport. Based on terminal size and employment estimates, the total public transport demand during the evening peak hour was estimated between 6,600 and 7,000 passengers, combining airport users and ASML commuters.

The MCA evaluated each transport mode based on six criteria: capital cost, capacity, environmental emissions, construction impact, implementation time, and system efficiency. Stakeholder interest were taken into account to conduct the pairwise comparisons to assign relative weights to each criterion. System efficiency was considered the most important, followed by capacity, implementation time, capital cost, with environmental impact and construction impact deemed less important but important nonetheless.

The results showed that the train station at Acht, combined with a BRT or shuttle system was the most suitable option for the near future. It scored higher than average across the board, due to existing infrastructure and proximity to the airport. The underground train station at the airport ranked second due to its direct terminal access and high efficiency, but its high cost and long implementation time made it less practical in the short term. BRT and LRT were viable mid-range alternatives, while the metro line was considered unrealistic for the region's current scale.

Contents

1 Introduction

Eindhoven Airport, the second biggest airport in the Netherlands, plays a big role in both regional and international connectivity. The airport is located in the heart of the Brainport region, a high-tech innovation hub in the Netherlands. The airport enables business travel between countries that are in the innovation business [22]. As both Eindhoven Airport and Brainport continue to grow, the strategic importance also increases.

However despite the growing importance, Eindhoven Airport does not have a direct train connection and is only accessible by car or bus services. From Eindhoven itself, the airport is relatively easy to reach thanks to the frequent bus services [6]. However, if travelers come from different cities within the Netherlands, the journey is often longer and less convenient if they decide to use public transportation. They need to take a train, transfer at Eindhoven station, and take a bus to reach the airport [1]. This multi-modal journey might discourage passengers and cause them to still rely on driving their own cars to the airport, and this is not in line with the goals to decrease the use of private transport and make travel more sustainable [23].

At the same time, the region is looking at a major increase in public transport demand. The Brainport Industries Campus (BIC) is located right next to the airport. The BIC is planning to add a 225,000 square-meter building as part of their phase two plan and construction is starting this year [21]. ASML is planning on opening an office on the north side of the campus that creates approximately 20,000 jobs [18]. For now ASML will be the biggest contributor to the public transport demand. As other companies start settling on the campus the need to update the public transport network to the airport becomes even more relevant.

This thesis focuses on how public transport to Eindhoven Airport should be improved to handle the future demand from the airport itself and the Brainport Industries Campus. By combining demand analysis and Multi-Criteria-Analysis the thesis aims to provide a possible solution to the growing demand of the region.

1.1. Problem description

The airport was originally designed to handle about 5 million passengers per year, but in 2023 and 2024 the airport received approximately 6.3 million passengers. Which prompted the airport to start expanding the terminal from 26,000 to 38,000 square meters [7] [13]. As stated, the Brainport Industries Campus will be a big contributor to the future demand in the region [19]. For example ASML is planning to open a big new office on the Brainport Industries Campus that creates 20,000 new jobs [18]. With 17,000 people working on site and their ambition that 30% of them will use public transport, it equates to 3,723,000 passengers yearly for the public transport network [12]. Together with the developments for the expanded terminal, the total amount of passengers that might use public transport will exceed 5 million per year and will possibly grow even more in the future. These developments create a need for an improved public transport network for the region that is efficient, has enough capacity and is future proof.

1.2. Research question

The research question for this thesis is: ”How should the public transport to Eindhoven Airport be improved to accommodate the increasing demand of the region?”. To answer this question, the following sub questions are used:

- ”What can be learned from similar airport rail projects about the cost, implementation, and performance of an underground train station at Eindhoven Airport?”
- ”What are the growth plans for ASML at the Brainport Industries Campus for the near future?”
- ”How much will the demand for public transport to Eindhoven Airport and Brainport Industries Campus increase in the next 5-10 years?”
- ”What transport methods can accommodate this demand?”
- ”How can the preferred transport method be implemented?”

These sub-questions guide the research in a structured way. The first two provide reference projects and projected growth in the region, this is mainly be done through a literature study. The third sub-question focuses on quantifying demand for the public transport network. The fourth sub-question explores different transport methods that will be able to handle the demand found in sub question three. Then using a Multi-Criteria-Analysis the best fit is found. The last sub-question will give a brief explanation on how this solution can be implemented in the region. Each sub-question is answered in separate chapters as outlined in the methodology.

1.3. Stakeholders

The stakeholders for this report are made up of a mix of institutions, companies and users. They are stated and explained below. At the end of each stakeholder description is a relative power assigned that will be used later.

1. **Province of Noord-Brabant:** The province is the regional decision maker for public transport planning, funding and integration. It holds both high power and high interest, as it finances mobility projects like this and does the coordination between local and national stakeholders.Power = 3
2. **Ministry of Infrastructure:** The Ministry holds the highest power due to its control over national infrastructure funding. However, its interest is moderate on specific regional projects, unless it aligns with national priorities. Power = 3
3. **Eindhoven Airport:** The airport has high interest in improving the accessibility of the airport for its passengers. Its power is moderate, it controls terminal infrastructure and is part of the Schiphol Group so it has some national leverage, but it depends on public authorities for approving the projects. Power = 2
4. **Municipality of Eindhoven:** The municipality controls spatial planning and road infrastructure, giving it moderate to high power in determining how and where new public transport infrastructure can be implemented. It’s interest is high, especially in light of city-wide sustainability and accessibility goals. Power = 2
5. **BIC / ASML:** ASML and the broader Brainport region are major demand generators for mobility, with growing commuter volumes. They have high interest and increasing indirect power, primarily through political influence and their strategic economic importance to the region. Power = 2
6. **NS / ProRail:**NS and ProRail are the national rail operators and have high power over rail based solutions, but have low to moderate interest unless a specific rail based plan is proposed. Power = 2
7. **Hermes (Bus operator):** Hermes is the regional operator of public buses, including the airport shuttle. While it has low power, it holds moderate interest as it directly implements any changes and interacts with passengers daily. Power = 1

8. **BIC employees:** Employees commuting to ASML and Brainport locations have a strong interest in fast, reliable public transport. Their power is low, but they represent a significant part of the demand in the region. Power = 1

9. **Residents:** Residents living along or near proposed transport corridors have moderate to high interest, depending on their dependence on public transport and concern for quality of life. Their power is low, but they can influence decisions through public participation or complaints. Power = 1

10. **Travellers of airport:** Travelers have high interest, as they directly benefit from improved access and frequency. However, their power is low, unless represented through surveys, political advocacy, or customer satisfaction feedback. Power = 1.

The power and interest positions of each of the stakeholders is shown in figure 1.1.

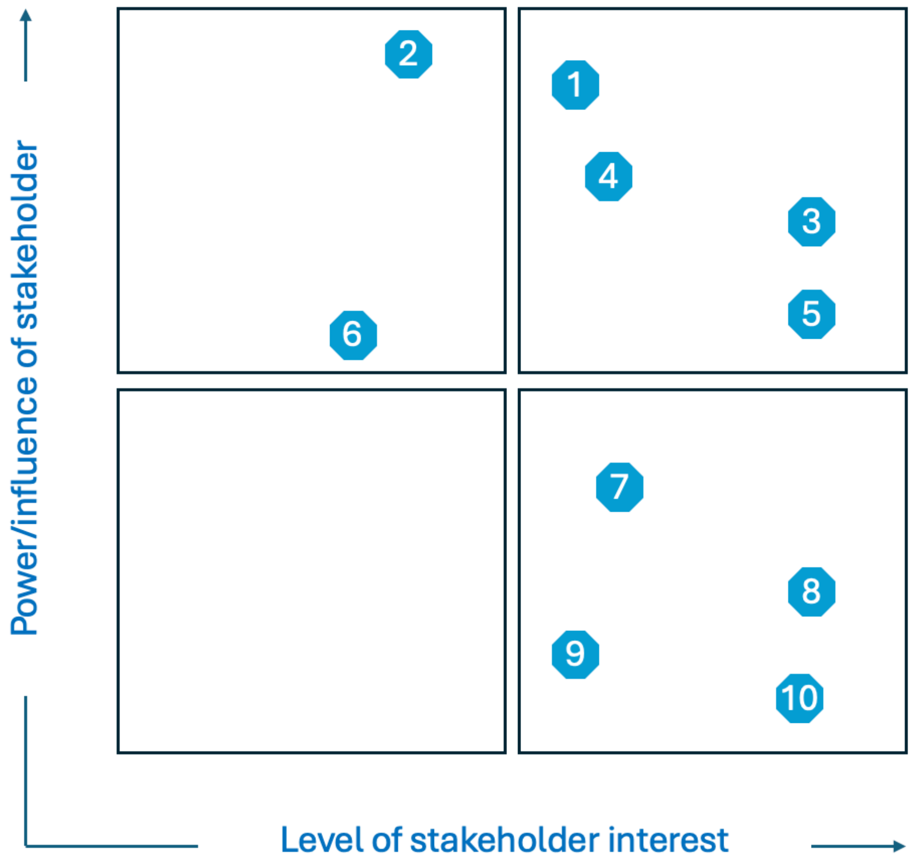


Figure 1.1: Stakeholder Power–Interest Matrix for Eindhoven Airport Accessibility

Beyond mapping their position, it is important to gauge what the most important criteria are for each stakeholder. These preferences were ranked, 1 = least important, 6 = most important as shown in table 1.1, and then multiplied by the stakeholder's level of power. The results of these are shown in figure 1.3.

Table 1.1: Stakeholder Rankings of MCA Criteria (1 = Least Important, 6 = Most Important)

Stakeholder	Capital Cost	Implementation Time	Environmental emissions	Construction impact	System Efficiency	Capacity
Province of Noord-Brabant	6	4	2	1	5	3
Ministry of Infrastructure	6	3	2	1	5	4
Eindhoven Airport	1	4	2	3	6	5
ASML / BIC	1	4	3	2	6	5
Municipality of Eindhoven	1	5	2	3	6	4
NS	3	4	2	1	6	5
Hermes (Bus operator)	1	4	2	3	6	5
Residents	1	5	3	4	6	2
Airport Travellers	1	5	2	3	6	4

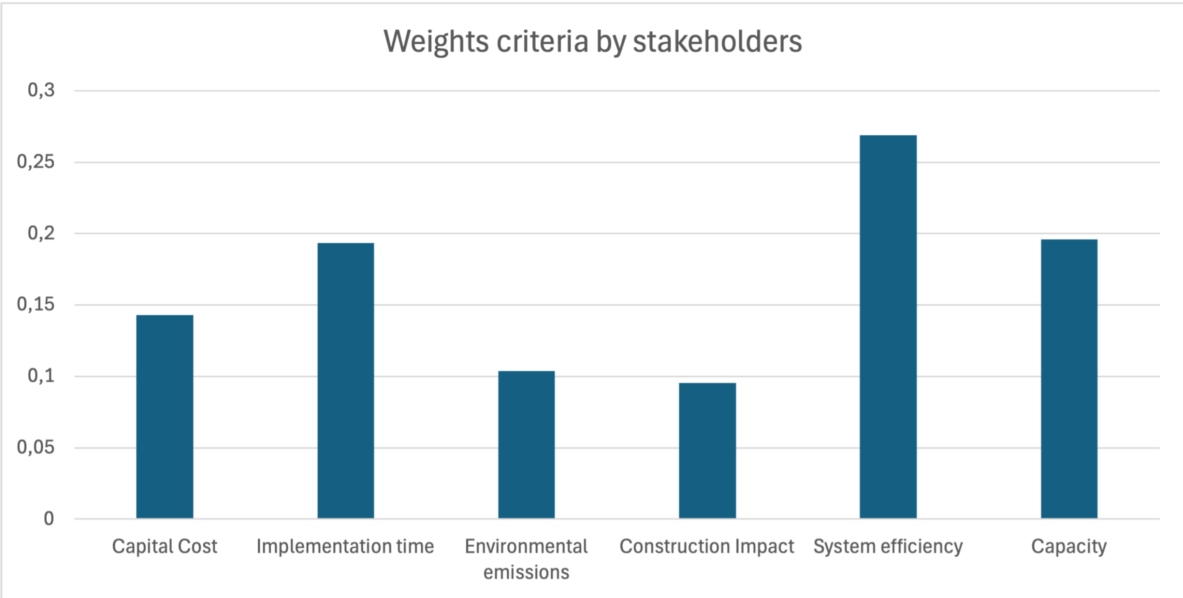


Figure 1.2: Stakeholder Power–Interest Matrix for Eindhoven Airport Accessibility

This ranking of criteria helps form a foundation for the pairwise comparisons between the criteria in the Multi-Criteria Analysis. This foundation gives insight in what the stakeholders overall find the most important with influence factored in.

