A study about the planning of The Copenhagen Metro and its effect on nearby local neighbourhoods

AALBORG UNIVERSITET
STUDENTERRAPPORT

P8 Project, 8. semester
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Title	A study about the planning of The Copenhagen Metro and its effect on nearby local neighbourhoods
Theme	Land Management
Project period	1. February 2023 – 1. June 2023
Project group	Group 1
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Keystrokes	Metro, Sustainability, Planning
Standard pages	83

Frontpage picture source: Copenhagen Metro by Stig Nygaard

Abstract

The Copenhagen metro is in constant development for the past decade, and plans for another M5 line have recently been announced. In light of the metro gaining a consistently larger importance to the overall transport network of Copenhagen, the following project examines the metro network in relation to the impact it has to the neighbourhoods it serves in terms of demographics, property value, and nuisances that lead to complaints. Furthermore, analysis of the metros impact on the city as a whole are also performed regarding the potential time saved and increased mobility that the metro can offer, and the environmental impact the metro has in terms of CO_2 emissions.

Through the process of case studies and processing available datasets surrounding demographics, sales data, received complaints, transport networks and traffic data, results show that there are slight demographic differences between districts in Copenhagen and a positive change in the property value of properties closest to the metro. Limitations in datasets present the challenge that the demographic changes cannot with certainty be attributed to the introduction of a nearby metro line, nor can an accurate percentage rise in the property values be assessed. Results further showed that potential complaints were thought to be anticipated and prevented by Metroselskabet I/S through several hearings and deals struck with properties in advance of the construction of a new metro line. However, unforeseen issues may still rise that lead to potential legal issues with affected residents. New metro lines are planned in such a way that they increase the mobility for all areas that pass by it, but previous transport planning shows that mobility isn't necessarily always the main objective for a new metro line in Copenhagen. Metros are a huge improvement in CO_2 emissions compared to private vehicles but are slightly less environmentally friendly compared to the buses in use. This may however change in the future as more passengers are using the metro while fewer use the bus lines. Overall, a slight positive impact can be seen on the CO_2 emission per passenger since the first metro lines were in operation.

Preface

This project is written by five students during the second semester of MSc in Surveying, Planning, and Land Management at Aalborg University in Copenhagen. The project has been written in the period from the 1st of February 2023 to the 2nd of June 2023. The project is written in accordance with the semester learning objectives and the theme of the project is Land Management. Furthermore, the project is based on knowledge acquired in the courses attended in the 2nd semester: *Spatial Planning and Governance* and *Property Rights*.

The semester project has been written by Liam Murphy, Oliver Friis, Oliver Kaarslev, Peter Ølgaard, and Ulrich Pless Sandland, with supervision by Jacob Norvig Larsen, to whom a big and appreciated thank you is due to his constructive guidance throughout the project period. In relation to obtaining and processing important data for several of the analyses, a big thank you must go to Jan Staunstrup and Jamal Jokar Arsanjani respectively for their indispensable help. Furthermore, thank you to Karsten L. Willeberg-Nielsen for the expert knowledge given in an interview about the process of the M3 Cityringen.

Reading Guide

The following project is divided into a Theory chapter with a subchapter of Literature Review. The following chapter contains the methods used during the project. The Analysis is based on the section Final Hypotheses for Analyses, which aims to gather the written theory into five hypotheses. In the end, the findings in the analysis and their correlation with the theory chapter, are discussed.

In this project, sources will be listed using the Chicago method and will appear at the end of the project in the bibliography. Appendixes appear at the end of the project. Danish legislation is translated into English, but the abbreviation will be written in Danish in table 1.

Name of Legalisation	Abbreviation
Act of a Cityringen	BLC
Promulgation of the Act on the procedure for expropriation of real estate	BPL
The Danish Constitution	GLB
The Public Administration Act	FL

Table 1: Abbreviations of Danish laws.

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Introduction

1. Description of the Problem Area

Infrastructure is an important factor to make a country more effective, it connects the community and connects countries to the global world. Infrastructure is a term that covers various constructions, but the common meaning is some sort of network that binds a society together. In the supply area, infrastructure is things such as the electricity network, water supply, or sewage network. These different networks serve as a base for citizens' daily lives and solve issues that would give work and concern if they haven't made it into an infrastructural network. Technological development gives some new infrastructural challenges that are improved over time. It could be cell phone coverage, cable TV, or broadband for the internet. This type of infrastructure has made it easier to communicate and get information, which helps companies and the business world improve the quality and effectiveness of how they produce their services. It also helps people in their everyday life, to communicate with each other and get new knowledge that helps to educate the population (Produktivitetskommissionen, 2014, p. 7).

All the constructions that make transportation possible are also infrastructure, such as roads, rails, bridges, and tunnels, which make it possible to navigate around a country both for individuals and goods. A higher number of constructed roads, rails, bridges, and tunnels, makes it faster to come around, which is good for the community and economy. Transportation can also be made across the world, and it became more important because of the globalizing world. Roads and railways across borders help to make trade across countries, both especially harbours and airports are important for trade across countries, because it is possible to travel all around the world (Produktivitetskommissionen, 2014, p. 8).

The United Nations has 193 member countries, including Denmark, and in 2015 during a meeting in New York, adopted a series of 17 ambitious universal sustainable development goals and 169 sub-goals. The goals entered into force on the 1st of January 2016 and are based on the three sectors of sustainability, economic, social and environmental, by obligating all of the member countries to work towards a better and more sustainable future for the planet as a whole, by abolishing hunger and poverty, ensure education and healthcare to all citizens and enhance equality (The Global Goals [A], 2023).

Public transport makes the infrastructure available for all people and in theory, it potentially results in a more equal society. Public transport can go across countries inside a country or be isolated to a specific city. Infrastructure can help achieve the UN's global goals, especially goal number 9 and 11. Infrastructure is fundamentally related to the opportunities and the economy for the population because infrastructure makes people come around in a city or a country (The Global Goals [B], 2023).

In Denmark, there are different types of public transport, including buses, ferries, trains, metro, and light rail. Metro and light rail, however, are only located in specific cities with a population large enough for them to serve. Light rails are placed in Aarhus and Odense, and another light rail line is under construction in Copenhagen. The only place in Denmark with a metro is Copenhagen, with even more metro lines under construction. The metro helps the infrastructure a lot, as it is mostly subterranean and thus reduces the needed space for traffic on the roads.

An infrastructure project like the metro can help to achieve some of the 17 goals. It plays a big part in the 9th sustainable development goal "*Industry, Innovation and Infrastructure*", by promoting sustainable and affordable infrastructure with outwardly being accessible for all as per subgoal 9.1 "*develop sustainable, resilient and inclusive infrastructure*" and 9.4 "*Promote inclusive and sustainable industrialization*". Furthermore, it is possible to draw parallels to the 11th sustainable development goal "sustainable cities and communities", and sub-goals 11.1 "*create affordable and sustainable transport systems*" and 11.3 "*inclusive and sustainable urbanization*" (Danmarks Statistik & 2030-Panelet, 2020, pp. 152, 220).

In 2030, infrastructure should be improved, giving a more effective city environment according to goal number 9 industry, innovation, and infrastructure. It would also help reduce the discharge of CO_2 if the cities are adapted to public transport there would be fewer cars on the roads which would reduce the discharge of CO_2, and at the same time give smoother traffic, which would give a more effective city environment (The Global Goals [B], 2023).

Goal number 11 is sustainable cities and communities, and public transport is a key factor to achieve this goal. Everybody should have access to secure and sustainable transportation systems, at a limited price, this should also help to more safe traffic. A way to get a more sustainable city is to get better air quality, a metro would help get better air quality because the metro takes the traffic down under the ground, and it gives fewer passengers in cars and buses, that have a negative impact on the quality of the air (The Global Goals [C], 2023).

The metro consists of different lines. The green line, M1, from 2002, the yellow line, M2, from 2007, the red line, M3 (Cityringen), from 2019 and the blue line, M4, which is extended from

8 stations to 13 stations in 2024 connecting south of Copenhagen to the rest of the city, as seen in figure 1. Furthermore, the purple line, M5, is expected to be ready for use in 2035.

Since the first metro line opened in 2002, 1 billion passengers have travelled with the metro. The Danish metro has on several occasions been nominated as the world's best metro where an average of 360,000 passengers use it to move through Copenhagen every day. The vision behind the Copenhagen metro is to have a metro system based on small trains with frequent departures down to about 120 seconds between, with the purpose is to transport as many people as possible. In addition, the vision is a classic Scandinavian design, constructions of longevity and surrounding areas that appeal to those who live near the metro stations (Metroselskabet I/S [A], 2023).

The metro is a counter move to the increasing growth in the capital which would influence the traffic and transport in Copenhagen heavily if the metro was not constructed. Furthermore, the idea was a metro system that should increase the popularity in, among other things, the newly built district, Ørestaden. Copenhagen's metro is driverless and fully automatic (Metroselskabet I/S [A], 2023) (COWI A/S, 2023).

Figure 1: The metro lines in Copenhagen today and in the near future (Metroselskabet I/S [A], 2023).

Copenhagen will get a new metro line in 2035 and it is the M5. The line will go from Copenhagen Central Station to Østerport and will go over Amager past Amagerbrogade, Refshaleøen, and the future panned island Lynetteholmen. It is an opportunity to make the metro line M5 into a ring like M3 and connect the line from Østerport to Copenhagen Central Station past Rigshospitalet, Stengade, and Forum, but it is not decided yet. The major goal for this metro line is to give a good infrastructure to Lynetteholmen, which is a big project, that will house thousands of citizens in the future. At the same time, Refshaleøen will also get a much better infrastructure, which will give the area a huge potential to be an attractive place to live in Copenhagen in the future. Right now there is not that much housing at Refshaleøen, but there is space to build a lot of apartments, which could help the problem of overpopulation in Copenhagen, and the metro will accommodate the urban development at Refshaleøen, and it will be the same case at Lynetteholmen when the island is finished, because then it is empty, and metro will help the island to be more attractive, and it gives a bigger incitement, to urban development the island.

M5 would get 10 stations and 6 of these stations will be new stations that need to be built from scratch. If the line will be connected as a ring, the ring will get three more steps, where two of these stations will be new stations. The planned line and stations are visualised in figure 2 (Københavns Kommune [A], 2023).

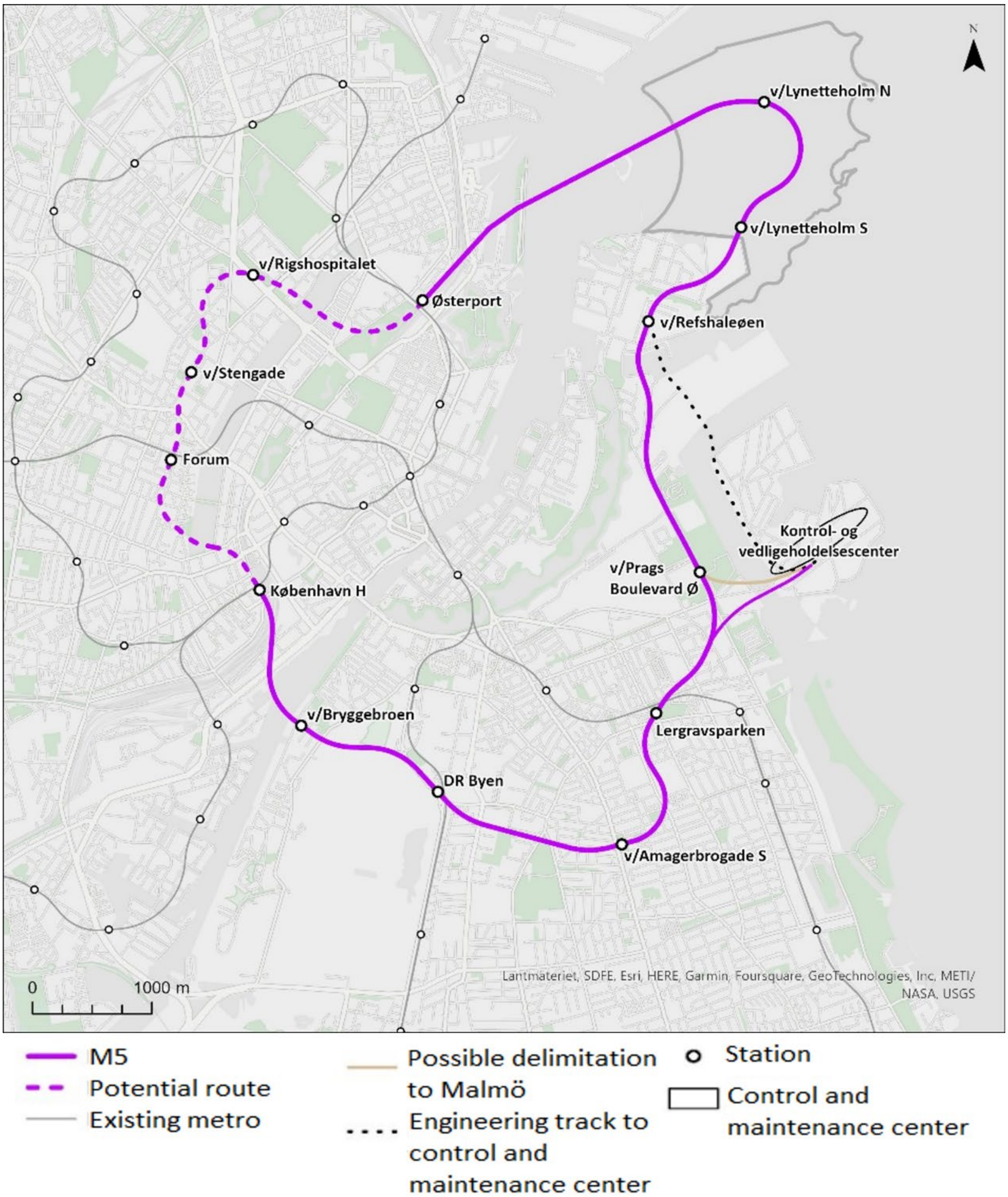


Figure 2: Proposal of the M5 line (Københavns Kommune [A], 2023).