1.4. Reading map

The structure of the report is as follows: chapter one is the introduction of the report, where the topic and research questions are introduced. Chapter two gives more in-depth background information. Chapter three addresses the methodology of the report and shows what methods are used in the report. Chapter four is the literature study, here the reference projects, growth plans of the BIC and different PT methods are discussed. Chapter five includes the data collection and demand analysis for the airport and the BIC. Chapter six is the discussion of the report. Lastly, chapter seven is the conclusion where the research questions are answered and recommendations are given.

2
Background

Eindhoven Airport was originally a military airfield that was opened in 1932 and has since developed into the second largest airport in the Netherlands. The airport grew with a steady pace after commercial flights were introduced in the 1980s and passenger totals started to take off in the 2000s as seen in figure 2.1. In both 2023 and 2024, Eindhoven Airport handled around 6.8 million passengers, reaching the same levels that were reached pre-COVID-19. A terminal expansion is currently underway to increase the capacity of the Airport, going from 26,000 to 38,000 m² [5] [7].

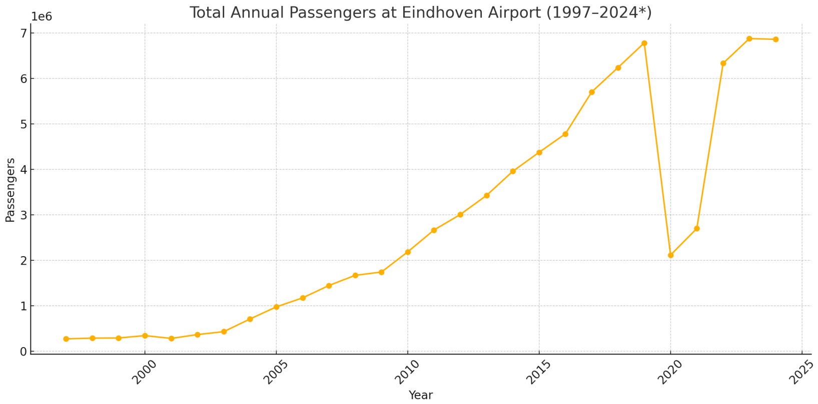


Figure 2.1: Passengers per month in 2024 [20]

At the same time, the Brainport region has developed into an important innovation hub. The Brainport Industries Campus (BIC), is located just north of the airport and was opened in 2018. The campus started with BIC cluster 1, where high-tech suppliers produce and innovate together. Now it is expanding again and developing BIC cluster 2, which will further strengthen the role of the Brainport region. BIC cluster 1 is the developed area in figure 2.1 and BIC cluster 2 is the not yet developed area on the top. Additionally ASML is planning to expand their operations to the BIC Noord area, the northern part of BIC cluster 2. The office will provide space for up to 17,000 employees and 3,000 employees in nearby facilities. This will make the BIC one of the most important employment locations in the region for the near future [17] [18].

This expected growth in passengers and daily commuters to the BIC creates pressure on the existing public transport network. As stated in the introduction, Eindhoven Airport does not have a direct train connection and is currently only accessible by bus and car. Previous ideas for a train station were discussed but due to high costs and lack of urgency they were not realized.

The first idea, was to create a train station in the neighborhood Acht. This is a small part of Eindhoven located just north of the airport and the BIC, the convenient part is that since there is a railway already running through Acht connecting Eindhoven Central Station to both Tilburg and s'Hertogenbosch. This means that to make this plan work only a train station needs to be build. The train station would be

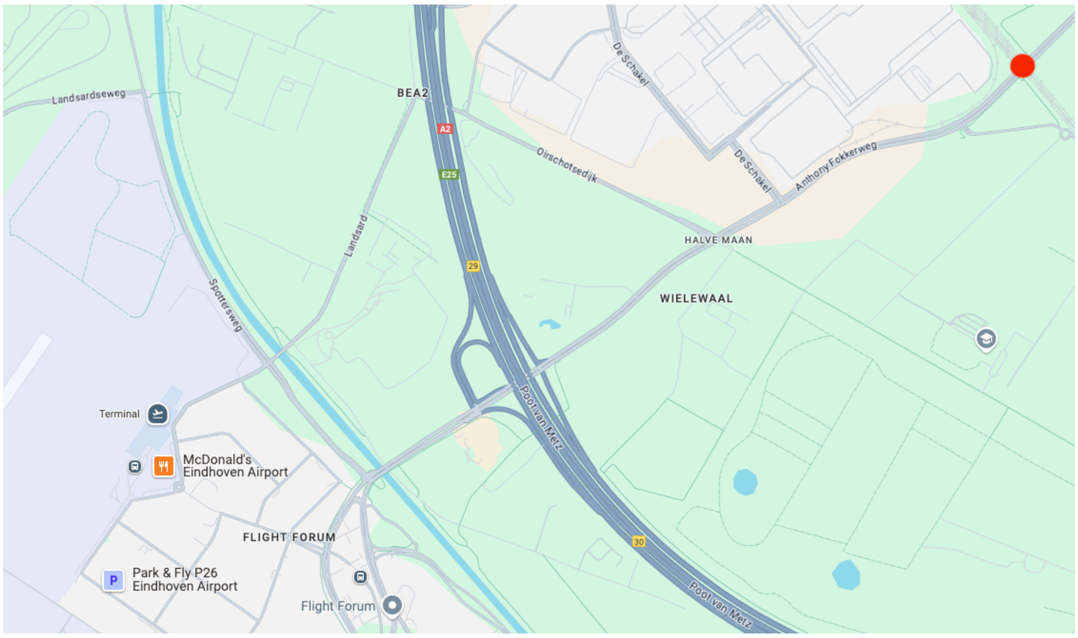


Figure 2.2: Location Train Station Acht (Google Maps)

located on the red dot in figure 2.2, with a shuttle bus to the airport it would only take 4 minutes without traffic. This plan was originally rejected in 2020, under medium or low growth conditions the demand was deemed insufficient to warrant building a whole new station. In 2024, the province of North-Brabant passed a motion to re-explore this option with the expansion of ASML. A newer proposal was made by Brainport Eindhoven, they proposed the Brainportlijn, a high quality and scalable public transport concept that aims to connect different parts of Eindhoven along the A2 corridor, such as Eindhoven Airport, the Brainport Industries Campus, the new ASML office, and the High Tech Campus, as seen in figure 2.3. The Brainportlijn is designed to provide fast and sustainable mobility that complements the existing public transport network. A key part that is mentioned in the proposal is a core corridor between BIC and Eindhoven Airport. This corridor is designed to get passengers quickly to the campus and airport with minimal stops and functions as the backbone of the Brainportlijn [25].

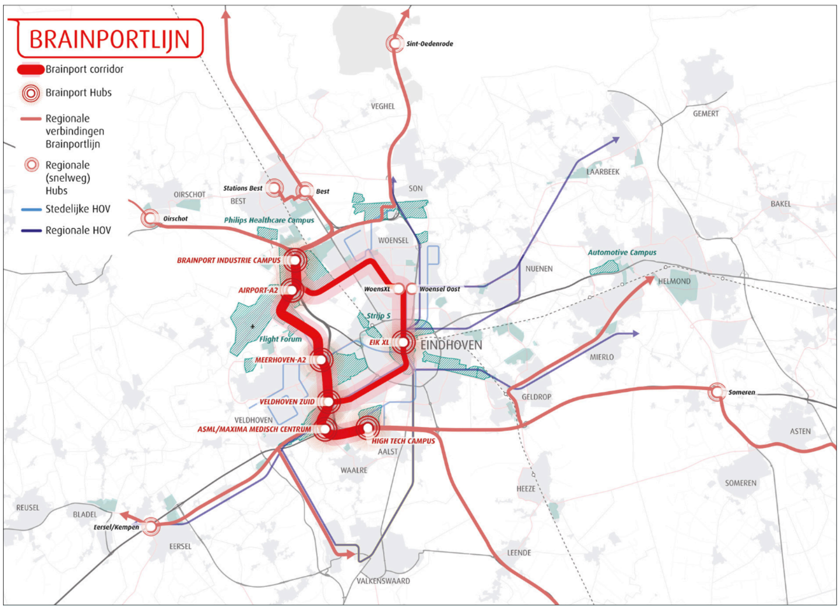


Figure 2.3: Brainportlijn [25]

3

Literature study

In the literature study, answers are found for sub-questions 1, 2, and 4. The answer to the first sub-question will be found in the reference project section. This section investigates European airports with existing train connections. This will give insight in the cost implementation time and performance of a train based solution. The second sub-question will be answered in the growth plans section and will give insight in what ASML are planning on implementing on the campus. These plans will help to create a visual of how the BIC will look and what their solution is to the problem of PT accessibility. The fourth sub-question will be answered in the public transport methods section and will discuss the different transport modes. Here some basic information about these methods is given regarding the criteria. This information will lay the foundation for the MCA.

3.1. Reference Projects

This chapter addresses sub-question 1: "What do reference projects at other European airports reveal about the cost, implementation time and performance of train-based public transport connections?". Here Brussels Airport, Stuttgart Airport, and Schiphol Airport are highlighted. These reference cases help evaluate the suitability of potential transport solutions in the Eindhoven context.

3.1.1. Brussels Airport

Brussels Airport, Belgium, handled around 23.6 million passengers in 2024, making it a much bigger airport compared to Eindhoven Airport [2]. Brussels Airport provides a relevant reference for understanding the cost and implementation of underground rail access. The Diabolo project involved constructing a new underground station beneath the terminal and connecting it to the existing national rail network. This project cost around €540 million and took five years to complete. It reduced the travel time from Brussels center from 40 minutes to 8 minutes. It consists of two tunnels with a diameter of 7.3 meters and a track length of 7.4 km, with 4 km for the Brussels connection and 3.4 km for the Flemish region connection. Given the complexity of tunneling and the need to work in an operational airport environment, the Diabolo project demonstrates that underground rail infrastructure tends to involve long timelines and substantial costs. The project was financed as a public-private partnership and faced challenges related to coordination and implementation, making it a useful comparison point for evaluating what a similar solution at Eindhoven might involve [33]. As of 2021, 36% of passengers use public transport to reach the airport of which 29% use the train [3]. Brussels airport aims for 40% public transport usage by 2027 [4]. This gives insight for

Figure 3.1: Brussels Airport [2]

the modal split that could be expected if Eindhoven Airport does implement a train station.

3.1.2. Schiphol Airport

Even though Schiphol Airport is significantly larger in both area and passenger totals with 66.8 million passengers per year [9], its public transport connections can provide valuable lessons for Eindhoven Airport.

Figure 3.2: Schiphol Airport [14]

Schiphol is one of the best connected airports in Europe, it features a multimodal transport hub directly underneath the terminal [35]. This includes a train station that offers high-frequency train departures and arrivals. For example every hour, eight trains run between Amsterdam Central Station and Schiphol Airport [32]. In addition to domestic destinations, passengers can reach international destinations like Brussels, Antwerp, Paris and London through the Eurostar train service [24]. In addition to the train station, a big bus network links Schiphol to the surrounding municipalities and business areas. What makes Schiphol particularly relevant as a reference project is the seamless integration between air travel and public transport. Transfers are fast and are available 24/7 and there is a good connection between flight schedules and bus or train departures [35]. These are components that can make a train station at Eindhoven Airport succesful.

While Eindhoven does not have the financial capacity and scale of Schiphol, several things can be taken away from Schiphol that can be implemented in Eindhoven. Obviously a train station right underneath the airport would help tremendously with efficiency and convenience, but that might not be possible to realize. Trains from Schiphol run every few minutes to major cities even during off-peak hours. Buses that run from the airport to Eindhoven Central station at off peak hours and night trains from the station to major cities is a good way to increase the willingness for passengers to use public transport to and from Eindhoven Airport. At Schiphol Airport using public transport is not a possibility, it is the default option. This is something that Eindhoven Airport should be looking at. In a report done by the RVO for Schiphol, they determined the modal split. 47.1% of passengers used public transport and 52.9% used private transport [26]. The numbers show that if an airport has an efficient train connection, people will use it. This modal split is something Eindhoven Airport should be aiming for.

Schiphol Airport is approaching its maximum capacity and regional airports like Eindhoven are becoming more important in accommodating the future growth in air travel. Schiphol is facing strict environmental and space limits which prevents them from expanding further. This creates an opportunity to take on a bigger role within the air travel of the Netherlands. Currently the travel time from central Dutch cities to Eindhoven Airport is a lot longer compared to Schiphol Airport, as shown in table 4.1. This shows that Eindhoven Airport is just not competitive at the moment in terms of reachability with public transport, and it needs to start improving it.

Table 3.1: Approximate travel times to Schiphol Airport and Eindhoven Airport [1]

City	To Schiphol Airport (Train)	To Eindhoven Airport (Train + bus)
Utrecht Centraal	30 minutes	1 hour 15 minutes
Rotterdam Centraal	30–40 minutes	1 hour 30 minutes
Arnhem Centraal	1 hour 10 minutes	1 hour 20 minutes
Zwolle	1 hour 30 minutes	1 hour 40 minutes
The Hague Centraal	28–36 minutes	1 hour 45 minutes

3.1.3. Stuttgart Airport

A relevant reference for the possible underground train station at Eindhoven Airport is the underground train station at Stuttgart Airport, currently being developed as part of the Stuttgart 21 project. Stuttgart 21 involves a complete reform of the Stuttgart rail network, it includes the construction of four new stations, 56 km of tunnel tubes, and over 100 km of new railway tracks. One of the key features is the integration of Stuttgart Airport into the long-distance rail network through a newly built underground train station. This will reduce travel times between the airport and surrounding regions and contribute to the shift from road to rail. The Stuttgart Airport station can provide a valuable benchmark for evaluating the cost of constructing an underground station at Eindhoven Airport. The cost estimation of the train station at Stuttgart Airport was projected to be around 320 million at first but later it was estimated to be around 490 millions euros, this includes the underground station itself, its integration into the high-speed rail network, and associated infrastructure such as access tracks, systems and platform facilities. Since the station is not yet operational, no conclusions can be drawn about its long-term performance.

Figure 3.3: Stuttgart Airport [10]

3.2. ASML expansion

ASML is planning a major expansion to the BIC Noord (figure 4.4). In their "Voorlopig Ontwerp Stedenbouwkundig Plan" [12] they proposed an expansion and it is expected to bring 20,000 employees to the BIC, 17,000 on site and 3,000 in surrounding facilities within the Cluster 2 area of the BIC. This would make BIC Noord one of the largest employment areas in the Eindhoven region. To accommodate the increase of commuters to the area, ASML wants a sustainable and high-capacity public transport system implemented. The company's vision is in line with the regions vision to reduce private transport use and increase the use of cleaner forms of mobility. The expansion proposal highlights the "Brainportlijn" as a viable method that can connect the campus to other key areas in the region, such as Eindhoven Airport, the High Tech Campus and Eindhoven Central Station. While the specifics of this method are still being planned, ASML supports the development of this transport system and they acknowledge the need for a new high-frequency and direct connection to accommodate the future demand. This indicates that ASML is not only aware of the transport pressure it will generate but is also open to supporting solutions that reduce car use. With so many employees concentrated in a single location, it is vital that efficient and attractive public transport is available. This will possibly push the municipality and the government to rethink the ideas, like the train station at Acht, that were previously not deemed feasible because of insufficient demand.

Figure 3.4: BIC 1, BIC 2 and BIC Noord [12]

3.3. Public Transport Methods

In this section the possible public transport methods that can handle the demand are discussed. The information about these transport methods are from the book "Landside Accessibility of Airports" by Milan Janic [29].

3.3.1. Bus rapid transport (BRT)

This section reviews Bus Rapid Transit (BRT) systems as a basis for the Brainportlijn proposal, which is treated as a BRT-based high-quality regional transit system in this study. BRT is a public transport system that uses dedicated lanes, priority at intersections and has higher capacity and reliability than conventional bus systems. BRT systems are designed to reduce travel times and increase frequency by avoiding delays that are caused by driving on mixed traffic lanes. In context of airport access, BRT is attractive due to lower infrastructure cost and highe flexibility compared to rail based transport methods. It can be adjusted based on demand. For Eindhoven Airport, BRT could play a big role in the proposed "Brainportlijn" by connecting Eindhoven Central Station, BIC and the airport. The speeds that the buses generally reach range between 20 and 35 km/h. The capacity range for this method lies between 2,000-10,000 passengers per hour per direction. A BRT system for Eindhoven could operate on existing road infrastructure with dedicated bus lanes where possible. The buses are electric so environmental impact is relatively low: 27.9 g CO2/pkm. However, its capacity and system efficiency depend on being fully separate from traffic and high service frequency, which may not be possible everywhere in dense urban areas. The capital cost to implement a BRT system is 7.86 million euros/km. In case of the Brainportlijn the proposed investment to fund the entire system is approximately 1 billion euros. This includes bus lines, hubs and stops, improving the central bus station and bus depot [16]. Implementation time for the Brainportlijn is between 5-7 years depending on how fast the funding is in order.

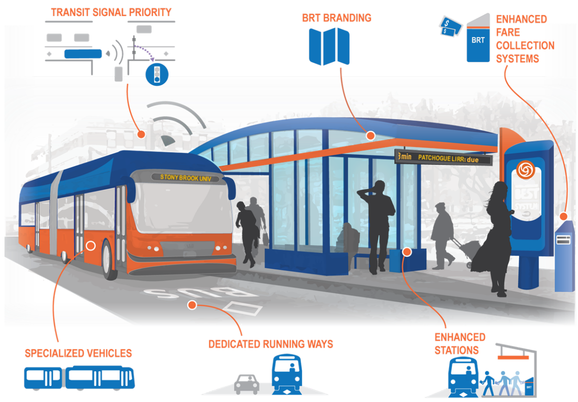


Figure 3.5: BRT [36]

3.3.2. Light rail transport (LRT)

Light rail is a transport method typically used for urban and regional connections. It operates at ground level and is able to run on dedicated tracks or mixed with traffic. Light rail typically reaches speeds of between 20-35 km/h. Light rail systems are especially effective in places where there is medium passenger demand, where a balance is needed between capacity, speed and integration in the city. There are relatively frequent stops and the generally less invasive than metro systems. Light rail is often chosen for its flexibility in routing and its ability to connect easily in urban environments. Light rail generally has a capacity range of 3,000-12,000 passengers per hour per direction. In terms of airport connection, light rail is most often used when the airport is situated within or just outside the city and the aim is to provide a direct but cost effective connection from the city to the airport. In Eindhoven a LRT system would likely follow the existing Brainportlijn concept, connecting Eindhoven Airport with the city and the BIC via a dedicated tracks. Implementation would

Figure 3.6: Light Rail in Sydney [38]

take 4–6 years, requiring track construction. LRT offers a high level of system efficiency and sustainability due to electric operation and reliable service, the average emission for a LRT system is 18.37 g CO2/pkm. While more expensive and complex than BRT at about 16-22 million euros/km, it provides higher capacity and long-term scalability. From the Eindhoven Central station, an LRT corridor from Eindhoven Centraal to the Airport via the BIC would span about 8-10 km, which brings the total investment between 150 and 200 million euros.

3.3.3. Metro/mass rapid systems (MRT)

Metro systems, or mass rapid transit (MRT), are high-capacity and fully separate rail networks that are designed for urban areas. These systems run on dedicated tracks on ground level or underground and are not mixed with other trafic. They offer high frequency and usually operate with speeds of 30-40 km/h. Because they are separated from other traffic, metro systems provide reliable and predictable travel times. Metro lines are best suited for places that have a very high demand, such as big cities or major international airports. The infrastructure costs are typically substantial but the result is a transport method that can accommodate large amounts of passengers and short headways. Metro systems generally can handle between 15,000-60,000 passengers per hour per direction and in some cases even more. These metro systems are often seen in large cities that have large airports such as Paris and London. The costs of a metro line range from 30-100 million euros/km. Environmental impact of a metro system averages out at 74 g CO2/pkm. Implementation time is typically between 7-12 years. Like the LRT corridor, a metro line from Eindhoven Station would be approximately 8-10 km depending on the route symmetry, which brings the cost between 600-900 million euros as some parts need to be underground.

Figure 3.7: MRT in London [**railsmartr_london_airports**]

3.3.4. Train

Heavy rail or train service, is generally used to connect cities and regions over medium and long distances and with high speeds between 60-130 km/h. In the context of airports, train connections are especially useful for passengers that wish to travel from other areas in the country without using private transport. Trains are operated on the national railway network and need a dedicated station at or close to the airport. This method can handle large amounts of passengers and long distance operations, making it particularly attractive to commuters and business travelers and people that come from outside the region. Usually train systems are able to handle around 6,000-25,000 passengers per hour per direction but this varies with train type and frequency. The emission from operating trains in the Netherlands is calculated every year by NS, in 2024 that was 52 gCO2/pkm. Schiphol Airport and Brussels Airport are examples of successful train system integration, where trains stop directly underneath the airport. In Eindhoven the train can play two roles in possible solutions namely, the train station in Acht and a train station underneath the airport:

Figure 3.8: Train Schiphol [28]

- Underground train station: The costs for the underground train station are significant, the Diabolo project for Brussels Airport serves as a good reference for the tunneling as it is also around 7-8 km of tunneling to connect Eindhoven Airport to the existing railway from Best to Eindhoven, the tunneling for Brussels Airport was around 500 million euros. As a reference for the train station itself the Stuttgart Airport underground station is used, this station is projected to cost 490 million euros but as the station for Eindhoven Airport does not need high speed rail integration and thus less complex it safe to assume the station will cost between 300 and 400 million euros. This brings the total cost for the station at Eindhoven Airport somewhere between 700-900 million euros depending on the final design and routing. A safe estimate for the implementation time is about 7-10 years.