The metro in Copenhagen will be investigated in this project to find out if it affects inequality in Copenhagen in the way the UN's global goals intend to do.

1.1. Problem Statement

What effects towards local residents should be considered when planning and operating a new metro line regarding demography, property value, common complaints, mobility, and the environment?

- How do selected demographics of a neighbourhood change after a new metro line opens in the near vicinity, and does it lead to inequality between neighbourhoods?
- Which properties experience the highest change in value near metro stations, if any, and by how much?
- Does the opening of a new metro line warrant a wave of complaints? Why do local residents choose to complain?
- How much time can a new metro line save, and is the main objective of a metro line solely to improve mobility?
- What environmental benefits can be attributed to the metro?

1.2. Structure Diagram

The results of determining the benefits and weaknesses of metro planning and the effects of neighbourhoods close to a planned metro line depend on how these questions are analysed. These questions are also asked by city planners when constructing a new metro line, where they easily can become politicised. The following section describes the chosen methodologies in relation to how they can be used to answer the main problem analysis, but also what biases could be included by using them, and what risks of exclusion arise. The five hypotheses are mentioned in figure 3 as H1, H2, H3, H4, and H5.

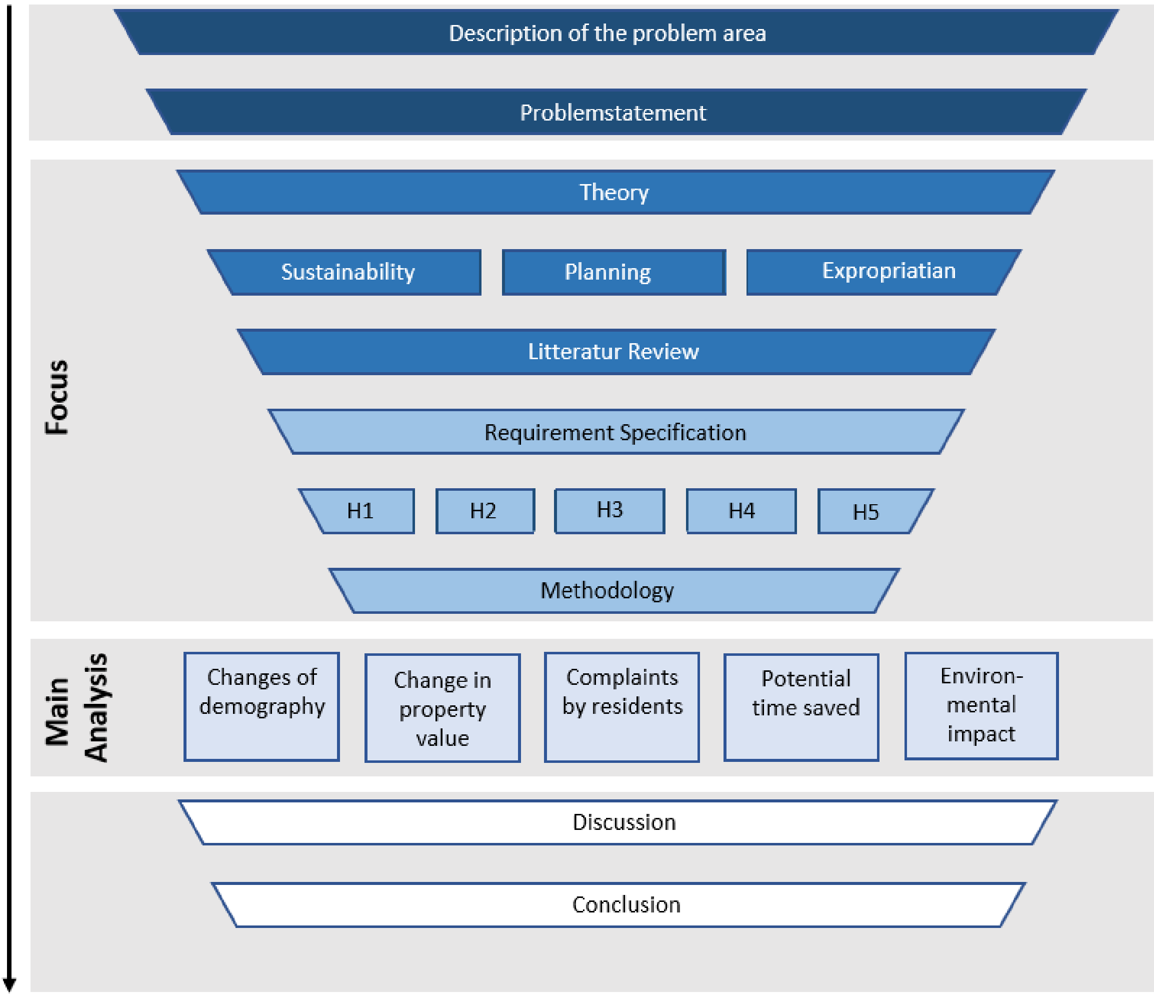


Figure 3: Structure diagram (Holgaard, 2018).

Theory

2. Theory Regarding Sustainability

The importance of cities in achieving sustainable development has kept increasing as the urban population continuously grows. The year 2008 marked a prominent time in human history due to the fact that, for the first time ever, more than half of the world's population was living in urban areas, and the number is expected to rise by 72 % between 2000 and 2030 (Dempsey, Bramley, Power, & Brown, 2011, p. 290).

Sustainability is a contested term and has through the years been subject to a great amount of change, with no consensus ever really existing. This was until the report "Our Common Future" published back in 1987, better known as the "Brundtland Commission Report", in which the concept of sustainability was first defined as the act of meeting our own present demands and needs, without compromising the demands and needs of the future generations. This definition of sustainability had a significant influence on the world and has gained widespread acceptance as the authoritative general definition. In 1992, the UN held a conference in Rio de Janeiro regarding the Environment and Development of the world, in which the term sustainability was further defined as the act of pursuing "human development and well-being" (Basiago, 1999, p. 148).

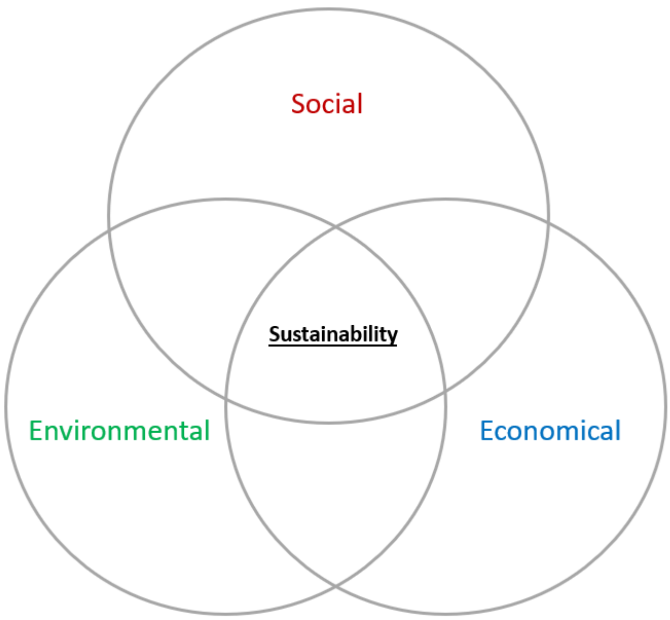


Figure 4: The three overlapping sectors of sustainability (Self-produced in PowerPoint).

Furthermore, the Brundtland Commission report changed the way in which the term sustainability is been viewed, by connecting the bio-physical environmental side of sustainability with more social and economic aspects, by turning it into three different sectors:

Social, Environmental and Economical sustainability (Vallance, Perkins, & Dixon, 2009, p. 1). However, these three sectors must not be viewed as separate or autonomous, as this could course the risk of handling the arising issues in regard to sustainability in a compartmentalized approach. It is important not to undermine the fundamental interlink between the environment, economy, and society (Giddings, Hopwood, & O'Brien, 2002, p. 190). In other words, the effects of the three sectors are overlapping, as visualised in figure 4, thus meaning, if one would inflict a change upon one of the sectors, this would undoubtedly result in a change in the remaining two sectors (Higgins, 2013).

The weakness of the three-sector divisions of sustainability is the fact that it could lead to the assumption that trade-off is possible and encourage a more technical and isolated fix of any encountered issue. This assumption ignores, that even if all of the problems regarding economical sustainability are solved, it would not compensate for the problems regarding the social or economic side (Giddings, Hopwood, & O'Brien, 2002, p. 190).

2.1. Economical Sustainability

The economy is often compared to growth by governments with the justification that inequality in education, wealth and power will raise economic growth, which over time will raise the living standards for everyone. In modern times, different growth concepts are used in terms of economical sustainability, for example, *green growth*. This concept is considered long-term economic growth that does not negatively impact social and environmental aspects (Arler, Mosgaard, & Riisgaard, 2015, p. 82). Additionally, growth and development raise the level of investments in social and environmental sustainability (Giddings, Hopwood, & O'Brien, 2002, p. 190). According to Giddings, politicians have historically prioritised the economy, relative to social and environmental sustainability, which is not necessarily compatible with sustainability, as mentioned in the previous paragraph.

Economical sustainability evaluates the impact of economic activity and collaborates with sustainable goals to secure and create a liveable future. In addition, sustainable practices seek to solve and/or limit human-made problems to the extent of the increased ecological footprint. Different approaches can be used to handle these problems, this could be reducing the amount of the natural environment that is depleted. Another approach is to create solutions that limit carbon emissions, reduce waste, and utilise renewable energy (MasterClass, 2022). As mentioned, sustainable economic development would be to reject short-term planning that would secure an instant economic outcome but also would harm social and environmental sustainability.

Rethinking and improving infrastructure along with other urban projects embrace the planet’s long-term well-being and ensure that the level of economic, social, and environmental sustainability is raised. This can be accomplished by using new technologies that allow for decreasing energy consumption and at the same time increase the effectiveness of production. Economic growth is essential to develop specific parameters in this world. However, growth must not happen at the expense of social and environmental sustainability. Therefore, the construction of infrastructural projects, which aim to secure sustainable transport and lower the ecological footprint, must be financially profitable for developers and constructors, but it cannot be the main goal of sustainable urban development (Giddings, Hopwood, & O'Brien, 2002).

2.2. Social Sustainability

Social sustainability is a concept with a substantial amount of literature devoted to it. It is a very complex concept with many trying to narrow it down to a singular, all-encompassing, definition. Social sustainability, like sustainability in general, is neither a constant nor an absolute, but should instead be considered a more dynamic concept, which is under the influence of constant change and is of utmost dependency on the place and time. This evolution is influenced by the evolving modern society, including the environment, the economy and political change at a local, but also global scale. At the same time, the concept of social sustainability is not only dependent on physical factors but also non-physical factors (Dempsey, Bramley, Power, & Brown, 2011, pp. 290-292). A series of factors can be seen in table 2.

However, if all of the physical and non-physical factors as well as the varying definitions and interpretations are to be considered, the core of the concept must lay in a great sense of equity. When it comes to urban development, equity shines through regarding social and environmental inclusion. An equitable society is defined as a society that distances itself from practices which are of an exclusionary or discriminatory nature, thus not economically, socially, or politically hindering individuals in that society. In order to achieve sustainability, one must think on a global scale and act accordingly. However, social stability is also very much dependent on local actions, which inflict upon the everyday experience of the citizens. Social exclusion and inequity are generally measured through accessibility, including vital public services and facilities, like public transport, decent housing, culture, etc., all of which are listed in table 2. The services and facilities can both be linked with the actual built environment or indirectly linked. In conclusion, social cohesion and inclusion society can be defined as a “strong, fair and just society for present and future communities” (Dempsey, Bramley, Power, & Brown, 2011, p. 193).

Non-physical factors	Physical factors
- Education and training - Social justice - Participation and local democracy - Health, quality of life and well-being - Social inclusion - Social capital - Public services - Community - Safety - Mixed tenure - Fair distribution of income - Social Order - Social cohesion - Community cohesion (i.e. cohesion between and among different groups) - Social networks - Social interaction - Sense of community and belonging - Employment - Residential stability - Active community - Cultural traditions	- Decent housing - Infrastructure - Green Spaces

Table 2: The physical and non-physical factors in social sustainability (Dempsey, Bramley, Power, & Brown, 2011, p. 291).