- Train station Acht: Estimates for this kind of train station where it uses existing tracks are found using a reference case: station Bleizo. This station also uses existing tracks and the full project costs around 70 million and the station itself around 20 million, a safe estimate will then be 30 million euros for the station itself [30]. Integrating a bus line to the airport is necessary and will add 7.86 million/km, connecting the station with the airport and the BIC would be a corridor with a length of 6 km, thus it will add around 50 million euros. This brings the total capital cost to about 80 million euros following reference cases, a safe estimate for the entire project is then between 80-100 million. Implementation time estimates are 3-5 years.

3.3.5. Comparison

Table 3.2: Quantitative comparison of transport modes

Transport mode	Capital cost	Capacity (pphpd)	Emissions (gCO_2/pkm)
BRT (Brainportlijn)	€1 billion	2,000–10,000	27.9
LRT	€150-200 million	3,000–12,000	18.37
Metro	€500-900 million	15,000–60,000	74
Train station Acht	€80-100 million	6,000–25,000	52
Underground train station	€700-900 million	6,000–25,000	52

Table 3.3: Qualitative comparison of transport modes

Transport mode	Environmental impact (Construction)	Efficiency	Implementation time
BRT (Brainportlijn)	Low	Medium	Medium
LRT	Medium	Medium	Medium
Metro	High	High	Long
Train station Acht	Medium	Medium-High	Medium
Underground train station	High	High	Long

With the information from thes tables 3.2 and 3.3, the scores for each of the modes can be determined in the MCA later in the report.

4 Methodology

In this chapter the methodology of the research is laid out. It will describe how the sub questions stated in the introduction are answered.

The first and second questions are solely answered through literature study. The third question is answered through collecting data and analysis of the data to get a concrete numbers that can be used for the fourth sub question. The fourth question will be answered by literature study to get transport methods and then when the demand is pointed out, the suitable transport methods are ranked through Multi Criteria Analysis by using the Analytical Hierarchy Process (AHP) method. AHP is chosen for its ability to handle both qualitative and quantitative factors and for its easy to comprehend structure, as used in similar transport analysis studies [31]. The last question will be briefly answered at the end with some recommendations.

4.1. Literature Study

Sub-questions 1, 2, and 4 are answered through a structured literature study, as presented in Chapter 3. This literature review provides essential context and reference points for the rest of the research. These insights serve as the foundation for the quantitative demand analysis (Chapter 5) and the selection of transport alternatives in the Multi-Criteria Analysis (Chapter 6).

4.2. Data collection

The third sub-question is about the increase in demand for public transport from the airport and the campus. To answer this question data needs to be collected:

- Square footage per passenger for terminal capacity estimation, FAA Guidelines for terminal design [15].
- Annual passenger data for Eindhoven Airport from 2016-2025, CBS [20].
- Amount of airport workers at Eindhoven Airport, ACI [11].
- Modal split data for airport passengers, report from 2018 from RoyalHaskoningDHV [27].
- Modal split data for Schiphol Airport and Brussels Airport, found in literature study.
- Amount of workers and modal split goals for ASML for BIC, ASML design proposal for BIC Noord [12].
- Public Transport mode capacities, speed, emissions, implementation time and flexibility, for BRT, MRT, LRT and train. Found in literature study.

Below is explained why the different data sets are needed:

The square footage per passenger for terminal capacity was needed to determine the annual capacity of passengers for Eindhoven Airport after the expansion. As it was hard to forecast the growth of passenger demand of the airport for the future, this number was taken as the amount of passengers that use the airport in the next 5-10 years. How this was done is explained in the demand analysis section.

Annual passenger data was needed to determine the peak month and peak hour for the passenger demand. The peak hour in the peak month was be used in the Multi-Criteria Analysis in terms of capacity. Next to the peak hour in terms of passenger travel demand, the amount of airport workers at the airport needed to be determined so the total amount of people that will travel during that peak hour was calculated.

To determine the amount of people that will use public transport to the airport during the peak hour, modal split data for airport passengers and airport workers was needed. This data was gathered by RoyalHaskoningDHV in a report in 2018. Next to this modal split the modal split for Schiphol Airport and Brussels Airport were needed to make an assumption on the modal split for Eindhoven Airport in the future, this was already found in the literature study, 49% of passengers used public transport to reach the airport and 36% at Brussels Airport.

ASML is planning on opening an office with 20,000 employees, a percentage of these employees will use public transport to get to work at the BIC. ASML strive for 30% of workers to use public transport to reach the new office, as found in the literature study [12]. With this percentage the PT demand for the ASML workers was calculated.

Data on the characteristics of four public transport options (BRT, LRT, Metro, Train) was collected in the literature study. The data includes estimates on cost per kilometer, capacity, travel time, environmental impact, and implementation duration. These values are used as input for the Multi-Criteria Analysis.

4.3. Demand analysis

With the data obtained through the data collection, the third sub-question can be answered. First the capacity of the new expanded terminal will be calculated. The FAA states that 1.9 square meters per passenger is used to determine capacity [15]. The terminal is currently 26,000 square meters and the future terminal is 38,000 square meters. To determine the capacity the following formula is used:

$$\text{Amount of passengers at the same time} = \frac{\text{terminal size (m}^2\text{)}}{1.9} \tag{4.1}$$

The rule of thumb is to multiply this number by the amount of days in the year to get the annual capacity.

As the amount of people traveling to the airport varies per month which was found in the data collection section, the peak month was determined, with the monthly passenger data from 2017-2024, this did not include 2020 and 2021, as during the COVID pandemic the numbers were not representative. The data was first processed in Python and then exported to Excel for further calculations. A graph based on this analysis was included in the results section. The Python script used for this process can be found in Appendix B.

For each month in each year the percentage of passengers traveling in that month is determined, then the mean percentage of the months over the years are calculated. The highest mean percentage will be used for the peak month. The data is first cleaned up in python and then exported to excel where the mean percentages are calculated. 'Landside Accessibility of Airports' gives formulas to determine the airport passenger demand for the peak month, average day in the peak month and the peak hour during that day. In the equations below, PM stands for Peak Month, ADPM stands for Average Day in Peak Month and PH stands for Peak Hour.

First the passenger demand in the PM of the year can be estimated as follows:

$$Q(\text{PM}) = p_1 \cdot Q \tag{4.2}$$

where

Q is the airport passenger demand per year;

p_1 is the proportion of the annual passenger demand concentrated in the peak month.

The number of passengers in ADPM can be estimated as follows:

$$Q(\text{ADPM}) = Q(\text{PM})/N \tag{4.3}$$

where

N is the number of days in PM

During the day, the amounts of passengers vary. The number of passengers during PH (Peak Hour) of the ADPM (Average Day of Peak Month) can be determined with the following formula:

$$Q(\text{PH}) = f_1 \cdot Q(\text{ADPM}) \tag{4.4}$$

f_1 is the factor of PH or the relevant peak period of the ADPM. This factor is usually dependent on the size of the airport as seen in figure 4.2 by the FAA. Eindhoven Airport. In the demand analysis chapter, the annual passenger amount for Eindhoven after the terminal expansion is 7.2 million. With the graph the factor can be determined, which is about 9.5%.

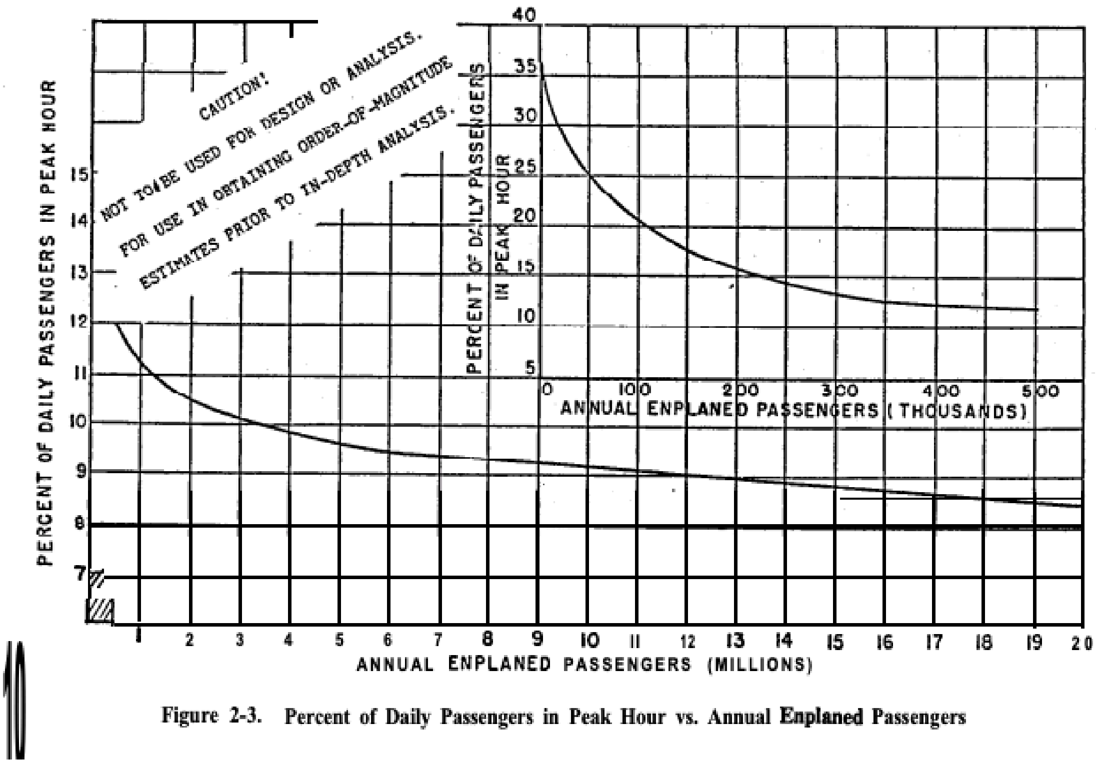


Figure 4.1: FAA graph for f1 factor estimation [15]

Next to the passengers, airport workers are also a big group that travel to the airport every day. The total amount of workers was determined with guidelines by the ACI [11]. The guidelines state that for airports with annual passenger amounts between 1 and 10 million, 0.95 workers are used per 1000 passengers. It also states that if the airport primarily serves low-cost carriers it needs 20% less workers. This gives the assumption that per 1000 annual passengers, Eindhoven Airport has 0.76 workers. With the annual passenger estimation after the terminal expansion the amount of airport workers was determined. This gives the amount of daily airport workers. To determine the amount of employees during peak hour the following formula is used [29]:

$$EM(\text{PH}) = \frac{EM(\text{Q})}{f2 \cdot ws} \tag{4.5}$$

where

$EM(PH)$ is the number of airport and aviation employees during PH;

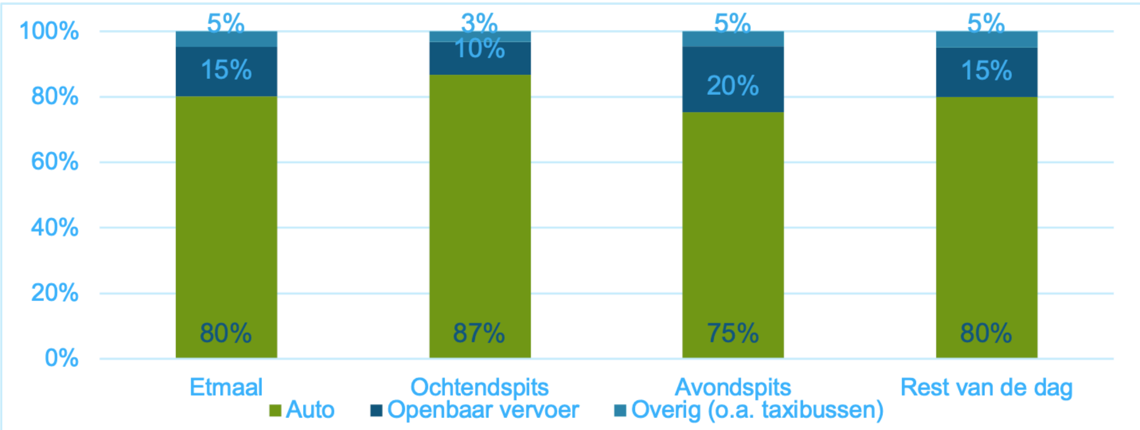
$EM(Q)$ is the number of employees;

f_2 is the number of PHs [Peak Hour (s)] per working shift of the airport;

ws is the amount of working shifts during the day;

Eindhoven Airport has two peak hours, one in the morning and one in the afternoon. Eindhoven Airport operates from 4:30 in the morning until 23:00 in the evening [8]. This means an operating time of 18.5 hours, the assumption is made that there are three working shifts per day for this amount of hours.

After combining these groups, the modal split for these groups was determined. In a report done by Royal HaskoningDHV on the landside accessibility of the airport [27], OVChipkaart data was collected for all people going to the airport in 2017. With this data they determined the modal split as seen in figure 4.3, this included both passengers and airport workers so it applies to both groups. They assumed that everyone not using public transport or a taxi-bus used a car as mode of transport.



Figuur 5, Vervoermiddel naar Eindhoven Airport per periode (modal split), OV-Chipkaart.

Figure 4.2: Modal split Eindhoven airport 2017 [27]

In figure 4.3, during the morning rush the percentage of people using PT is relatively low, the report stated that this was caused by the pre-transport being insufficient both in quality and quantity. If passengers need to be at the airport early, it is likely that they will use their car or taxi, as taking the train and bus in the early morning is not efficient. So according to Royal HaskoningDHV, approximately 10% of airport passengers used public transport to reach Eindhoven Airport during the morning peak period. During the evening rush period (16:00 - 18:00) the percentage of people using public transport was 20%.

In this report future scenarios where public transport accessibility is improved are evaluated, a higher modal share of public transport is required to estimate a realistic demand. Therefore it is useful to look at an airport like Schiphol Airport that has a well incorporated public transport system, in the literature study it was found that 49% of passengers use public transport to get to and from Schiphol Airport. Therefore three scenarios are evaluated for the evening rush period:

- Scenario 1: Public transport usage stays at 20%
- Scenario 2: Public transport usage rises to 25%
- Scenario 3: Public transport usage rises to 30%

To incorporate the commuters from the Brainport Industries Campus, the amount of commuters can be calculated by estimating the amount of workers that will use public transport, ASML aims for 30% of employees to use PT to go to the office. It is assumed that the employees commute between 7:00-9:00 and between 16:00-18:00, the evening rush coincides with the peak period of public transport users of

Eindhoven Airport. This will be the time the public transport needs to be tested on. Adding this amount to the amount of people using public transport to and from the airport, gives the total demand for the public transport system during the peak period on an average day in the peak month.

4.4. Transport methods analysis

To evaluate and compare possible public transport solutions to accommodate the demand from Eindhoven Airport and Brainport Industries Campus a form of Multi Criteria Analysis (MCA) is used, the Analytic Hierarchy Process (AHP). AHP is a structured comparison technique to make decisions, it allows qualitative and quantitative criteria to be used. The method involves pairwise comparisons of criteria, which creates a ranking of the different methods [34]. AHP is often employed in traffic and transport infrastructure planning due to the clear structure and it is easy to explain to readers who are unfamiliar with MCA [31].

The AHP process involves the following steps [37]:

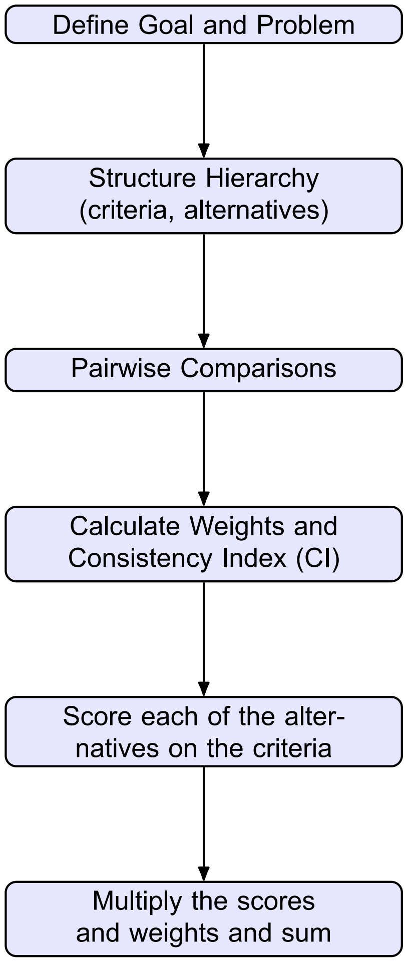


Figure 4.3: Steps of the Analytic Hierarchy Process (AHP)

First the goal and problem need to be defined, here the problem is: ”Determine the most suitable public transport method to improve the accessibility of Eindhoven Airport and the Brainport Industries Campus”. The alternatives for this analysis were found in the literature study when answering the fourth sub question. Second, the hierarchy had to be structured. This was done in three steps:

- Finding the overall goal: Optimal transport method selection
- Selecting criteria that influence the decision, in this case the following criteria are used: Capital cost, capacity, environmental emissions, construction impact, implementation time and efficiency.

- Selecting the transport options, found in the literature study: BRT (Brainportlijn), LRT, MRT, and train (Split in two options: Train station in Acht and underneath Eindhoven Airport).

The modes are scored on the criteria using the literature study:

- Capital cost captures the estimated upfront investment required to implement each mode, including infrastructure construction, vehicle acquisition, and station facilities. It reflects how big the investment needs to be from the different stakeholders involved, the operational costs are not included.
- Capacity reflects how well each mode can accommodate the estimated peak demand of public transport users. Modes that can comfortably meet or slightly exceed this threshold are rated highest. Extremely high-capacity options were not scored higher if they offered capacity far beyond what is realistically needed for Eindhoven, as this may lead to oversizing and inefficient investment.
- Environmental emissions captures the operational CO2-emissions, the estimated greenhouse gas emissions associated with the transport modes daily use in g CO2/pkm, with lower emissions rated highest and the highest emissions rated lowest.
- Construction impact is the qualitative construction impact the implementation of the mode has in terms of nuisance, noise and reduced accessibility, with modes that require short and minimal interruption to the public rated highest and long and high interruption to the public rated lowest.
- Implementation time, is the time needed to finish the implementation in years.
- Efficiency reflects how well the transport mode performs in terms of frequency, reliability, directness, and user experience. Modes score higher if they offer direct connection without transfers, high frequency during peak hours and reliable travel times.

Third, the pairwise comparisons were done. This involved comparing the pairs to assess their relative importance using Saaty's 1-9 scale, where 1 indicates equal importance and 9 indicates extreme importance of one over another [34]. This scale is shown in table 3.1. The comparisons were made based on the stakeholder analysis. The stakeholder analysis gave insight in what the most important things were for each party, and what the most important criteria were in general. For instance the system efficiency is considered the most important and the construction impact the least important.

Table 4.1: Saaty's 1–9 scale for pairwise comparisons in AHP [34]

Intensity	Importance	Explanation
1	Equal importance	Two elements contribute equally
3	Moderate importance	Moderate preference of one over another
5	Strong importance	Strong preference, clear importance
7	Very strong importance	Very strong or demonstrated importance
9	Extreme importance	Extreme preference, highest level of importance
2, 4, 6, 8	Intermediate values	Used when compromise is needed

The stakeholder analysis showed that there is a clear difference in importance between certain criteria but the criteria are all important. If the criteria are close to each other a 1 or 2 is given, if they are further apart a 3 or 4 is given. In this report the highest value was 4 as all the criteria were valued important but there was a difference.

The pairwise comparison matrix is a square matrix in which each criterion is compared to every other criterion in terms of relative importance. The diagonal of the matrix always consists of 1's, since each criterion is equally important to itself. If a criterion A is judged to be more important than criterion B, a value from Saaty's 1–9 scale is placed in cell (A, B). The reciprocal value is then placed in cell (B, A), i.e., if Efficiency is rated 4 times more important than Construction Impact, the matrix cell at (Efficiency, Construction Impact) is 4, while (Construction Impact, Efficiency) becomes ¼. This ensures the matrix is reciprocal and logically consistent.

Next, the weights, the Consistency Ratio (CR) the Consistency Index (CI) were calculated. The CR and CI indicate whether the judgments made during the pairwise comparisons are logically coherent. These calculations were calculated in the following way:

1. Each column of matrix A, the original square matrix with the Saaty scale values, was summed.
2. Each element was divided by its column total to normalize.
3. Each row was averaged to get the weight vector W, which contained the relative weight of each criterion.
4. The matrix A was multiplied with the weight vector W to get the weighted sum vector: $A \cdot W$.
5. Each value in the weighted sum vector was divided by the corresponding element in the weight vector:
$$\frac{(A \cdot W)_i}{W_i}$$
6. The average of the consistency vector was taken. This gave an approximation of the matrix's largest eigenvalue:
$$\lambda_{\text{max}}$$
7. Calculated the Consistency Index:
$$CI = \frac{\lambda_{max} - n}{n - 1}$$
where n is the number of criteria.
8. Calculated the Consistency Ratio (CR):
$$CR = \frac{CI}{RI}$$
RI is the Random Index and they are dependent on n, the number of criteria. The values for RI are given in table 4.2, in this case a RI of 1.24 was used.

Table 4.2: Random Index (RI) values for different matrix sizes [34]

n	RI
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

If the CR<0.10, the matrix is considered acceptably consistent. If the CR≥0.10, the pairwise comparisons need to be revised for consistency [34].

With the characteristics of each transport mode, found in the literature study, and the demand analysis each mode was scored on each of the criteria between 1-5, where 1 is the worst and 5 is the best. Finally, to find the best alternative the weights and the scores for each transport mode are multiplied and the sum of these are the final scores for each transport mode. The mode with the highest score was considered the preferred mode.

4.5. Implementation of the preferred transport mode

Following the identification of the preferred transport modes through the MCA, two practical implementation scenarios were developed to assess the spatial and infrastructural feasibility of realizing these solutions in the Eindhoven region. This step aimed to visualize the abstract alternatives.

The two scenarios selected for further elaboration were: (1) A new train station at Acht, located on the existing Eindhoven–Boxtel rail line, combined with a short shuttle connection to Eindhoven Airport and the Brainport Industries Campus (BIC); and (2) An underground train station located directly underneath Eindhoven Airport, linked via a new tunnel to the national rail network.

For each scenario, a figure was drawn to visualize the proposed routes and connections. These figures were made to give a visualization of the two options and the underground station option incorporates ideas from the Diabolo project at Brussels Airport. These analyses were qualitative in nature and served to give context to the outcomes of the Multi-Criteria Analysis.