2.3. Environmental Sustainability

Local Agenda 21 (LA21) in Rio de Janeiro included topics regarding social and economic development and strengthening, however, LA21 primarily focused on environmental sustainability. The existence of human beings takes place within the environment, and most human activities impact the environment that we live in. Civilizations have always had material needs, such as food, light, heat, clothing, medicines, etc., in order to thrive and grow. These products, whether it is classified as goods or waste, return to the environment after use. Satisfying needs are enjoyed from the environment, mostly culture, art, spiritual patterns, and science are drawn directly by the environment as well as lots of the technology used, are the result of environmental evolution. The environment can be named the most important source of sustainability because the economy does not exist without a society and environment, but if there is no society, the environment will continue without an economy and society (Giddings, Hopwood, & O'Brien, 2002, p. 189).

In sustainable transportation, limits and complexities are faced in the process:

- Energy input, the shift to renewable energy
- Street capacity, making excess area (e.g. stations) from transportation into space-efficient and multipurpose areas
- Finance, ensure resources to construct and maintain the transportation infrastructure
- Policies, ensure support for developing sustainable transportation (Tumlin, 2012, p. 10)

Therefore, the well-being of humanity depends on the environment, which contributes to a win-win scenario where sustainable development is integrated into society. An example is shifting into renewable energy which will benefit human well-being and the environment. Hence, the argument could be to rethink the priority on the economy and give primacy to sustainable satisfying needs and human provisioning (Giddings, Hopwood, & O'Brien, 2002).

Sustainable urban development refers to parameters within environmental sustainability. According to Professor in urban development, Petter Næss, density is essential to create a sustainable district or urban. The dense city is supported by well-functioning social life which includes access to cultural functions, various services and sustainable transport opportunities (Næss, 2015, p. 247). Density refers to how dense a city is built and the number of people living in that city. Density is essential when planning the infrastructure of a city. According to Næss, it is possible to reduce the use of energy to transport, because the higher the density in a city the lower amount of energy needed for transport. This is examined in 22 Scandinavian cities and concludes that cities with high density have 25 percent less energy consumption (Næss, 2015, p. 247). In addition, a city consisting of high density, the choice of public transport (bus, metro and train) become more obvious for the inhabitants. The density is not enough to change the habit of choosing a car. The infrastructure must support the choice of sustainable transport to make people travel by walking, cycling, or the metro (Næss, 2015, p. 248).

Furthermore, the strongest cities are those that offer different ways of attractive transportation, whether it is automobile, bus, train, or metro. Cities that solely focus on automobile transportation may benefit economically in the short-term but are vulnerable to spikes in prices of essential resources such as petroleum. Contrary, cities that offer different transportation choices reduce the increased dependency on only one mode of transportation and they can benefit from economic trends (Tumlin, 2012, p. 11).

3. Theory Regarding Planning

Planning theory spans over a vast variety of different studies and can be separated between one another in several ways. One of the more widely used modern ways to do so was made by John Friedmann in 2003, dividing planning theory into theories *in* planning, theories *of* planning, and theories *about* planning (Friedmann, 2003). The following sections consider different theories in and of planning in relation to the past and present metro projects in Copenhagen. Theories in planning mainly centre around transport and infrastructure planning which naturally are key elements that are included when planning new metro lines. Various theories of planning, which are also included to lesser or larger degrees in metro planning, are also examined.

3.1. Soft Spaces in Planning

The globalist and neoliberal tendencies of today's planning contribute to the creation of larger regional areas of development which have been coined as "soft spaces". These soft spaces are the result of groups of smaller authorities and interests with power who have a common political view and interest to create new planning cultures, along with further developing a larger, sometimes international, region (Olesen & Hansen, 2020). The goals of these larger soft spaces are to increase the development and by extension the competitiveness in attracting business to the region. It can be viewed as an attempt to face challenges of becoming "backwater" areas on a global scale, which for a long time has been viewed as a growing problem both on a national and an international scale (Brunet, 1998). Soft spaces thus attempt to achieve enough power to develop their region either without the need for help or investment from larger governmental bodies, or by making it an interest of these governmental bodies to cooperate with them. Soft spaces gather the power to do so through investments from various actors with interests in the area and/or smaller governmental institutions, such as municipalities. Soft spaces could therefore be considered as attempts to improve mainly the economic and social sustainability of their areas.

Soft spaces can exist in the shape of business regions, as they do in the case of Denmark. Copenhagen is the centre of its own international soft space business region named Greater Copenhagen. Greater Copenhagen was formed in 2015 as a reform of the older Region Øresund, enveloping the Capital Region and the surrounding regions of Zealand, Scania and Halland. Greater Copenhagen has recently shown interest in the further development of the Copenhagen metro and has openly supported the latest suggestion for the new metro line M5.

The support originates from the plan of creating stations at Refshaleøen and the future Lynetteholm, which leaves the possibility for an extension of the metro towards Malmö to relieve the Øresund Bridge, which is expected to become more congested following the construction of the Femern Tunnel (Greater Copenhagen, 2023) (Øresundsmetroen, 2023). The interest in building metro lines is therefore one of increasing the mobility of residents within the soft space, and by extension the economic and social sustainability of the biggest cities in the business region.

3.2. Rational- and System Planning

Rational planning and system planning are two planning theories that can be used to develop and plan city spaces. System planning is complex and dynamic, and rational planning is specific. System planning looks at the population's choices and behaviour, and how people change the way they live, and one factor can lead to other choices that influence the way people want to live (Allmendinger, 2009, p. 52). Rational planning is based on the previous choices and behaviour the population has made. This is a more statistical way to plan, where analysis is used to make the decision about the development in planning a city (Allmendinger, 2009, p. 63).

These theories can be executed in two different ways, system planning as process-orientated planning and rational planning as blueprint planning. In process-orientated planning there are listening to inputs that will come through the work process, this will help to get planning customized to the population behaviour as it is currently. In blueprint planning, everything is planned before the work process starts, and the plan does not change because, of inputs, this will do the process more effective, but potentially would the project fit the population worse (Faludi, 1973, pp. 131-132).

3.3. Communicative Planning

Post-positivist planning theory is a school of thought that has slowly emerged, especially through the 90s, when planning theory began to move away from rational thinking, and instead slowly became more communicative (Huxley, 2000, p. 333).

Communicative planning seeks to escape from the locked one way of planning where the planners follow the narrow rational way of planning. Communicative planning stems from the diversity in the community. It takes into consideration that people live in complex different social and economic relations which develop different values and various ways to see the world, highlighting there is no one encompassing way of planning new development.

Communicative planning is a way of trying to accommodate the diversity and find the best possible fit for everybody by sorting through different arguments and creating a new discourse (Healey, 1996, pp. 218-219).

The process of communicative planning involves reviews of the issues through surveys, an analysis where the issues is sorted and explored, related to the values in an evaluation of the impacts. Afterwards inventing and developing new strategy ideas and a review of the new strategy (Healey, 1996, p. 230). When executing communicative planning, the tasks that are relevant to discuss, are:

1. The place of the discussion.
- As the location can have a say in who gets a larger voice.
2. The scope and style of discussion.
- Is important that the right languages and the most inclusive style of them is used in balance to ensure that everyone feels they can participate in the debate while also reducing misunderstandings.
3. Sorting through the arguments
- Where understanding the most important wishes, as well as concluding which of them can't be fulfilled, and how any objections could instead be mitigated.
4. Creating a new discourse
- New strategies for the project will be created with new different angles and perceptions from the public hearing.
5. Agreement and critique
- Agreement or illumination of conflicts on the new discourses and a review (Healey, 1996, p. 231).

Planners need to be aware that there is a tendency to become biased, both upwards towards their superiors and downwards towards their subordinates. Likewise, politicians are influenced since bureaucrats strategically value their own field of expertise more than others and give it a higher importance. This means that planners tend only to be influenced by the information they deem relevant to their field and risk neglecting other information that may be equally relevant (Rademann, 2022, p. 52).

In the case of larger projects - such as the expansion of the Copenhagen metro would be - the output of the policy of planning authorities is influenced by interactions with third-party actors. These interactions can be grouped in several ways. One way is formal participation schemes that the respective ministry is behind, with public participation. The ministry can also choose to hold informal consultations with administrative or economic actors. In addition, third-party actors can also be statements from organized interest groups and local citizens' initiatives, also helping to influence political actions. It is therefore possible at city and county level that the ministries' policy is not solely influenced by top-down communication but should also be supported by bottom-up constellations with input from locals (Rademann, 2022, pp. 198-199).

This stems from a study in Germany together with Switzerland and Austria, which has also shown that, in general, the administrative tasks carried out in a decentralized manner have been successful. The study further concludes that since there is even more decentralization in Scandinavia, the generalization would also be applicable to these countries (Rademann, 2022, p. 207).

One way to make planning more communicative in Denmark has been to decentralize administrative tasks and give the municipalities more power, which they got after the municipal reform in 2007, where there were fewer but larger municipalities. The municipalities have an overall framework from which they must work but can angle the planning so that it fits the traditions and mentality of the individual municipality. This is because the municipalities are closer to the local community and have an easier time conducting a dialogue as well as more knowledge of the area than with top-down planning (Hansen, 2018).

The communicative way of planning is a democratic way of thinking, where as many stakeholders as possible should be heard. A disadvantage of the communicative planning method is that it extends the period for the construction of a project considerably compared to rational planning.

3.4. Transport and Infrastructure Planning

Transport and infrastructure planning doesn’t solely consist of planning for congestion but also includes aspects such as forecasting increases or decreases in traffic following new infrastructure, planning for the needed availability, and making new infrastructure seem more attractive and useful than the already existing network opportunities.

One of the keywords of transport and infrastructure planning is mobility, both in terms of transport of goods, information, and people. Mobility is a heavily researched subject as several studies have mentioned the changes experienced as a result of increase in mobility. An important aspect of the increase in mobility through transport and infrastructure planning is how demographics change. Several studies have been made on how increase in mobility may lead to various demographic changes in terms of changes in education, wealth and economic stability, industrialisation and other factors (Bergman & Joye, 2002) (Erikson & Goldthorpe, 1992). However, a more recent study presents the increase of mobility as a challenge towards being able to examine single areas for specific demographic changes, as an increase in mobility leads to a higher change and mix in between areas. Increasing the integration of various classes and backgrounds renders analysis of certain demographics for an area smaller than large transnational areas, such as soft spaces, irrelevant. In the theory of social sustainability, as mentioned previously, a more mixed demographic, that doesn't significantly vary from neighbourhood to neighbourhood, would generally be considered a more positive change towards social sustainability (Manderscheid & Richardson, 2011).

Theory surrounding specifically the planning of a new metro line surrounds itself with what needs the line can fulfil, which in the cases of new transport lines mainly is about mobility. On many occasions new lines are also advertised to reduce congestion in the city; however, these claims are not always ultimately correct - When constructing new transport lines, most models usually determine a relief in road traffic congestion, but typically do not take the growing amount of traffic into account, which will happen as a result of the new transport line itself. Typically, when new transport lines open, many different travellers who previously would take other routes converge on the new route believing it to be faster. Overall, along with increasing the value of nearby properties, it also increases the demand in traffic, rarely relieving the congestion previously advertised. However, this can be mitigated through strong land-use legislation (Tumlin, 2012, pp. 244-246).

When selecting a route and mode of transportation, a traveller will typically have three aspects in consideration (Tumlin, 2012, p. 243):

- ***Time***, which is how quick the route and mode of transportation are. If a certain route is typically congested at the time of travel, a traveller may look into alternative routes which on paper are slower but may overall save time by avoiding the congestion. Time can also be less of a factor if the traveller can use their time productively during travel, such as when aboard a train.
- ***Quality*** is a more overlooked aspect that still has quite an influence on the choices of a traveller. Quality covers the aspects of comfort, dignity and safety that influence the choice of route. A traveller may choose to travel by car or bus rather than a bicycle in

bad weather, even if the route may take longer time. Likewise, stigmas surrounding modes of transport may rule out several quicker routes. For instance, in many western countries, buses are typically avoided in favour of cars or other modes of transport, as they are seen as the poor person's mode of transportation (Hess, 2012). Some places may also be seen as dangerous at certain times, leading travellers to prefer routes that avoid stations near such places.

- ***Cost*** can also lead travellers to pick alternate routes. Cost is typically considered more heavily on longer distances, as shown by the many websites to find the cheapest plane tickets from one city to another. However, cost also exists within public transport in a city. A rise in costs for the construction of the Copenhagen Metro Cityringen was part of the rise of cost to travel with the metro, a decision which led many to avoid the metro in favour of cheaper alternatives (Rantorp, 2019).

Determining the placement and design of the transport line stations also has an equal effect on the traveller's choice due to similar aspects as the ones mentioned above. A station is considered best for pedestrians who wish to use the station if it follows six conditions that can be achieved through planning:

- Safety and security
- Directness and ease of entry
- Comfort and aesthetic

Furthermore, stations are preferred to be placed near other modes of transportation to provide further connections and streamline travels (Tumlin, 2012, pp. 217-223).

4. Theory Regarding Expropriation

The vertical property boundary in Denmark is juridically defined by measuring sheet and is practically illustrated by boundary marks. However, there is no regulation in the Danish legalisation, that directly defines where the horizontal property rights boundary is, in regard to the underground. But according to the Danish lawyer Fr. Vinding Kruse, the property owner only has the right to the underground as far down as the usual usage of the property would need (Kruse, 1951, s. 315).

4.1. Expropriation and Neighborship Rights

In order to understand the difference and relation between neighborship rights and expropriation, one must separate the terms special and general disadvantages.

Expropriation concerns properties which are inflicted by disadvantages of special nature. Special disadvantages are disadvantages, which are directly correlated with the expropriation itself. As stated by GL §73, section 1, the property right is inviolable, and one can only refrain from one's property due to the welfare of the common good by law and with total compensation. Property right is to be understood as the ownership of both lands and easements and refrain in the terms of land acquisition, easement order or by cutting one from exploiting one's right in relation to a certain area (Mørup, 2015, s. 1).

The standard neighborship right concerns properties, which are inflicted by disadvantages of general nature. General disadvantages are natural side effects concerning the usage and establishment of an expropriation project, like noise or shadows, which affect all of the surrounding properties to a certain extent. Unlike special disadvantages, general disadvantages don't deal with the infringement of one's rights, but more the concrete use of an area. More often than not, one must often utilize unwritten law developed by the Danish Courts in order to determent the extent of the topic, as there is generally no regulation to be found in the Danish legislation regarding the topic of Neighborship rights apart from a selected few, which only concerns private affairs. Regulation regarding public affairs is characterized by them having to be found in the unwritten law (Mørup, 2015, s. 1).

4.1.1. The Process of Expropriation

As mentioned in the previous section, the property right is inviolable and can only be taken away against full compensation. It is expropriation if the intervention that is carried out affects either a protected right, such as real property, or a protected right holder such as a tenant of the property (Flensborg, Mørup, & Mølbeck, 2019, p. 25).

After it has been investigated where the most optimal location of a project is and archaeologists have examined the land, the planning authority requests the Ministry of Transport to carry out expropriation according to BPL § 11. Afterwards, the Ministry of Transport forwards the application to the Expropriation Commission. “Inspection business” of the area can now take place where the physical location is marked with flags, with the purpose to show the commission and get their acceptance, on the project or whether there are circumstances that need to be changed by it according to BPL § 13, section 1.

When a facility is about to be built, whether it’s a road, railway or metro, there are quite a few instances that need to be involved. It is The Danish Road Directorate that decides where it is necessary to place a new road. New railways and updating of the existing railways are decided by Banedanmark which is under the Ministry of Transport.

The Copenhagen Metro company is owned by the municipals of Copenhagen and Frederiksberg and by the government under the Ministry of Transport, which decides where to place the new metro lines. Whether it is a new road, railway or metro must be built, a construction act must be adopted by the parliament.

Expropriation is a forced surrender of a property where compensation is given for the lost property or the lost part of it. As the metro is placed around 20 meters under the ground surface, there can be no question of compensation for the landowner as this area does not fall under its usual purpose of the property right (Løvborg, 2023).

When a metro is about to be built, there has to be a statutory “VVM report”, that highlights the impact the construction of the new metro has on the environment, people, and wildlife around the project (Metroselskabet [B], 2023). During the metro's construction and subsequent operation, neighbours may be affected by noise that exceeds the tolerable limit. The noise limit is given by the Ministry of the Environment (Miljøministeriet, 2023). If the neighbours are affected by noise, they are able to get compensation for those genes that exceed the natural tolerance limit.

4.1.2. Determining the Compensation

The main principle, when dealing with compensation in regard to expropriation or neighbouring law problems, is that the inflicted property owners must not be placed in a worse financial situation after a given operation. One important thing to keep in mind is the fact that every property is unique, and therefore every case needs to be evaluated differently, which involves discretionary elements (Hessner, 2023).

4.1.2.1. Compensation of Expropriation

As stated by GL § 73, section 1, the owner of a property inflicted by expropriation is entitled to total compensation, which is usually evaluated by the market value of the property in question. The market value is estimated with the use of the property valuations, but also similar property transactions in the nearby area, which acts as fertile ground for comparison. One must also consider the actual qualities of the property, e.g. quality of the soil is of utmost importance when dealing with properties located in rural areas, but also the glory value of the property is important. Another significant aspect to consider is the present and future land use of the property as defined by various plans, in which the municipality addresses how the property is to be used in the future. However, future land use cannot solely be based on the expropriation plans but must be defined by pre-existing plans formulated before the expropriation plans. Lastly one must also consider the pollution of the property, which, if detected, generally would bring the compensation fee down. However, the compensation cannot be lowered, if the pollution doesn't have an impact on the correct usage of the property or if the owner bought the property not aware of the said pollution (Hessner, 2023).

In some instances, the government must restrain from evaluating a property by using the market value, if the property doesn't have a market value or if the property is designed in a certain way in order to obtain a specific purpose, thus making it non-replaceable for the owner. Another problem, which can arise when evaluating the value of a property, is if the property is laid out for public purposes or if the property is necessary for the fulfilment of any local plans, thus making it a lot less valuable in comparison to properties which are not. The solution for this problem is the government must try to evaluate the property based on how much it would be worth if the before-mentioned scenarios weren't the case (Hessner, 2023).

4.1.2.2. Compensation of Neighborship Rights

Unlike cases of expropriatian, the owners of properties inflicted by problems regarding neighborships rights is not entitled no full compensation. Instead, the compensation is calculated by the difference principle, which states that only disadvantages which exceeds a fixed endurance limit are to be compensated. How this fixed endurance limit is defined is very much depended on previous judgments and the nature of the case (Hessner, 2023).

4.2. Legality of Planning a Metro Line

In this chapter, the legalisation that affects the property owners according to BLC will be presented. The legalisation is made by The Ministry of Transport and is passed by The Danish Parliament. This legalisation is made in relation to the work of Cityringen (M3) and the metro line from Nordhavn to Sydhavn (M4).

In connection to a metro project, there will be made building lines to secure the construction of the metro. These building lines last for a maximum of 10 years, but they can be imposed again for another 10 years. The properties that are located within the building lines are not allowed unless they have permission from the minister of transport to make new constructions. According to BLC § 8, sec. 1-2, this is buildings, additions, reconstruction of burned down or demolished buildings, no essential changes of existing buildings, and placing other constructions that are permanent. If a property is affected by the projecting of the metro, but isn't inside the building lines, the minister of transport can make a prohibition against the changes named in BLC § 8, sec. 1-2, but only for a year, and they can only make this prohibition one time according to BLC § 9, sec. 1. The properties affected by the building lines must be informed by The Minister of Transport, and afterwards, the owners have 4 weeks to complain, and after the 4 weeks when the complaints are solved the building lines will be noted as land register according to BLC § 10, sec. 1-2.

Properties that are affected by the building lines need to be overtaken by The Ministry of Transport on behalf of Metroselskabet I/S. The property owner should get compensation if the property lost an area that affects the property in a negative economic way. As mentioned in the sections regarding expropriation, compensation is only given if the property cannot be used in the same way as before and thus loses an income that nearby areas can still benefit from. If the building lines take a significant part of the property that makes the property too small, the whole property needs to be overtaken and the owner will get compensation from The Ministry of Transport. These examples could also be done on properties that will be expropriated, before the point where the property actually is expropriated according to BLC §11, sec. 1-3.

If the resident has inconvenience in relation to noise or pollution with the construction of the metro, they will get compensation from The Ministry of Transport if they assess the noise or pollution is too much. In some cases, The Ministry of Transport can make rules about rehousing that Metroselskabet I/S should be responsible for according to BLC §14b, sec. 1-2.

Literature Review

5. Sustainable Urban Development

The quality of life is of utmost importance in regard to the vision concerning modern day urban development, and is thus something municipalities, property owners and investors needs to consider. The agency of Nature in Denmark has conducted a report, in which a series of methods is presented, with the purpose of quantifying the decision-making with regard to investments in liveability and the subsequent effects. Out of five total key methods, the methods relevant to the report are presented in the following sections.

5.1. Utilizing Key Figures

Urban development is a very complex skill, and a lot of factors and needs have to be accommodated for it to be successful. Utilizing key figures in regard to urban development, is a way of quantifying the decision making and the dialog between the different parties, e.g. municipal, investor, and planners, and helps to understand which parts of a city would need certain development, and how various investments will affect the value of the city. In this context, a study was conducted by Copenhagen University (KU), with the aim of highlighting the financial benefits of investing in initiatives which will further the quality of life. The study was based on 60.000 property transactions distributed between different types of properties in selected parts of Greater Copenhagen and Aarhus, and resulted in 10 rules of thumb, of which four is relevant to the theme of this project:

1. Proximity to a station will result in an exponential increase in regarding the value of the surrounding properties by up to 4-8 %. However, this effect will slowly decrease for properties with a distance surpassing 1,5km.
2. Proximity to a metro station will result in an increase of all of the surrounding properties, but only regarding the properties within a distance of a few hundred meters.
3. Exposure to noise surpassing 60 dB will result in a decrease in the value of the property by 2 % and if the noise surpasses 70 dB the value will decrease by 10 %, and in some cases around 20 %.
4. Proximity to railway will, besides the effect of the noise, result in a decrease in the value of the surrounding properties by 10-15 %. However, the effect of the railways will decrease to around 0 %, when the distance to the railways surpasses 100m.

(Naturstyrelsen et al, 2013, pp. 8-10).

5.2 Market Checks

Performing market checks can be essential in determining the support of the local area for a certain development. A market check is an investigation into the effect of urban dwelling values on a certain nearby amenity or development. Market checks can be done by modelling relevant factors such as projected use, noise, attraction etc. If other examples of the development exist, using case studies as a supplement could create a better market check, as factors could be calculated more precisely leading to a better understanding of the expected changes in value of surrounding dwellings (Naturstyrelsen et al, 2013, p. 11).

Market checks are also useful in the case of the development of future metro lines and stations. Performing a market check of an area around new metro stations could determine the importance of precise placement from urban areas that are in need of a station, so that value changes are positively maximized and negatively minimized. Market checks could also be used near an already existing station to spot any effects in value which could be attributed to the station (Naturstyrelsen et al, 2013, p. 11).

6 Social Inequality

Social inequality is the difference between living conditions and chances in life for individuals and population groups. Inequality is an increasing problem all around the world and is one of the United Nations Sustainable Development Goals. In 2019, the world's richest one percent owned almost half of the entire world's wealth (Mellemfolkeligt Samvirke/VerdensKlasse, 2023).

Social equality is about sharing the wealth of the world and securing that everyone has the same opportunity to get the resources of society, thus being heavily connected to economic and social sustainability. Social inequality between people and population groups can be measured in several different ways, for instance by the level of education, economic inequality or through the housing market.

Equality can also be measured in health, ensuring that everyone must have equal opportunities to be able to go to the doctor or to the hospital if they are ill. One way to measure inequality in a population's health is by looking at life expectancy, sickness absence at work or habits in relation to smoking and drinking (Ploug, 2006).

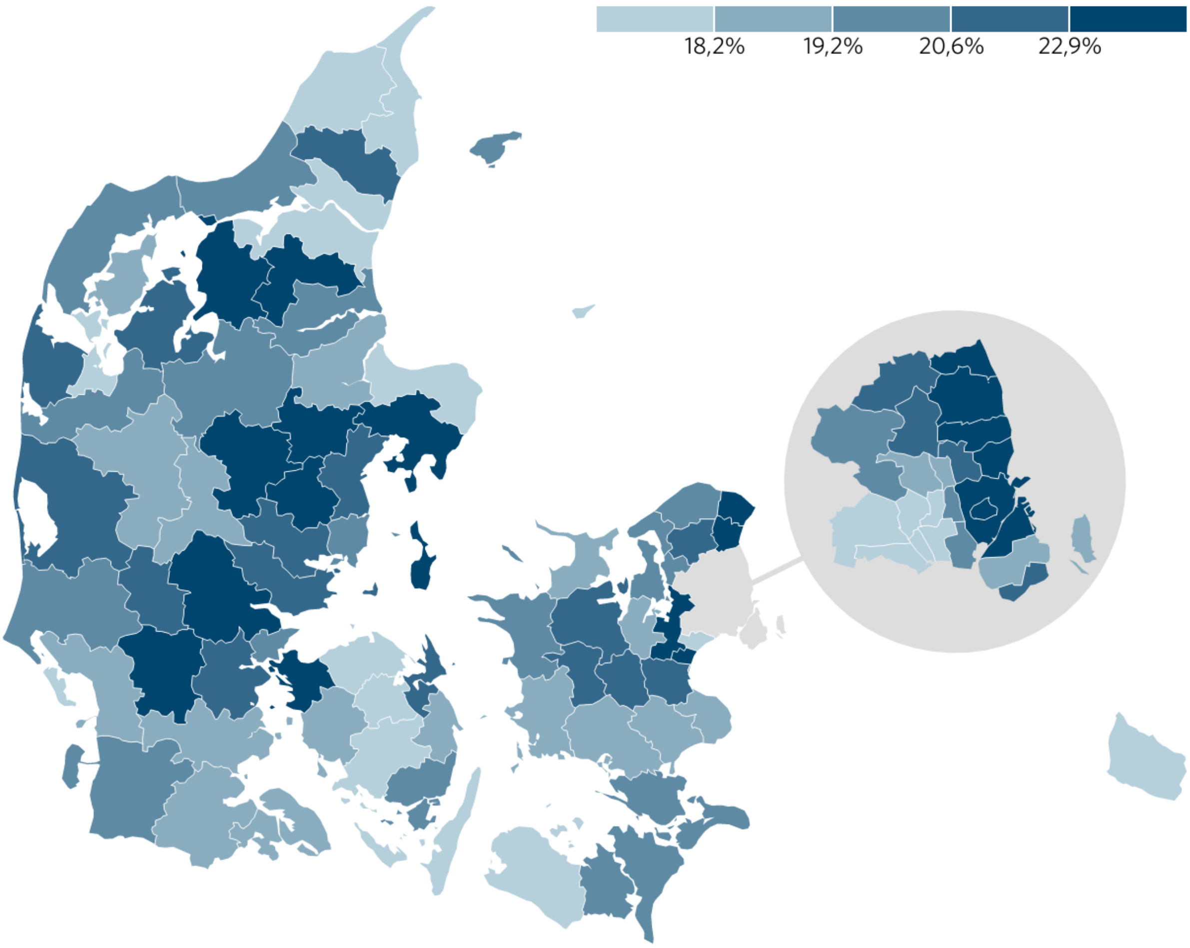
The education level is a way to measure equality and compare people living in the city with the ones living in the country. But also, the ability to break the social heritage from one generation to the next is a factor that shows equality.