5
Results

5.1. Data collection and demand analysis

5.1.1. Terminal capacity airport

Eindhoven Airport has experienced significant growth over the past decades. Originally the airport was designed to handle around 5 million passengers, but in both 2023 and 2024 the airport received approximately 6.8 million passengers [7]. To accommodate the increasing number of passengers each year the airport started a terminal expansion project in November 2024. The expansion will add about 10,000 square meters after security and 2,000 square meters before security. [7]. Before the expansion, the terminal is approximately 26,000 square meters [13]. This means that the terminal will be about 38,000 square meters.

For a terminal of 26,000 square meters, that means:

$$\text{Amount of passengers} = \frac{26\,000}{1.9} = 13,684 \text{ passengers} \tag{5.1}$$

$$\text{Amount of passengers per year} = 13,684 \times 365 = 4,994,660 \text{ passengers per year} \tag{5.2}$$

This is almost the same as the stated standard capacity by Eindhoven Airport itself, 5 million. For a terminal that is 38,000 square meters:

$$\text{Amount of passengers} = \frac{38\,000}{1.9} = 20,000 \text{ passengers per day} \tag{5.3}$$

Per year that comes to a capacity of 7,300,000 passengers. This means that the airport has a design capacity of 7.3 million passengers per year after the expansion.

5.1.2. Peak month and peak hour airport

To find the demand that needs to be accounted for, there needs to be an estimate for the peak moments during the year. During the year the amount of passengers is obviously not equally distributed. Eindhoven Airport gets a lot of people that use air travel to go to their holiday destination like other airports as seen in figure 5.1. The graph shows data from CBS on the amount of passengers that Eindhoven Airport received each month for the years 2017-2025. In the graph 2020 and 2021 are excluded as during the COVID pandemic a large part of air travel was restricted. The graph shows that air travel is the highest during the period from May to October. This makes sense as most people travel to other countries in the spring, summer and fall.

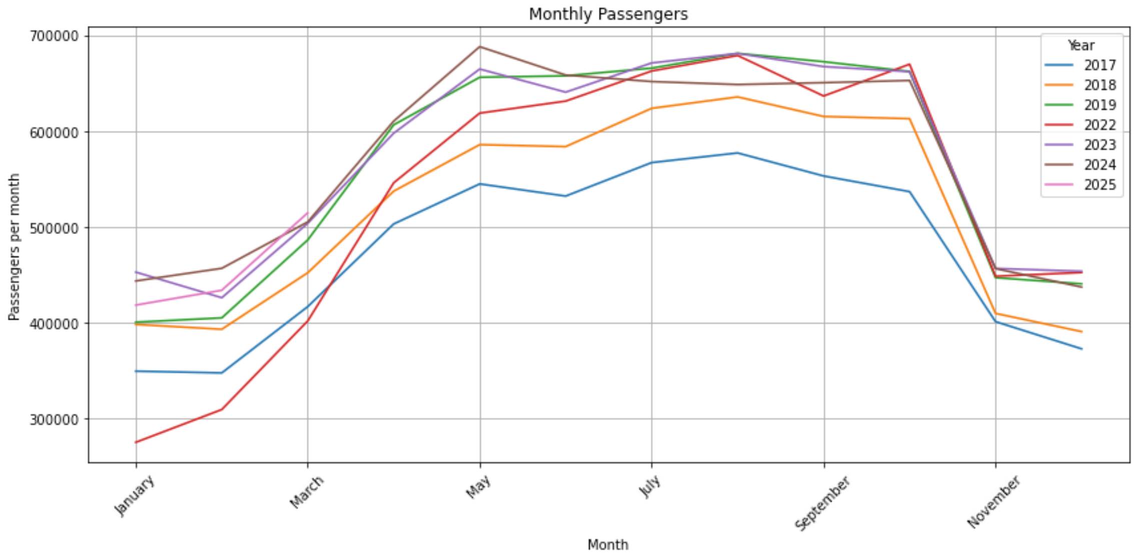


Figure 5.1: Passengers per month in 2024 [20]

The calculations and raw monthly passenger data are included in Appendix A. These calculations were done in Excel to determine the average distribution over the months using data from 2017 to 2024. Next the peak month was determined:

Month	Mean Percentage (%)
January	5.97
February	6.02
March	7.13
April	8.77
May	9.68
June	9.55
July	9.91
August	10.07
September	9.79
October	9.79
November	6.76
December	6.57

Table 5.1: Average Monthly Percentage of Annual Passenger Traffic

As the airport passenger demand was already determined by the terminal size and the proportion of the annual passenger demand was determined above, the passenger demand in the peak month could be determined:

$$Q(\text{PM}) = 0,1007 \cdot 7,300,000 = 735,110 \text{ passengers} \tag{5.4}$$

As August has 31 days the demand during ADPM was then:

$$Q(\text{ADPM}) = 735,110/31 = 23,713 \text{ passengers} \tag{5.5}$$

The peak hour was determined next:
The f1 factor was determined to be 9.5% or 0.095 for Eindhoven Airport.

$$Q(\text{PH}) = 0.095 \cdot 23,713 = 2,253 \text{ passengers} \tag{5.6}$$

This is the total amount of passengers that travel to Eindhoven Airport in the peak hour. Next the amount of passengers that use public transport for the three scenarios was determined:

- Scenario 1, 20% use PT: 451 passengers
- Scenario 2, 25% use PT: 564 passengers
- Scenario 3, 30% use PT: 676 passengers

5.1.3. Airport workers

One group that travels to and from the airport, are the airport workers. As stated in the methodology, for an airport the size of Eindhoven Airport approximately 0.76 workers are needed per 1000 annual passengers. The amount of airport workers can be estimated by dividing the annual passenger amount by 1000 and multiplying by 0.76:

$$\text{Airport workers} = 0.76 \cdot 7,200,000 \cdot 0.001 = 5472 \tag{5.7}$$

The amount of employees during peak hour is then estimated with the peak hour formula for employees.

$$EM(\text{PH}) = \frac{5472}{2 \cdot 3} = 912 \text{ employees} \tag{5.8}$$

For each of the scenarios the usage of public transport is then;

- Scenario 1, 20% use PT: 183 employees
- Scenario 2, 25% use PT: 228 employees
- Scenario 3, 30% use PT: 274 employees

5.1.4. Demand ASML

The new ASML office will have 20,000 employees, 17,000 in their own office and 3,000 in other places on the BIC. As ASML stated they aim for public transport usage of 30%. The assumption was made that for the peak hour all these employees will leave the office at the same time, during the evening rush (16:00 - 18:00) in the peak month on an average day. With the 30% PT usage this gives a demand of:

$$\text{Public transport demand ASML peak hour} = 20000 \cdot 0.30 = 6000 \text{ employees} \tag{5.9}$$

This means that the majority of the public transport demand will come from ASML instead of the airport.

5.1.5. Combined demand

The total public transport demand toward Eindhoven Airport includes three key user groups: airport passengers, airport workers and ASML employees at the BIC. Based on projected terminal capacity, peak-hour demand from airport passengers is estimated for three scenarios, and lies between 450-700 passengers. The airport workers contribute an additional 200-300 passengers. Finally, ASML's future office complex at BIC is expected to generate a peak-hour public transport demand of approximately 6,000 persons. In total, the combined demand during the evening peak hour in the peak month amounts to approximately 6650-7000 persons, which serves as the basis for determining the required capacity of each transport mode in the Multi-Criteria Analysis.

5.2. Multi Criteria Analysis

The multi criteria analysis was done with the AHP method, for this method the weights of the criteria and the scores had to be determined first to get to the final scores.

5.2.1. Weights

Based on the pairwise comparisons described in the methodology, the final weights for the five criteria were calculated using the Analytic Hierarchy Process (AHP). These weights reflect stakeholder priorities as seen in the stakeholder analysis.

The final weights are shown in Table 5.2.

Table 5.2: Final criterion weights from AHP analysis

Criteria	**Final Weight**
System efficiency	0.337
Capacity	0.201
Implementation time	0.201
Capital cost	0.128
Environmental emissions	0.069
Construction impact	0.066

To make sure that the pairwise comparisons were logically coherent, the Consistency Index (CI) and Consistency Ratio (CR) were calculated. The CI for the matrix was 0.01896, and the CR was 0.0153. According to Saaty's a CR value below 0.10 indicates an acceptable level of consistency in the judgments. Since the calculated CR is well below the threshold, the pairwise comparison matrix can be considered consistent and reliable.

These weights are applied in the next section to score the performance of each transport alternative and determine the most suitable option for implementation.

5.2.2. Scores

The five proposed transport modes were evaluated across six criteria using a 1–5 scoring scale, where 1 represents a very poor performance and 5 represents a very good performance relative to the other options. The scores were assigned based on a combination of literature values, reference project data, and how well the mode fits the projected demand. In table 5.3 the modes are scored on the criteria: System Efficiency (SE), Capacity (CP), Implementation Time (IT), Capital cost (CC), Environmental Emissions (EE), and Construction Impact (CI).

Table 5.3: Scores per criteria for each mode

Transport mode	**SE**	**CP**	**IT**	**CC**	**EE**	**CI**
BRT (Brainportlijn)	4	4	3	1	5	4
LRT	3	4	3	4	5	3
Metro	3	4	2	2	2	1
Train station (Acht)	4	4	4	5	3	4
Train station (Airport)	5	5	2	2	3	2

Combining the weights and the scores give the final scores for eacht transport mode, where a higher score is considered better, the results are in table 5.4.

Table 5.4: Final scores PT modes

Criteria	Final Score
BRT (Brainportlijn)	3.48
LRT	3.47
Metro	2.81
Train station Acht	4.06
Train station airport	3.68

The full MCA calculation, including weights, scores, and consistency check, is provided in Appendix A.

5.2.3. Interpretation of MCA

The results of the Multi-Criteria Analysis reveal how each proposed transport mode performs relative to the defined criteria and stakeholder preferences. The final scores reflect the combined weightings and scores across six criteria: capital cost, capacity, environmental emissions, construction impact, system efficiency, and implementation time.

The train station at Acht scores the highest overall, with a final weighted score of 4.06. This outcome is largely due to its low capital cost, relatively short implementation time, and acceptable performance across all other categories. Although it does not offer direct access to the terminal and relies on a shuttle connection, its balanced performance and cost-efficiency make it the most attractive short-term solution.

The underground train station beneath the airport scores 3.68, placing it second. It performs exceptionally well in terms of efficiency and capacity, as it allows direct terminal access and removes any reliance on secondary transport. However, its high capital cost and long implementation time significantly lower its total score. This option is best interpreted as a long-term investment, viable if sufficient funding and political support can be secured.

The Brainportlijn scores 3.48, performing similarly to LRT but limited by its extremely high capital cost, which received the lowest possible score. The Brainportlijn focuses on connecting multiple hubs in Eindhoven which makes it so expensive, this score does not reflect that aspect as this is only aimed at an airport connection and the BIC. So in a broader perspective it could play a big role but for this purpose it is not the best fit.

The LRT system achieves a score of 3.47, demonstrating medium performance across all criteria. While its environmental and construction impact is relatively low, it does not deliver the direct airport access or long-term capacity benefits of the rail alternatives. Its moderate cost and implementation time make it a feasible compromise option, but not the most effective solution.

Finally, the metro system scores 2.81, the lowest overall. Despite excellent performance in capacity and system efficiency, it suffers from high construction cost, long implementation time, and significant disruption. In addition, Eindhoven's current population density and scale are not high enough to support the demand required for a metro system, making this option unrealistic in the foreseeable future.

These results suggest that the Acht station is best suited for short-term implementation, while the underground station offers the strongest long-term functionality if funding can be secured. The remaining options LRT, Brainportlijn, and Metro may only be justifiable in a broader regional mobility vision rather than as standalone airport connections.