Economic inequality is an unequal distribution of financial resources, which can be measured by looking at the disposable personal income. Economic inequality can be compared between geographic location, population groups or education.

In the housing market, inequality is seen in the size and how many people live in how much space. The quality and location of the house or apartment are also a measurement of equality, where some areas may have become so attractive that the original segment of inhabitants can no longer afford to live there.

Even though Denmark is one of the most equal communities, with a welfare state that attempts to ensure that no one is lost in the system, social inequality is increasing. The richest 10 % of the Danes have increased by 18 % in income, while the poorest 40 % have only increased by 2 % in income. In 1995, the one percent richest Danes earned 5,8 % of the total income in Denmark. This number has increased to 9,1 % in 2021 and shows that economic inequality is going the wrong way in Denmark (Caspersen [A], 2023).

Figuren viser den reale udvikling i den gennemsnitlige disponible indkomst i kommunerne fra 2011 til 2021.



Anm.: Opgjort på baggrund af husstandsækvivaleret disponibel indkomst fremskrevet til 2023-prisniveau på baggrund af forbrugerprisindekset og forventninger hertil.

Kort: Arbejderbevægelsens Erhvervsråd • Kilde: AE på baggrund af Danmarks Statistiks registre.

Figure 5: The development of the disposable income in the Danish Municipalities from 2011 to 2021 (Caspersen [B], 2023).

Figure 5 shows that the general development in disposable income is higher around the bigger cities. In the big cities like Odense (16 %), Aalborg (18 %) and Aarhus (21,4 %), the tendency for income development is low compared to Copenhagen (29,1 %). Those immigrating the cities have contributed to a decrease in disposable income between -2,8 % and -3,5 %. What the cities have in common is that all of them are large student cities and students reduce the general disposable income. Even though Copenhagen is a large study city too, the income has increased by 29,1 % in the period. In this case, immigrants have contributed 7,9 % of the growth in disposable income and not as a decrease like the other cities, why the income has increased more (Caspersen [B], 2023).

Geographically, there is a tendency for inequality to increase between town and countryside. Which can be seen in figure 6, the migration to the area among larger cities contributes to a higher average disposable income. Conversely, immigrants to the country contribute to a lower average disposable income.

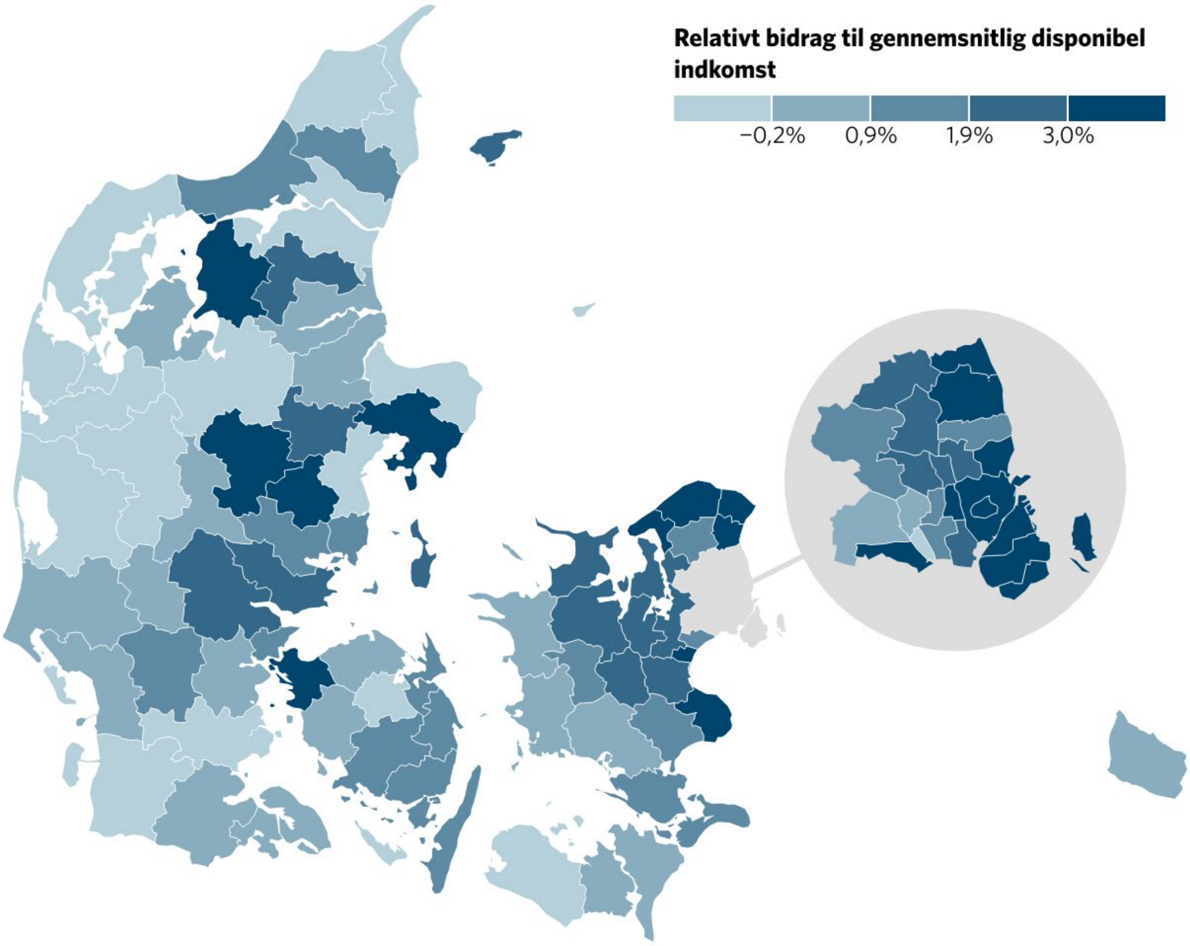


Figure 6: Shows the contribution to the average disposable income in the municipality from immigrants in the period from 2011 to 2021 (Caspersen [B], 2023).

This means that the purchasing power in the larger cities becomes even greater and the prices of housing increase. The inequality between rural and urban areas is therefore increasing sharply (Caspersen [B], 2023).

The two figures show that the general percentage growth in disposable income in the municipality of Copenhagen is among the five largest in Denmark. At the same time, the contribution from immigrants to the municipality is the second highest in the country. These figures indicate that Copenhagen is to a greater extent a place for people with a high income and those with a lower income are vacating the city.

7 VVM Statement

Whenever a large project such as a new metro line is commenced, a VVM statement is made. The purpose of the VVM statement is to investigate how the construction of a new metro line will affect people, cultural heritage, the city's landscape, and the environment. This will help to get a more sustainable city and give a high environmental protection level (Københavns Kommune & Frederiksberg Kommune, 2008, p. 9).

In relation to the M3 Cityringen, there was made a VVM statement that will be examined to get knowledge about how the metro line affects the environment as the VVM statement for the newly suggested M5 is yet to be made.

Through the construction of the M3, the traffic will be diverted in a period, because of work around the new metro stations. Strategies will be made to make the detour as fast as possible for the citizens that are affected by the work related to the stations (Københavns Kommune & Frederiksberg Kommune, 2008, p. 12). It is inevitable to avoid noise under the construction of the metro line. There will be limited values for the amount of noise the entrepreneur needs to comply with, and this means the method to make less noise as e.g., noise screens need to be used in some cases. If it is not possible to comply with the limit values, there can be applied for dispensation, but it is only given if the construction is crucial for the metro, and a strategy for rehousing the affected citizens needs to be made. In relation to the strategies for noise, a strategy for vibrations and air quality also needs to be made. It is the same machines that make the noise, that also make the vibrations and affect the air quality, and there are also made limit values for vibrations and the amount of particles, that entrepreneurs need to comply with, because vibration can make building damage (Københavns Kommune & Frederiksberg Kommune, 2008, pp. 15-16)

8 Inclusion of Residents in the Pre-processing of Mega Projects

Mega project as a term is relatively new, with it emerging during the 1970s. A mega project can generally be defined as a large-scale highly visible infrastructure and construction projects and is typically either financed or executed by the state. However, the most prominent characteristic which differ these so-called mega projects from the standard public projects is the cost. For a project to be considered a mega project, the cost of the said project must exceed 250 million dollars, however more often than not mega projects actually exceed the 1 billion dollar mark (Bearfield & Dubnick, 2009, p. 398). The construction of Cityringen alone cost 3,6 billion dollars and would thus most certainly be defined as a mega project, if the before mentioned definition is to be applied (Chor, Jakob, 2017). Due to the enormously high cost and the fact that the number of mega projects, which are under construction, are increasing, said projects have been placed under growing scrutiny by public interest groups and politicians. According to Bent Flyvbjerg, the increasing number of mega projects actually forms a paradox called the “mega-project paradox”. Mega project is often surrounded by a lot of controversies and is generally not well received by the public, but the proliferation of these project still stands (Bearfield & Dubnick, 2009, p. 398).

Infrastructure megaprojects are complex ventures, with a vast amount of unpredictable and conflicting elements involved, with multiple public and private actors and stakeholders. There exists no universal way of planning and constructing mega projects and it needs to be supported with a diverse collection of knowledge, information and evidence regarding its impact on urban development, the economy and society. Mega projects often generate a lot of criticism regarding its predominantly top-down approach and how they negatively impact the local communities. Research regarding a project like the metro has thus shown the importance of shifting away from viewing them as a linear and rational processes, and instead adopting a more fluid approach with e bigger focus on communative planning. A way of accommodating this is by utilizing participatory governance. Jens Newig, professor of Governance and Sustainability at Leuphana University, defines the concept of participatory governance as:

"*All processes and structures of public decision making that engage actors from the private sector, civil society, and/or the public at large, with varying degrees of communication, collaboration, and delegation of decision power to participants.*".

In other words, participatory governance removes the barrier between the state and the citizens and creates a place in which they can interact with each other. Therefore, a public meeting is a great tool to use, where the voice of the public has the chance to express their frustration, interests, and suggestions regarding the project (Esposito, Felicetti, & Terlizzi, 2023, pp. 2-3).

In relation to the comments and objections regarding the development of the metro Cityringen, they are all collected in a report, Hvidbog, made by the municipality of Copenhagen and Frederiksberg. The purpose of the Hvidbog is to summarize the comments and objections to the VVM statement so they can be included in the further political assessment of the project. The public meeting regarding the development of metro Cityringen has shown that the citizens are positive towards the idea of improved public transport but have uncertainties about the construction and operating phase. In the construction phase, the locals are interested in traditional environmental conditions such as noise, vibrations, traffic, and air pollution during the construction works. In addition, they are interested in possible building damage, access conditions to buildings, fire rescue, rehousing and compensation. Furthermore, there has been particularly great interest in the location of stations. In the operating phase, interest has gathered around the design of urban spaces and the changed experience of the urban spaces (Københavns Kommune & Frederiksberg Kommune, 2009).

Furthermore, the following table 3 shows the number of objections the citizens have had during the public meetings:

Area of Objection	**Number**	**Percentage**
Location of stations and route	160	22%
Expropriation	142	20%
Urban spaces	84	12%
Noise	81	11%
Traffic	69	10%
Recreational conditions	58	8%
Air pollution	51	7%
Socioeconomics and health	37	5%

continued		
Vibration	32	4%
Total	**714**	**100%**

Table 3: The comments and complaint by citizens in the municipality of Copenhagen and Frederiksberg. Self-produced (Københavns Kommune & Frederiksberg Kommune, 2009).

Most of the comments and objection from the public meeting shows that the citizens are mostly concerned about the location and the route of the metro line with 22 % of the comments. Regarding the mega-project paradox, the table shows that in the pre-processing phase of a mega project the biggest concern for the citizens is how they will benefit from the project. As mentioned in section 4.1 “Expropriation and neighborship rights”, one can only refrain from one’s property due to the welfare of the common good by law and with total compensation, which was the case when constructing the Metro Cityringen. Therefore, a lot of the concerns are about expropriation and what they can expect. Furthermore, only 11 % of the comments are about noise and 4 % about vibrations, which indicates an unawareness of the possibility of noise and vibration and their effect on daily living. Most of the objections and comments are submitted by cooperative housing associations, companies, educational institutions, local committees and other interest groups which explain the number of objections.