5.3. Implementation

In this section the implementation of both the train station options are laid out with maps. The maps and routes in this section are intended as conceptual visualizations of the proposed options and do not represent detailed route designs.

5.3.1. Train station Acht

The scenario where a train station is build at the Anthony Fokkerweg in Acht would drastically reduce the travel time passengers experience if they use the train to come to Eindhoven Airport. The train station will be build on the Best - Eindhoven rail corridor so only a train station needs to be build. To connect this train station a BRT line needs to be implemented that runs frequently taking passengers to the BIC and the airport. The use of BRT offers flexibility in frequency and routing, and the alignment can be realized with little spatial intervention. While this option requires a transfer between train and bus, the total travel time is competitive, especially given the short distance of 3 km between Acht and the airport, which corresponds with a 3-4 minute travel time. The two stop approach enables the station to serve both air travel and commuter demand. An example of how the connection could look like is shown in figure 5.2, containing the station at the red marker, bus line and stops at the airport and the BIC.

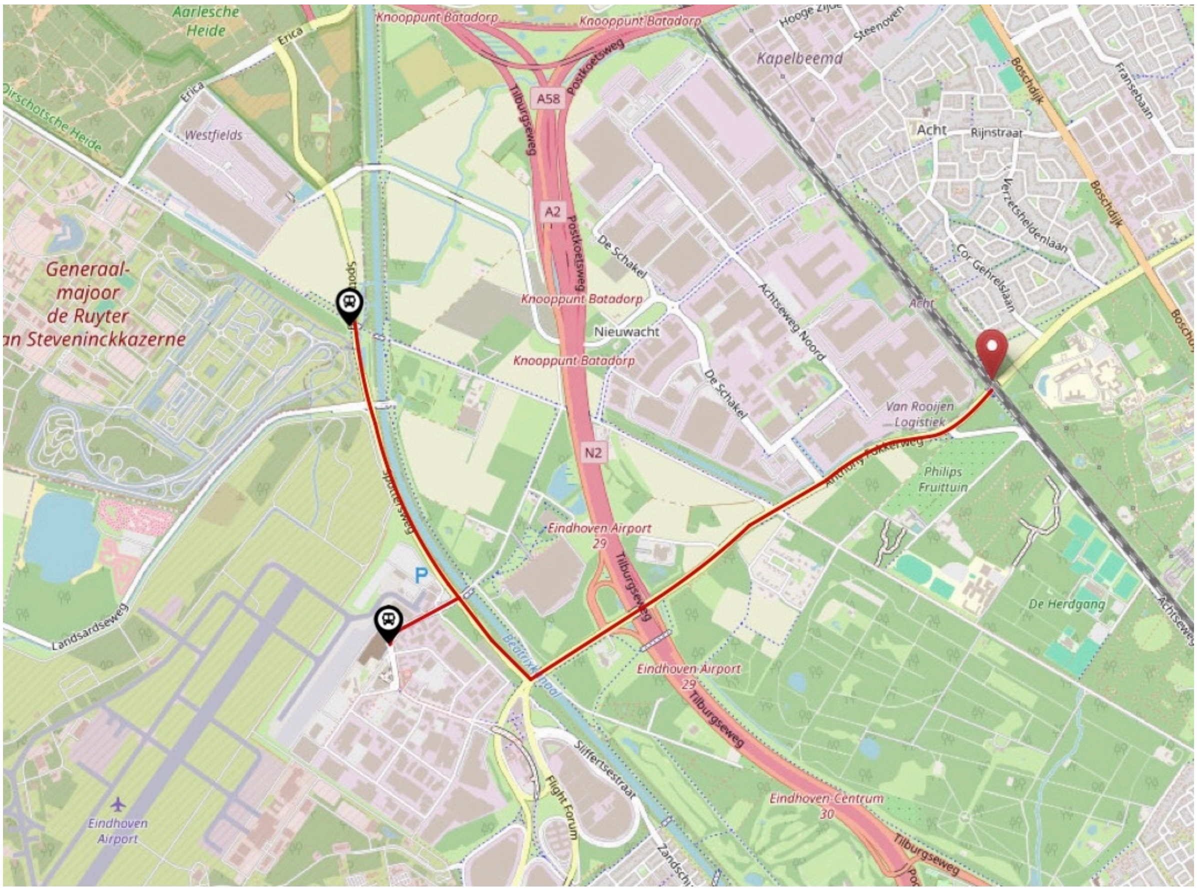


Figure 5.2: Train Station Acht

5.3.2. Train station Eindhoven Airport

In this scenario, a new underground rail connection is constructed to directly connect Eindhoven Airport to the national railway network. The possibile connection would branch off from the existing Best-Eindhoven line and follow a tunnel of approximately 3 km toward the airport terminal underneath the highway, from there another tunnel of about 2-3 km is implemented to connect the station back to the existing rail network near the Anthony Fokkerweg. This is visualized in figure 5.3. This approach mirrors the Diabolo project at Brussels Airport, which significantly improved public transport access.

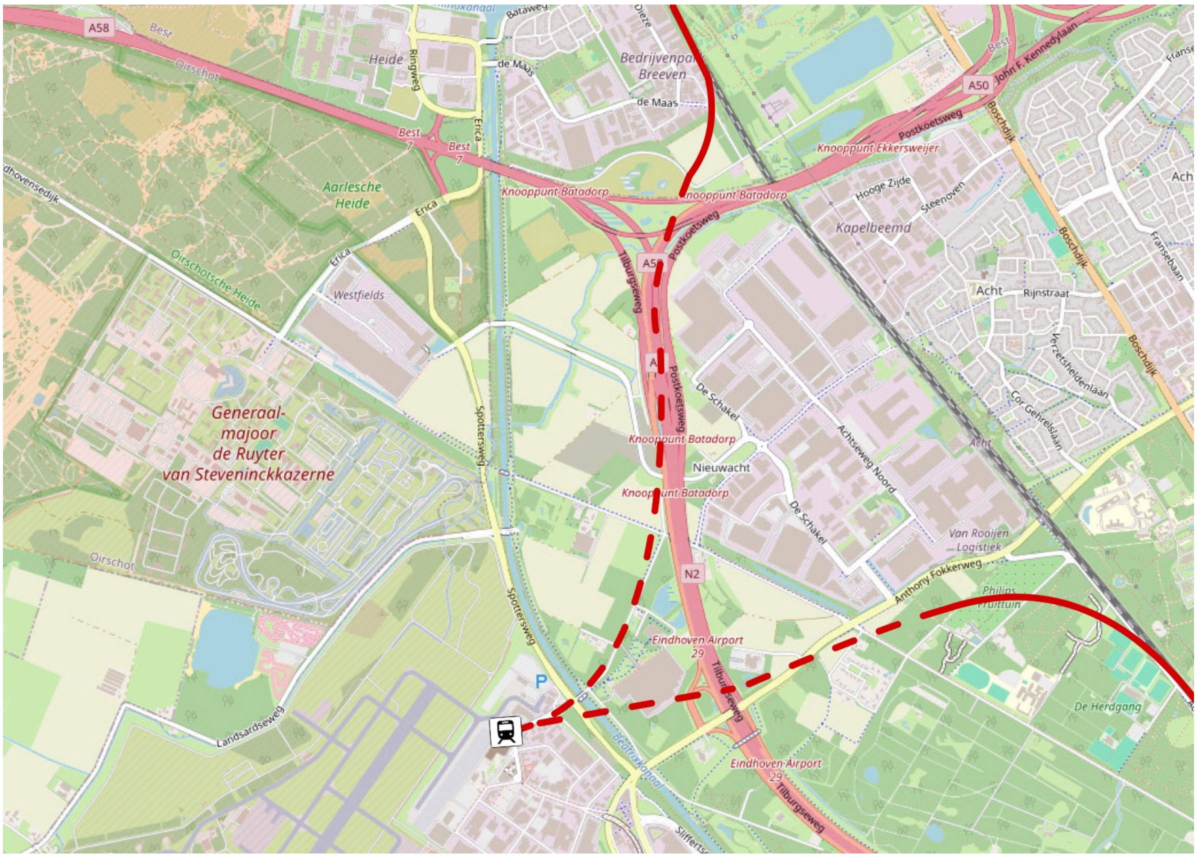


Figure 5.3: Train Station Airport

The underground station at Eindhoven Airport offers a very future-proof solution, as it enables direct, high-capacity rail access to the terminal without reliance on secondary transport modes, and can accomodate long-term growth in air travel and the BIC.

6 Discussions

6.1. Interpretation of results

The highest score for the train station at Acht shows that under financial and planning constraints, using existing infrastructure provides the best short term solution. While the underground train station offers superior direct access, its high capital cost and long implementation time lowers its practicality, especially given the urgency of the increasing demand within the next decade.

The Brainportlijn, although not achieving the highest score, could still play a big role if the regional transport plan is expanded beyond just Eindhoven Airport and the BIC. The Brainportlijn is aimed at the whole of Eindhoven and this means other Brainport hubs too, in this report only the BIC and the airport are considered.

6.2. Implications

Even though this research focuses specifically on Eindhoven Airport, the approach used can be applied to other growing regional airports, especially those located near innovation hubs like the BIC. The combination of demand analysis and a stakeholder informed Multi-Criteria Analysis offers a structured way to compare transport options, even when detailed forecasts or budgets are not available.

It also shows how regional developments, like the expansion of ASML, can create momentum for improving public transport infrastructure. As more companies cluster in places like the Brainport Industries Campus, better public transport becomes not just a mobility issue but also a regional priority. For planners and decision-makers, this link between accessibility and economic growth can help make a stronger case for investment in sustainable transport.

6.3. Limitations

This thesis makes several assumptions to keep the scope manageable given the available data and time. This means that the outcomes may not fully reflect the real world situation in detail.

The priorities and scores used in the Multi-Criteria Analysis are not based on interviews or direct input from the stakeholders themselves. Instead, they are based on publicly available information and assumptions. While care was taken to reflect realistic priorities, the outcomes might differ if actual stakeholder input were collected.

The demand estimation is based on terminal capacity guidelines (1.9 m^2 per passenger) and guidelines for workers (0.76 workers per 1,000 passengers), which are not specifically tailored to Eindhoven Airport's operational model. Although these values are commonly used in airport planning, more precise data could improve accuracy.

The demand analysis assumes a 30% modal split for ASML commuters and 20–30% for airport users during peak periods. Although these are reasonable estimates, they do not include survey data. Additionally, if either group under or over performs this expectation, the capacity evaluation may under- or overestimate the actual usage. A more robust approach could have included a scenario-based analysis, exploring how rankings shift under lower or higher demand.

It is assumed that all 20,000 ASML employees will be present and contribute to peak hour demand from the start, and that 30% of them will use public transport. Also all demand from the airport and ASML is assumed to overlap in a single evening peak hour. In practice, travel patterns may be more distributed across the day, affecting the estimated capacity needs.

While the AHP-based MCA provided a structured and transparent way to evaluate alternatives, it is inherently dependent on the assigned weights. These were derived from a qualitative stakeholder matrix, which, while logically justified, could be seen as subjective without direct stakeholder interviews or surveys. Additionally, the scoring of each transport mode on qualitative criteria like “system efficiency” involves a degree of interpretation that may vary for different people.

Lastly, the implementation section includes two maps showing possible train connection routes. These are meant to give a visual idea of how the preferred option could be integrated into the region. However, no official planning guidelines, technical design rules, or feasibility studies were used to support these routes. The maps are purely illustrative and should be seen as rough concepts rather than concrete proposals.