9 The Metros Effect on Property Value

An opening of a new type of public transport can affect the surrounding neighbourhood, in case of property value. An expropriation committee, that was made in connection with the construction of the M3 Cityringen in Copenhagen, has assessed that the properties effect of noise from the metro will not decrease in property value, but instead increase, because they will get better mobility because they will be placed near a metro station when the M3 is running (Kjeldsen, et al., 2020, p. 19).

A study about this was made in connection to the new M2 metro line in Warsaw in Poland. The M2 was announced in 2009 and was operating in 2015. The property values were analysed in a radius of 3 km from each metro station from 2008 to 2015, to see if there were tendencies in the development of property values based on the distance to a metro station. The changes in the property values generally in Warsaw were analysed, and the results were compared to the general increase in the property values in Warsaw. The results show that the properties within a 1 km radius of a metro station have increased by 5,8 % in value since 2008, compared to areas that are more than 1 km away from a metro station. The increasing property value was affected positively by the construction of the new metro line, and the year it was finished (Trojanek & Gluszak, 2016, pp. 20-24).

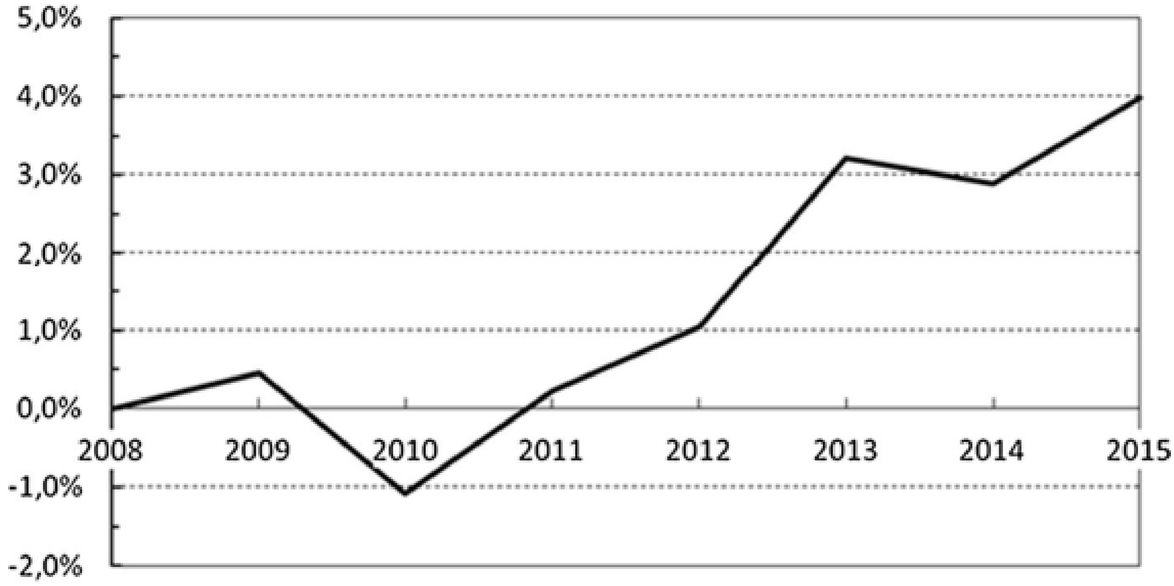


Figure 7: Percentage change in property prices in areas near metro stations compared to the average change in Warsawa (Trojanek & Gluszak, 2016, p. 20).

Figure 7 shows the development of the increasing property prices, for properties near a metro, and has had a positive effect on the property prices, in the period from 2010 to 2015, which is the period where the metro was constructed. The reason why the differences are 5,8 % for properties within 1 km and outside 1 km, is because the properties within 1 km are increased compared to the general tendency, and the properties outside 1 km for a metro station, are decreased compared to the general tendency (Trojanek & Gluszak, 2016, pp. 20-24).

Requirement Specification

10 Final Hypotheses for Analyses

The five different aspects that are examined in this project each have different datasets and information that are required to analyse the aspects and draw conclusions on which effects happen to residential areas close to metro stations. The following section draws the theories needed to formulate a hypothesis for each of the analyses.

10.1 Analysis of Changes in Demography

Building a metro is a way to improve the public infrastructure and fulfils the three aforementioned requirements of good transport planning, as it is both fast, comfortable, and cheap. One of the purposes of a better public infrastructure is to secure more equality in the community and to ensure that all people have an equal right to transport themselves, regardless of their economic situation. As mentioned in the section 3.4, an increase in mobility would thus result in it being harder to examine single areas for specific demographic changes, as an increase in mobility leads to a higher change and mix in between areas making demographic changes more overall irrelevant.

However, as mentioned in section 9, property values should be expected to rise following the construction. If this effect is found to be large enough, an argument could be made that this effect should also manifest in demographic changes. If a property becomes more valuable, the sales price when the properties change hands should rise, meaning that the buyer could have a richer background than the seller. This argument may also be supported by literature reviewed in section 6 surrounding Social Inequality, as the general tendency for people with a higher income is to move to Copenhagen and people with a lower income to move away. The question is whether the metro helps to create more equality in society, with room for everyone where it is placed, or whether it has the opposite effect.

This leads to the following hypothesis:

Metro stations should not be able to drastically change the demography of a neighbourhood but will secure an equal development in Copenhagen.

10.2 Analysis of Change in Property Value

This analysis will be based on the theory of economical sustainability and the report “Byliv der betaler sig”. As mentioned in section 2.1 about the economical sustainability, an essential part of economical sustainability is the concept of *green growth*, which can be translated into long-term economic growth, which does not negatively impact social and environmental aspects. The improvement of urban infrastructure, in the form of constructing projects like the metro in Copenhagen, would both embrace the planet's long-term well-being, by utilizing electric public transportation, but at the same time ensure that the level of economic growth is raised, as a result of the increasing value of all of the surrounding properties, as stated by the report "Byliv der betaler sig", and the additional tax on metro tickets. This statement is also shared by sources regarding transport planning that are referred to in section 3.4.

However, the magnitude of the increase along with the distance from the station where the effect can be observed varies in different sources in the theory and literature review. Previous studies of the suburbs of Aarhus and Copenhagen mentioned, in section 5.1, was a 4-8% increase for train stations in general where the effect would slowly drop over the course of 1500 metres - regarding metro stations, the effect was reduced to only be within a distance of a few hundred meters from each station. The same analysis also remarked that open rail next to properties however would have a negative effect towards the values, which may also be the case regarding the metro on the overground sections. Studies specific towards metro networks mentioned in section 8 stated that the value increase would only be around a 5,8% increase, which was experienced from within 1 kilometre.

The above-mentioned leads to the following hypotheses:

Planning a metro station at a certain place result in an increase in the property value within a few hundred meters of each station over time compared to the general price development of Copenhagen.

10.3 Analysis of Complaints by Residents

As mentioned in section 3.4 regarding transport planning, besides the three elements of time, quality, and cost of the travel being the main attractors for travellers, the location of the transport line station also has importance. The placement of future stations is preferred to be near dwellings and other stations to streamline other travel opportunities and connect other modes of transportation. Stations become more attractive to pedestrians and the surrounding residents if six conditions are considered important to use the station: safety, security, directness, ease of entry, comfort, and aesthetic. Most important to the hypothesis of this analysis is the directness and ease of entry, being the main arguments for placing stations as close to dwellings as possible.

Typically, megaprojects such as the construction of a new metro lead to an increased resistance from local residents as mentioned in section 7, as the increased operation and traffic near dwellings usually disturb the local neighbourhood. The section also states the need for residents to have a voice in the planning to curb the rise of criticism towards megaprojects. Metroselskabet I/S however followed the policies adopted in Danish law, which could be argued to be influenced by more communicative and post positivist planning theories, that created statements from the construction companies and hearings for local citizens; the results of which were noted in section 6 regarding the construction of the M3 Cityringen.

As expected, several worries would have to be quelled during these hearings. Planners and policymakers have adopted elements of both rational and communicative planning as described respectively in section 3.2 and 3.3 in order to develop the expropriative process that exists today and which are described in section 4, which both gives the top-down power needed for authorities to complete projects while giving affected residents a bottom-up power through the opportunities given to them to have their say in the process.

When done right, most of the worries and negative effects, that would normally influence local residents to oppose a project, are circumvented, leaving a net positive project for the residents, which improves both the social and - as what may be the case in the previous analysis - economical sustainability. The above-mentioned arguments concluded from the theory and literature review lead to the following hypothesis:

Placing stations near residents would ultimately solely provide benefits for neighbouring residents.

10.4 Analysis of Potential Time Saved

As mentioned in section 3.4 about transport and infrastructure planning theory, time is one of three important factors for the type of mode of transportation. The most direct mode of transportation from one point to another is not always the fastest in the real world due to congestion, and this will in some cases make an alternative route faster. This further expresses the interest in mobility which in the same section is established as the main improvement that a new transport line - such as a metro - can offer, whereas any other promise of improvement needs additional planning to be fulfilled.

Better infrastructure will give bigger efficiencies, less energy consumption and increase production when the population can get easier and faster around with public transport. This will help to get a more sustainable future; in particular to both social and economic sustainability as described in their respective sections, as inclusiveness towards the city centre and one another is increased to a larger part of the population, as well as creating a more competitive region for economic growth, partly through the soft space known as Greater Copenhagen.

More metro will also help the social inequity according to established theory in section 5, as while it makes public transport available to a wider range of the population, it should in return make the city more equal in terms of mobility opportunities; it becomes possible to come around the city fast, from all areas of the city. This will give a more equal environment, which is one of the keys to make a socially sustainable city, as mentioned in both sections 2.2 and 5.

The above-mentioned references to theory leads to the following hypothesis:

The main objective of constructing a new metro line is to improve the mobility of the transport network.

10.5 Analysis of the Environmental Impact

Copenhagen has the highest density of any city in Denmark; In order for the place to be well-functioning, it must be supported by infrastructure. However, as mentioned in section 2.3 surrounding environmental sustainability, the well-being of humanity is very much depended on the environment and thus it is important to move away from infrastructure powered by fossil fuels towards more sustainable infrastructure, such as having a higher percentage of the population change from private to public modes of transportation.

This sentiment is also mentioned as a benefit of the construction of the metro as mentioned in the VVM statement summarized in section 7. As the VVM statement is to examine how the construction of a new metro line will affect people, cultural heritage, the city’s landscape, and the environment, it indirectly contributes to achieve a more sustainable city and give a high environmental protection level as mentioned above. This would at the same time result in a stronger city, by not relying solely on one form of mode of transportation and instead benefiting from economic trends.

In places with high density, the choice of public transportation also becomes more obvious for its citizens, which leads to the following hypothesis:

The construction of the metro lines will have a measurable positive effect on the CO_2 emission in Copenhagen with regard to the mobility of the people.

Methodology

11 Introduction to the Methodology

The following chapters present both the overall mythology of the analysis, as well as more in-depth description of the methodology used regarding the five analyses, including the data collection and the execution, as well as the ongoing thoughts and choices.

12 The Use of Case Studies

All but the analysis regarding the environmental analysis will be based on a series of selected cases. The goal of the project is to capture the complexity and uniqueness of the investigated phenomena and to bridge the established theory with practice and effects that can be measured through the analyses. Case studies are assessed to be the best approach to the majority of the analyses, as determining stations based on their usefulness to the analysis allows for all the analyses to be performed within the established size and time frame of the project as well as compensating for the restrictions placed by the limited amount of data that is available, which are described in the following sections, thus avoiding the risk of worsening some of the analyses.

13 Methodology Surrounding GIS-analyses

GIS is a useful tool in creating an overview of an issue or a construct, which has a spatial aspect. Calculations of objectively obtained data can result in powerful arguments for the development of an area. Even before computers and GIS programs have been developed, systems for portraying spatial information have already been developed for creating analog maps, such as the example shown in figure 8. It can therefore be argued that GIS is not only a digital tool used in modern times, but a variant of such has also been used since the dawn of mapmaking as a tool for portraying information rather than being solely an artistic statement.

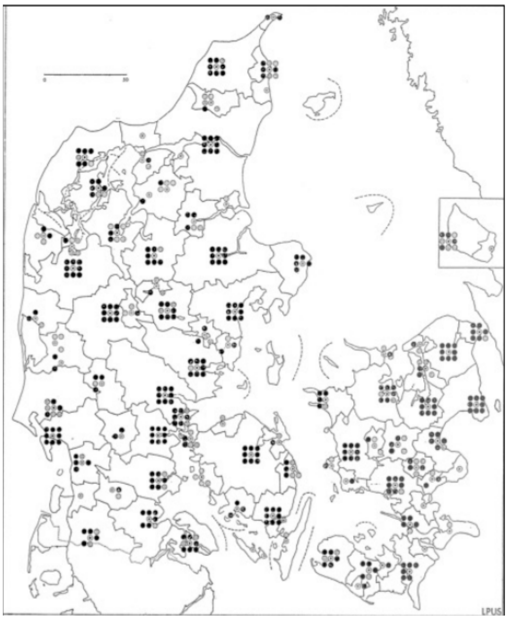


Figure 8: An example of how GIS existed before becoming digitalized. This map shows development of key features in different areas of Denmark. Source: (Planstyrelsen, 1978).

GIS was used partly in relation to answering some of the questions raised by several of the analyses in the project, namely how local neighbourhoods were affected by the planning of a future metro station, how much transport time current and future metro lines potentially could save, and where complaints about the operation of the metro were located. The process of how GIS was used for this project is described further below.

13.1 Examining the Effects of a Local Neighbourhood - Analysis of Value and House Price

The State Sale and Value Assessment Register (SVUR) is a database of all current and historical property assessments of land lots including and excluding any structure on the lot, which have been made by the Danish Tax Agency. Records of any property sale are also included in the database. SVUR is maintained by the Agency for Data Supply and Infrastructure (SDFI) and accessible via their website datafordeleren.dk. The sale properties could be connected to their spatial location through the Danish Address Register (DAR).

The retrieved data would be filtered to only include purchases by private persons, excluding purchases not relevant to the problem formulation, such as purchases of entire blocks by larger companies with the intention to market the apartments as rentals. The filtered data was afterwards sorted according to how close to a current metro station they were and the time since the sale was made. As the distances between metro stations are rather small, a distance of 500 metres from the station was used for analyses of metro stations along the lines. At terminal stations, the distance could be increased to see if the pattern extends beyond the 500-meter-limit.

To normalize the data, the value assessments and sale prices were divided by the area of either the apartment (in cases of apartment blocks) or land lot (in cases of villas and row houses). The result was a monthly average price per square meter of each individual sale. General trends, such as overall rises or falls in the average asking price or value of a property could then be related to the completion of the metro station by plotting the data as a line graph. The resulting data would be quite scattered - to gain an overall rise in percentage, the average price per square meter was used, and larger outliers were removed from the calculation. Data sets that contain information about the square meter size of each building could however not be obtained.

Information regarding the area of each building would be found in the Register of Buildings and Dwellings (BBR), but data of this register could not be gathered for smaller specific areas. A larger dataset for entire municipalities could be acquired yet it did not contain the registered square meter size in a standardized format for each building, nor could the dataset be processed for the analysis, as the file size is so large that it couldn’t be processed by any program that is accessed for free or with the tools given by Aalborg University. As an alternative, the square meter of the cadastral lots of the properties was used, which were supplied via the Ownership Information Register (ESR). This was a suboptimal solution, yet it was the only option left to normalize the sales records.

General economy data has been obtained from Boliga and Danmarks Statistik to further compare the findings of the GIS-produced data. Datasets have been obtained from Boliga and Danmarks Statistik. The data from Boliga shows the development of the average property prices for apartments and houses in Denmark and Copenhagen from 1992 to 2022. The data from Statistics Denmark contains the economic situation in Denmark during the same period, based on GDP in Denmark.

Ultimately, all datasets were exported to Excel where calculations, graphs and tables could be produced in combination with one another. The Excel file exists in the accompanying ZIP-file under the name “Property Value Analysis”.

A main risk of the analysis was the impact of unknown and unwanted factors that were not relevant to the metro project affecting the analysis result in unpredictable ways. In order to gain a good argument for the metro being responsible for the impact of sales prices would therefore require the ability to see direct patterns in favour of the argument across multiple stations. Another potential risk specific to the solution was if the progress of planning two stations had variances in time. As values already vary from neighbourhood to neighbourhood, the rises and falls in price would only be compared to each other through the percentage-wise change. This would also combat problems regarding normalizing the sales data to cadastral areas rather than for buildings, as long as selected areas were more spatially homogeneous.

13.2 Analysing the Saved Time with Current and Future Metro Lines - Network Analysis

Network analysis can create isochrone maps, which can be used to show the area that is reachable from a given point in the network within a certain amount of time. By including any future metro line or removing any existing lines, the analysis can show how important the metro lines are in Copenhagen's public transport system or show how much larger an area could be reached from various points if a potential metro line was built.

A network analysis of public transport could be made through the access of GTFS-data. GTFS is a data format specifically designed for public transport networks, that contained all information on stops, transport lines and routes, interchanges, agencies, and travel times. Rejseplanen supplied the data for all transport networks of Denmark, leading to a dataset containing almost 40.000 stops, over 1500 routes, 64.000 interchanges, 175.000 possible trips, 4.000.000 time schedules and an additional 4.000.000 points that provided spatial information of the routes. All information could be connected with one another through various ID's for each stop, route, trip and shape as shown in figure 9.

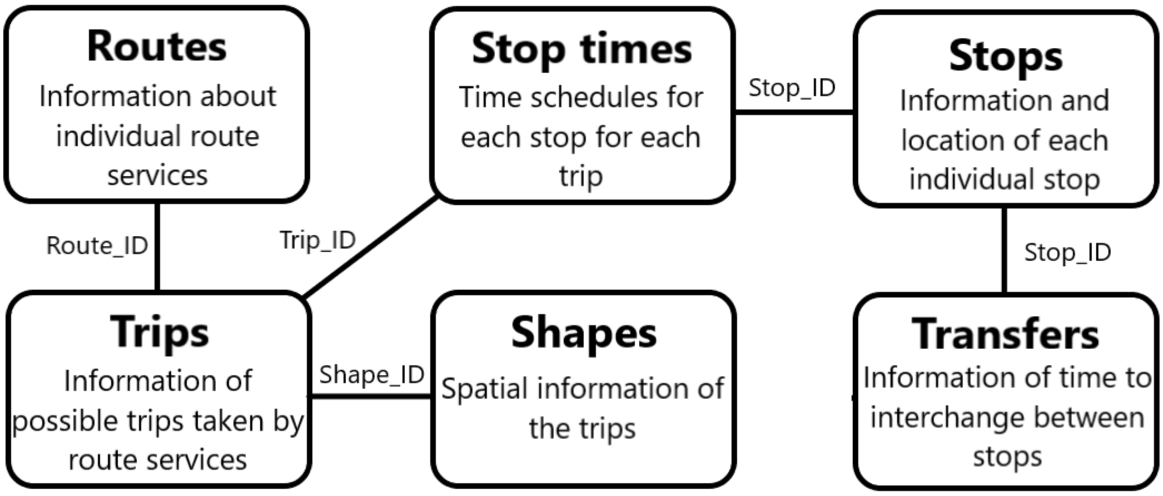


Figure 9: Key tables in the GTFS-dataset. Lines represent the attributes that link each table with one another. Self-produced.

Much of the information needed to be dissolved or removed by clipping the area by location in order to improve the processing time. A major obstacle to creating an accurate and precise network was connecting each individual stop to the routes that utilized it. A transport network should only allow line changes by stops, which could be marked by breaks of the trip lines, which were unbroken from start to end.

Theoretically, it was possible, as seen in figure 9, to connect routes to individual trips, then connect the time schedules, and finally the stops. The attribute ID's however were not designed optimally for these connections, and any attempt led to many errors in the datasets, that were easily overlooked. A more direct way that could be used, was to use the tool named "*split line at point*", which divided the trip shapes at the points marked for stops (ESRI, 2023). This could be done as the points were close enough to the line that served them but distant enough from other lines, that non-existent "interchanges" would be created by the tool. However, this method did abolish any express lines that skip certain stops, such as the Bx S-train line, which is an express version of the B line. Express lines were however usually a limited service only operating in rush hours and would only represent the network as a whole on selected times of a typical day, thus being an acceptable "loss". For the same reason of representing the network on a typical day, train-replacement-bus lines and night bus lines were also removed from the network.

This "*split line at point*" method worked in all cases of bus lines but could create issues with train lines. All stops were given a single coordinate whereas many routes may utilize it and could potentially have various stopping locations for the same stop. A relevant example of this could be seen by any train station stop in Copenhagen that serves both the local S-trains and the larger InterCity trains. These two train types stopped at different tracks at the station, yet the coordinate for the train station stop would typically be located geographically in between the used tracks. The "*split line at point*" would therefore not divide the line by the stop as it should. Examples as extreme as these were few and could be manually fixed.

The slight difference in the coordinates of the line in the "shape" file and the coordinates of the "stops" file presented a problem in connecting to the network lines of the "shape" file, and network lines that could be generated from the coordinates of the stops in the "transfers" file, meaning that interchanges weren't possible in the network analysis. This was fixed by using the tool "*snap geometries to layer*", allowing any points to snap onto the line they were closest to and connecting the entire network (QGIS, 2023).

Another simplification needed to be made was the transfer times. The "stop times" file presented timetables for all 1600 routes during a 24-hour cycle where the route was in service. To ease the processing of the network, the timetable was dissolved into an average travel time of the route rather than including every bus or train that operated that route. A network analysis would therefore not take into account the normal waiting time that occurred when changing routes, but instead assumes that the travel time was as optimal as possible: as soon as a person stepped off one bus at an interchange, they could walk to another stop and immediately step onto another bus and be on their way. Or if two different bus lines operated the same bus stop, a passenger would be able to change from one route to the other instantly. Some bus lines and the metro and train lines would therefore be slightly faster to interchange between than they should. This was assumed to be tolerable, as this broadly affected the network rather than only one specific mode of transport, and would therefore not change the overall outcome significantly, when looking at a difference in the network with or without metro lines. In other words, it was assumed that an optimal network without time spent at interchanges would significantly affect the calculated time to reach a certain distance but would only slightly affect the calculated difference in times by changing the network, mainly in maps showing the extent that was able to be reached. The maps showing the distance reached should therefore also be viewed as a way of seeing improvement rather than the factual extent that is reachable.

13.3 Noticing Patterns in Complaints - Mapping Addresses of Complainants

Since the introduction of the GDPR act was enacted in the EU, a record free of personal data has been kept by Metroselskabet I/S of all complainants and the nature of their complaints. Thanks to § 9 in FL, legal access to the metadata of the complaints can be requested, including the location and nature of the complaints. However, the GDPR act also led to any data from before the enactment being deleted as data about these complaints were not compliant with the act. After requesting access to the complaints, Metroselskabet I/S supplied an Excel table containing information on the date of the complaint, the location of the residence of the complainant, the nearest station to the location, and the type of complaint.

The format of the addresses in the Excel table was not standardized, and therefore needed to be cleaned by capitalizing starting letters of all names, removing floor numbers and other information not relevant to the location of the address (such as building names etc.). By data cleaning the Excel document, addresses could be joined to the spatial location using the aforementioned DAR register through the name of the road and the number of the address. Approximately 300 unique complaints, corresponding to about 16 % of all complaints, did not have a specific address but would contain only a street name or a city area in general. These complaints would still have a registered closest station, thus allowing them to be included in maps showing complaints by the station but would not be included in maps showing individual locations of complaints.

14 Interview Methodologies

Interviews are one of the typical go-to methods of acquiring qualitative data surrounding any subject. Gathering information through interviews is a versatile tool, as various methods can lead to different pieces of information being attained. Interviews vary in the setting and/or medium that is used for the interviews, how the interview is conducted, and who is interviewed.

Interviews are not restricted to in person meetings, but can also function through telephone, e-mail or other digital solutions. Interviews held over the phone or computer are a more informal and spontaneous interview setting that could reduce the time needed to plan the interview. If willing participants would be hard to find, a less demanding method for the interviewee could potentially be answering questions through e-mail. This is a very simple way of interviews, reducing the human to simply giving a statement through text, and removes any obligation to respond immediately to the questions asked, and allowing an interviewee to spend time to research and formulate their answer. This form of interviewing also therefore requires the interviewer to break from the ordinary rule of asking one question at a time but can instead send all questions at once (Bampton & Cowton, 2002). Due to the lack of an obligation to respond immediately, response times with public authorities have been experienced to be extremely slow, also deterring the possibility of countering responses with further questions to get a more refined answer. Another importance to improve the usefulness of the statements for the analyses is the ability to transcribe or record the interview (Fontana & Frey, 2000). Due to the timeframe of this project, any interview made for the project was planned to be held through the computer using the program Microsoft Teams, as this would be the best solution to gain an interview that does not require a lot of time to plan nor conduct and is easy to record for transcription.

Ultimately an interview was arranged with Karsten Willeberg-Nielsen, a leading land surveyor in the department of expropriation for the M3 Cityringen and M4 line.

15 Methodology of Demography

The effects of a neighbourhood's demographic change that are related to the metro were analysed. The analysis will be investigated in 1993, 2002, 2007, 2012, and 2021, to have information before under and after the metro lines M1 and M2 were established, to spot any direct changes which could be potentially attributed to the metro.

To investigate how the demography has changed in different districts in Copenhagen, with and without the metro, the statistical bank of Copenhagen municipality has been used to derive useful data. The municipality of Copenhagen is divided into different divisions by the statistical bank of Copenhagen municipality. Smaller areas, which will be named districts, are chosen as the case areas. In relation to the demography, the implementation of the metro could affect a change in disposable income, education level, and economic inequality according to the theory of social inequality in section 6. The age distribution has also been analysed to know if there are tendencies of which age group that have settled near the metro, and what interaction it has in relation to the other analyses examined.

The type of housing in the chosen districts will also be investigated. If the structure of the type of housing is different in the chosen districts, the basis on which the analysis is made will not be equal. Therefore, the type of housing analysis is placed in the beginning, to examine the differences within the districts before comparing them in other analyses. The size of the district can impact the analysis, if the chosen district is small, the same housing type might appear more often, compared to other districts, which could affect the analysis.