6.4. Recommendations for future research

This thesis provides a good first step in exploring how public transport to Eindhoven Airport could be improved, but there is still a lot to build on. Future research could start by collecting more detailed travel data and stakeholder insights. Surveys with airport passengers, workers, and future ASML employees would help to better understand how people actually travel and what would make them switch to public transport. It would also be valuable to do the MCA process with input from actual stakeholders, either via surveys or structured interviews, to base the criteria weights on real-world priorities.

Future studies could explore more dynamic modeling techniques, such as Discrete Choice Models or agent-based simulations, to more realistically predict traveler behavior under various infrastructure scenarios. Another useful next step would be to carry out a cost–benefit analysis. This would include not just construction costs, but also operational costs, ticket revenues, and long term benefits like fewer car trips and improved accessibility.

It would also be valuable to look more closely at the environmental impact and technical feasibility of the different transport options. For example, a real alignment study for the train line or light rail route could show whether the proposed maps in this report are actually possible.

Finally, future research could test how sensitive the preferred solution is to different scenarios, such as faster ASML growth, delays in infrastructure planning, or higher public transport usage. This would help prepare for uncertainty and make the recommendations better.

7 Conclusions

This thesis concludes that the most suitable public transport improvement to Eindhoven Airport, in light of the expected regional growth, is the development of a train station at Acht, supported by a shuttle service to both the airport terminal and Brainport Industries Campus.

Key findings include:

- The total peak-hour public transport demand in the peak month is projected at 6,650–7,000 passengers, mainly driven by ASML commuters.
- AHP-based MCA reveals that system efficiency, implementation time, and capacity are most valued by stakeholders, but cost also plays a critical role in decision-making.
- The Acht station alternative balances capacity, feasibility, and cost, making it the top short-term solution.

While the underground station would offer optimal long-term connectivity, it is up to the government and investors to determine the feasibility in terms of cost and implementation time. Other options like LRT and BRT remain valid for broader regional mobility but they are less specifically targeted at the airport and the Brainport Industries Campus.

The recommendations are:

- Pursue the Acht station option with detailed engineering and funding studies.
- Integrate bus or shuttle planning with BIC stakeholders for smooth multi-modal connections.
- Conduct stakeholder interviews to validate criteria weights and implementation priorities.
- Monitor demand after the ASML expansion to assess future need for scaling to Brainportlijn or other solutions.

This thesis provide clear, data-driven insights for improving the public transport system at and around Eindhoven Airport and the BIC. It offers clear direction for short-term improvements and long-term rail based solutions.

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A
Excel sheets

Normal Matrix	Capital Cost	Implementation time	Environmental emissions	Construction Impact	System efficiency	Capacity		Power
Province	6	4	2	1	5	3		3
MOI	6	3	2	1	5	4		3
Airport	1	4	2	3	6	5		2
ASML	1	4	3	2	6	5		2
Municipality	1	5	2	3	6	4		2
NS	3	4	2	1	6	5		2
Hermes	1	4	2	3	6	5		1
Residents	1	5	3	4	6	2		1
Travelers	1	5	2	3	6	4		1
Power Matrix								
Province	18	12	6	3	15	9		
MOI	18	9	6	3	15	12		
Airport	2	8	4	6	12	10		
ASML	2	8	6	4	12	10		
Municipality	2	10	4	6	12	8		
NS	6	8	4	2	12	10		
Hermes	1	4	2	3	6	5		
Residents	1	5	3	4	6	2		
Travelers	1	5	2	3	6	4		
TOTAL	51	69	37	34	96	70		357
	0,142857143	0,193277311	0,103641457	0,095238095	0,268907563	0,196078431		

Figure A.1: Stakeholder weights

	System efficiency	Capacity	Implementation time	Capital Cost	Environmental emissions	Construction impacts	
System efficiency	1,00	2,00	2,00	3,00	4,00	4,00	
Capacity	0,50	1,00	1,00	2,00	3,00	3,00	
Implementation time	0,50	1,00	1,00	2,00	3,00	3,00	
Capital cost	0,33	0,50	0,50	1,00	2,00	3,00	
Environmental emissions	0,25	0,33	0,33	0,50	1,00	1,00	
Construction impacts	0,25	0,33	0,33	0,33	1,00	1,00	
	2,83	5,17	5,17	8,83	14,00	15,00	
Normalized matrix							**Weights (averages)**
System efficiency	0,352941176	0,387096774	0,387096774	0,339622642	0,285714286	0,266666667	0,336523053
Capacity	0,176470588	0,193548387	0,193548387	0,226415094	0,214285714	0,2	0,200711362
Implementation time	0,176470588	0,193548387	0,193548387	0,226415094	0,214285714	0,2	0,200711362
Capital cost	0,117647059	0,096774194	0,096774194	0,113207547	0,142857143	0,2	0,127876689
Environmental emissions	0,088235294	0,064516129	0,064516129	0,056603774	0,071428571	0,066666667	0,068661094
Construction impacts	0,088235294	0,064516129	0,064516129	0,037735849	0,071428571	0,066666667	0,06551644
	Final weights						
System efficiency	0,337						
Capacity	0,201						
Implementation time	0,201						
Capital cost	0,128						
Environmental emissions	0,069						
Construction impacts	0,066						

Figure A.2: AHP Matrix and weight calculation

2,059708704		6,1205575
1,22797023		6,1180903
1,22797023		6,1180903
0,77463391		6,0576632
0,416054216		6,0595338
0,394741435	**Lambda max**	6,094787
	Consistency index (CI)	0,0189574
	Consistency ratio (CR)	0,0152882

Figure A.3: CR and CI calculation

Scores	System efficiency	Capacity	Implementation time	Capital cost	Environmental emissions	Construction impacts	
BRT (Brainportline)	4	4	3	1	5	4	
LRT	3	4	3	4	5	3	
Train (station Acht)	4	4	4	5	3	4	
MRT	4	3	2	2	2	1	
Train (airport)	5	5	2	2	3	2	
Weighted scores	System efficiency	Capacity	Implementation time	Capital cost	Environmental emissions	Construction impacts	**Final score**
BRT (Brainportline)	1,346092212	0,802845447	0,602134086	0,127876689	0,34330547	0,26206576	3,48
LRT	1,009569159	0,802845447	0,602134086	0,511506757	0,34330547	0,19654932	3,47
Train (station Acht)	1,346092212	0,802845447	0,802845447	0,639383447	0,205983282	0,26206576	4,06
MRT	1,346092212	0,602134086	0,401422724	0,255753379	0,137322188	0,06551644	2,81
Train (airport)	1,682615266	1,003556809	0,401422724	0,255753379	0,205983282	0,13103288	3,68

Figure A.4: Final scores

	Year	Month	aantal	Percentage
1	2017	January	349354	6,13
2	2017	February	347522	6,10
3	2017	March	416705	7,31
4	2017	April	503029	8,82
5	2017	May	544797	9,56
6	2017	June	532103	9,33
7	2017	July	567053	9,95
8	2017	August	577120	10,12
9	2017	September	553096	9,70
10	2017	October	536736	9,41
11	2017	November	401036	7,03
12	2017	December	372669	6,54
13	2018	January	398089	6,38
14	2018	February	393080	6,30
15	2018	March	452090	7,25
16	2018	April	537248	8,61
17	2018	May	585787	9,39
18	2018	June	583746	9,36
19	2018	July	623708	10,00
20	2018	August	635624	10,19
21	2018	September	615201	9,86
22	2018	October	612905	9,83
23	2018	November	409628	6,57
24	2018	December	390649	6,26
25	2019	January	400481	5,91
26	2019	February	404961	5,97
27	2019	March	486336	7,17
28	2019	April	606490	8,94
29	2019	May	656099	9,68
30	2019	June	657648	9,70
31	2019	July	665638	9,82
32	2019	August	681093	10,04
33	2019	September	672355	9,92
34	2019	October	662238	9,77
35	2019	November	446930	6,59
36	2019	December	440506	6,50

Figure A.5: Passenger data with percentage per month per year

61	2022	January	275066	4,35
62	2022	February	309283	4,89
63	2022	March	401775	6,35
64	2022	April	545981	8,62
65	2022	May	618681	9,77
66	2022	June	631243	9,97
67	2022	July	662646	10,47
68	2022	August	678848	10,72
69	2022	September	636581	10,06
70	2022	October	669753	10,58
71	2022	November	448417	7,08
72	2022	December	452325	7,15
73	2023	January	452713	6,58
74	2023	February	425978	6,19
75	2023	March	503693	7,32
76	2023	April	597756	8,69
77	2023	May	664708	9,67
78	2023	June	640577	9,31
79	2023	July	671051	9,76
80	2023	August	680983	9,90
81	2023	September	667278	9,70
82	2023	October	661976	9,63
83	2023	November	456544	6,64
84	2023	December	453660	6,60
85	2024	January	443501	6,47
86	2024	February	456692	6,66
87	2024	March	505130	7,36
88	2024	April	610342	8,90
89	2024	May	688046	10,03
90	2024	June	658426	9,60
91	2024	July	651651	9,50
92	2024	August	648552	9,46
93	2024	September	650478	9,48
94	2024	October	652775	9,52
95	2024	November	456393	6,65
96	2024	December	437158	6,37

Figure A.6: Passenger data with percentage per month per year

Month	Mean Percentage
Jan	5,97
Feb	6,02
Mar	7,13
Apr	8,77
May	9,68
Jun	9,55
Jul	9,91
Aug	10,07
Sep	9,79
Oct	9,79
Nov	6,76
Dec	6,57

Figure A.7: Mean percentage per month

B
Python scripts

```
import pandas as pd
import matplotlib.pyplot as plt

data = pd.read_csv('Luchtvaart___maandcijfers.csv', delimiter=';', skiprows=[0, 1, 2, 3], index_col='Perioden')
data = data.reset_index()
data[['Year', 'Month']] = data['Perioden'].str.extract(r'(\d{4})\s+(.*)')
data = data.dropna(subset=['Year'])
data['Year'] = data['Year'].astype(int)
data['Month'] = data['Month'].str.replace('*', '', regex=False).str.strip()


data = data[~data['Year'].isin([2016, 2020, 2021])]


data = data[['Year', 'Month', 'aantal']]


month_order = ['januari', 'februari', 'maart', 'april', 'mei', 'juni',
               'juli', 'augustus', 'september', 'oktober', 'november', 'december']
month_order_en = ['January', 'February', 'March', 'April', 'May', 'June',
                  'July', 'August', 'September', 'October', 'November', 'December']
month_map = dict(zip(month_order_nl, month_order_en))
data['Month'] = pd.Categorical(data['Month'], categories=month_order_nl, ordered=True)
data['Month'] = data['Month'].map(month_map)


pivot = data.pivot_table(index='Month', columns='Year', values='aantal')

# Plotting
pivot.plot(figsize=(12, 6))
plt.title('Monthly Passengers')
plt.xlabel('Month')
plt.ylabel('Passengers per month')
plt.xticks(rotation=45)
plt.grid(True)
plt.tight_layout()
plt.legend(title='Year')
plt.show()
```

Figure B.1: Python code for monthly passengers

C
Use of AI

During the writing of this thesis, I used AI in the form of ChatGPT. I used this tool for:

- Help with formulating research questions.
- Language and grammar checks to improve the flow of the text, as well as translating Dutch to English.
- Assist with coding in LateX and Python and use of Excel.
- Guidance for the structure of the report.

All the generated AI content was thoroughly reviewed and backed with sources. All core content, analysis, and interpretations were done indepently by me.