Most of the demographic changes will be visualized as diagrams, graphs or tables, and made as percentage changes. This will make it easier to derive the different districts' changes compared to each other and give an overview of the changes. All the calculations, graphs and tables are made in Excel.

The tendencies in the districts with metro stations will in some cases be analysed together to give a picture of the changes in these districts compared to those without metro stations because the main focus of the analysis is the difference between districts with metro stations and districts without metro stations.

16 Methodology of the Environmental Impact

To determine whether or not the metro has an actual measurable effect on the CO_2, it is necessary to calculate and visualize the evolution of the CO_2 emission in Copenhagen in regard to transportation as a whole both before the metro was introduced in Copenhagen, but preferably as far back in time as the available data allows and compare it with the evolution after the metro have been introduced.

The analysis will consist of a series of subchapters, each of which will focus on a different mode of transportation, including personal vehicles, the metro, buses, and bikes. Due to the lack of data, it has not been possible to include the S-train network. An argument could however be made that the metro operates in different areas of Copenhagen and has a different purpose which focuses more on navigating around internally in Copenhagen rather than accessing Copenhagen, which the S-train lines help with. A lot of assumptions have been made through the analysis to fill the gaps that exist due to the partly limited data that is available. Thus, the result of the analysis will therefore be an estimate based on these assumptions. Afterwards, the CO_2 emission of each mode of transportation will be compared. To do so, the number of passengers utilizing each of the modes of transportation must also be considered.

All of the calculations have been made in Excel along with the auxiliary graphs. The Excel file has been placed as an appendix under the name “Environmental analysis”.

16.1 Methodology Regarding the CO_2 Emission of Vehicles

Since 1989, the Municipality of Copenhagen has documented the total kilometres driven on its road network. However, it was only after the year 2003 that the local roads were included in the analysis, and in order to illustrate the vehicle-activity without a huge crack appearing on the graph, the municipalities of Copenhagen have calculated an estimate of the vehicle activity on the local roads, by looking at the development from the year 2003 and beyond and considering how the road network has evolved.

Furthermore, the municipality of Copenhagen has counted the number of vehicles in a series of places across Copenhagen from 1970 to 2022. This results in a dataset, which illustrates the daily average vehicle count per year in both directions. Additionally, the counting places have been divided into two subcategories: City centre cross sections and municipality border. The city centre cross section gives an overview of the traffic within the city centre of Copenhagen, whereas the municipality border gives an overview of how many citizens travel in and out of the municipality on a daily basis.

Depending on a vehicle's fuel, it has a varying impact on the environment. Thus, the percentage of each type of vehicle per year must be considered to calculate how the evolution of vehicle activity in Copenhagen impacts the environment in the form of CO_2 emissions. It was not possible to find data regarding this only for the municipality of Copenhagen, however, the data does exist for the whole of Denmark, which was retrieved from the statistical bank of Copenhagen municipality. The data, therefore, doesn't exactly illustrate the evolution in Copenhagen; however, it gives an overall indication of it. In 1993, 99,9 % of vehicles in Denmark were fuelled by either electricity, diesel or petrol, and in 2022 the number was 97,2 %. Given the fact that only such a small margin of the vehicles in 2022 used a different type of fuel and that they will make the examination of the CO_2 evolution much more difficult, they are deemed as negligible.

As mentioned before, each type of vehicle has a varying impact on the environment depending on the fuel type. The "New European Driving Cycle" (NEDC) provided a series of numbers regarding the average CO_2 emissions per mileage (emission-rate) of diesel and petrol vehicles from different years. In 2021 the average of said types of vehicles was $142{,}4\,\frac{g}{km}$ and $129\,\frac{g}{km}$ respectively (Danmarks Statistik [C], 2021) and in 2010 this number was $179\,\frac{g}{km}$ and $149\,\frac{g}{km}$ (Danish Transport Authority, 2011). The missing data from the remaining years were calculated by linear regression under the assumption that the evolution was somewhat linear. Electric vehicles do not emit CO_2 when in operation, however, according to The International Council on Clean Transportation the production of the said vehicles actually emits more CO_2 compared to fossil fuel vehicles in the same weight category. If the production of the vehicles was to be considered an average, the electric vehicle has an emission rate of around $35\,\frac{g}{km}$, which is still significantly less than its counterparts (Vistisen, 2022). Considering the above-mentioned information, the emission of each type of vehicle each year can be calculated with the use of the following equation.

$$VE_{x_y} = VER_{x_y} \cdot VCP_{x_y} \cdot VCA_{x_y} \cdot 365$$

$x = the\ type\ of\ vehicle$
$y = the\ year$
$VE = CO_2\ emission\ for\ vehicles\ [g]$
$VER = Emssion\ rate$ for vehicles $\left[\frac{g}{km}\right]$
$VCP =$ vehicles $procentage$
$VCA = The\ total\ vehiclesactivity\ [km]$

Afterwards, the total amount of CO_2 emissions can be calculated as the sum of each type of cars emission:

$$VE_{total_y} = VE_{electric_y} + VE_{diesel_y} + VE_{petrol_y}$$

The total amount of emissions doesn't say anything if the total number of passengers is not considered. Thus, to compare the CO_2 emissions of the vehicles to that of other modes of transportation, the total amount of emissions must be divided by the total amount of passengers. However, not every vehicle is operated by only citizens at the time. According to a report by the Institution of Transport at The Danish Technical University, DUT, the occupancy rate in Copenhagen is 1,2 - 1,3 passengers per vehicle. Given the fact that the occupancy rate of the municipalities surrounding Copenhagen is 1 - 1,2, an occupancy rate of 1,2 are used in the calculation. Considering the above-mentioned information, the CO_2 emission of vehicles per passenger each year can be calculated with the use of the following equation.

$$VEP_y = \frac{VE_{total_y}}{V_y \cdot OR}$$

$VEP = CO_2\ emission\ per\ passenger\ for\ vehicles\ [g]$
$V = Number\ of\ vehicles$
$OR = Occupancy\ rate = 1{,}2$

16.2 Methodology Regarding the CO_2 Emission of the Metro

Since the first metro line opened in 2002, Metroselskabet I/S documented the number of its passengers each year. It is to be noted that these numbers emulate the total numbers of both M1/M2 and the M3/M4 and thus don't consider changeovers between the lines. It is also to be noted that in 2017, Metroselskabet I/S adopted a new counting system, which differs from the previous one, and thus the numbers before and after 2017 are not totally compatible (Metroselskabet I/S, 2022).

In 2010, Metroselskabet I/S published a sustainability report, in which they documented the total CO_2 emission from the metro during the period from 2003 to 2010. A similar report was made in 2022; however, this report only contained data from 2020. The remaining numbers are not available meaning assumptions must be made to do the calculations. First of all, Cityringen was finished in 2019 and because no additional construction was made to the metro during the period from 2011 to 2019, the CO_2 emission is assumed to be the same as the one from 2010. Secondly, the CO_2 for 2021 and 2022 is assumed to be the same as the one from 2020, as no additional construction was made during this period as well.

Considering the above-mentioned information, the CO_2 emission of the metro per passenger each year can be calculated with the use of the following equation.

$$MEP_y = \frac{ME_y}{MP_y}$$

$y = the\ year$
$MEP = CO_2\ emission\ per\ passanger\ for\ the\ metro\ [g]$
$ME = CO_2\ emsission\ [g]$
$MP = \ Number\ of\ passagers\ riding\ the\ metro$

16.3 Methodology Regarding the CO_2 Emission of the Buses

The data regarding the CO_2 emissions of buses per passenger is rather limited, and thus the investigation of the said matter is based on a series of assumptions. In 2015 and 2022 the municipality of Copenhagen released a report titled “The Status of Copenhagen”, in which they documented the passenger of the buses from 2014 to 2021 and from 1995 to 2013 respectively. The numbers from the 2015 report were in the form of index numbers, meaning the 2013 number of passengers must be a known figure, to calculate the remaining numbers. This meant that the number of passengers in 2013 would have to be assumed the same as in 2014.

Movia, the company which owns and operates the buses in Copenhagen, have published the CO_2 emission per passenger of the diesel and electric buses, with 88g CO_2 per passenger and 30g CO_2 per passenger respectively (Movia, 2023). These numbers are assumed to be the 2022 numbers, with numbers of the remaining years not available. The calculation of said numbers is rather simple, the more people who are riding together on the buses would result in fewer CO_2 emissions. Thus, to calculate the CO_2 emission per passenger for the remaining years, the numbers are assumed to be inversely proportional to the number of passengers. However, it must also be considered that the CO_2 emissions of the buses in Copenhagen have been reduced by 60 % from 2008 to 2021, according to Movia. The reduction is assumed to be linear, due to the lack of data. At the same time, Movia also states, that 23 % of its buses were electric in 2021, with the first one being introduced in 2019. This evolution is also assumed to be linear, due to the lack of data (Københavns Kommune [B], 2023).

16.4 Methodology Regarding the CO_2 Emission of Bikes

Similar to the vehicles, the municipality of Copenhagen has counted the number of bikes in a series of places across Copenhagen from 1970 to 2022. This results in a dataset which illustrates the daily average bike count per year in both directions. Additionally, the counting places have also been divided into two subcategories: City centre cross sections and municipality border.

16.5 Methodology Regarding the Weighted Average

As a conclusion to the analysis, the evolution of the CO_2 emission per passenger for each mode of transportation will be combined. To do so, a weighted average must be used, as a different number of passengers are using the four modes of transportation each year. It is to be noted, that the weighted average will only be conducted over the period of 1995 to 2021, as this is the period in which data exist for all four of the modes of transportation. Considering the above-mentioned information, a weighted average of the CO_2 emission per passenger each year can be calculated with the use of the following equation, with the number of passengers being the predetermined weight:

$$WA_y = \frac{\left(EP_{Vehicles_y} \cdot P_{Vehicles_y}\right) + \left(EP_{Metro_y} \cdot P_{Metro_y}\right) + \left(EP_{Bikes_y} \cdot P_{Bikes_y}\right) + \left(EP_{Busses_y} \cdot P_{busses_y}\right)}{P_{Vehicles_y} + P_{Metro_y} + P_{Bikes_y} + P_{Busses_y}}$$

$y = the\ year$

$WA = CO_2\ emision\ pr.passenger\ weighted\ average$

$EP = CO_2\ emission\ pr.passenger$

$P = passengers\ pr.year$

Analysis

17 Introduction to Analysis.

In the following five chapters, the five analyses “Changes of demography”, “Change in property value”, “Complaints about the metro”, “Potential time saved” and “Environmental analysis” will be presented. The analyses are based on the theory at the beginning of the project and prepared based on the requirements specifications in Chapter 10.

Each analysis contains the hypothesis from the requirement specification and a case delimitation. It describes the requirements for metro stations that are needed for the best possible analysis in accordance with the method of analysis, and ultimately a final selection of which stations will be examined for each analysis.

All of the analysis will include a series of stations spread throughout Copenhagen, with a different local dispensary, thus securing a diverse result and avoiding isolated examples, which does not represent the full picture. At the end of every analysis, a partial conclusion with an answer to the single hypothesis, will be given.

18 Changes of Demography

The following analysis are based on the hypothesis.

Metro stations should not be able to drastically change the demography of a neighbourhood but will secure an equal development in Copenhagen.

18.1 Case Delimitation

The method that this hypothesis will be analysed is by looking at the change of the demography in the surrounding residential areas next to metro stations. The requirements to be able to do this analysis are that there must have been housing both before and after the construction of the metro station. The housing in the neighbourhood around the stations must be mixed flats and houses in an effort to find as much diversity as possible. The most optimal case metro stations that will be investigated are:

- Vanløse
- Sundby
- Amager Strand
- Øresund

The same analysis that is made of the demographic changes around Vanløse, Sundby, Amager Strand, and Øresund will also be made in similar areas, that are not affected by the metro. These areas are chosen based on the population's disposable income in 1993, which should be in the same amount as in the three chosen cases. The control areas that are chosen are Emdrup, Bispebjerg, Bellahøj, and Ålholm. The disposable income in 1993 in all chosen 7 areas are between 90.000 DKK and 100.000 DKK per year. All the case areas also have a distance of around 4 km to 6,5 km to Nørreport station, meaning the income and distance to Nørreport station would not play a role. It is chosen to make an analysis of the control areas, because it will show if the areas affected by the metro have a different change in demography, compared to the rest of Copenhagen. Figure 10 shows an overview map of the metro stations and case districts.

As mentioned in 2.2 "Social Sustainability", the social inequality between people and population groups can be measured in several different ways, for instance, by the level of education, economic inequality or through the housing market. Economic inequality is an unequal distribution of financial resources, which can be measured by looking at the disposable personal income. Economic inequality can be compared between geographic location, population groups or education.

Control areas are important to the analysis of demographics, as there may be overall trends in education and income for all residents in Copenhagen; if the analysis was not made on the control areas the conclusion of the demography analysis will be misleading. The analysis of the demographic change will be based on data collected from the statistical bank of Copenhagen Municipality Areas that are chosen for the analysis are all districts in Copenhagen which is a smaller area of the city (Københavns Kommunes Statistikbank, n.d.).

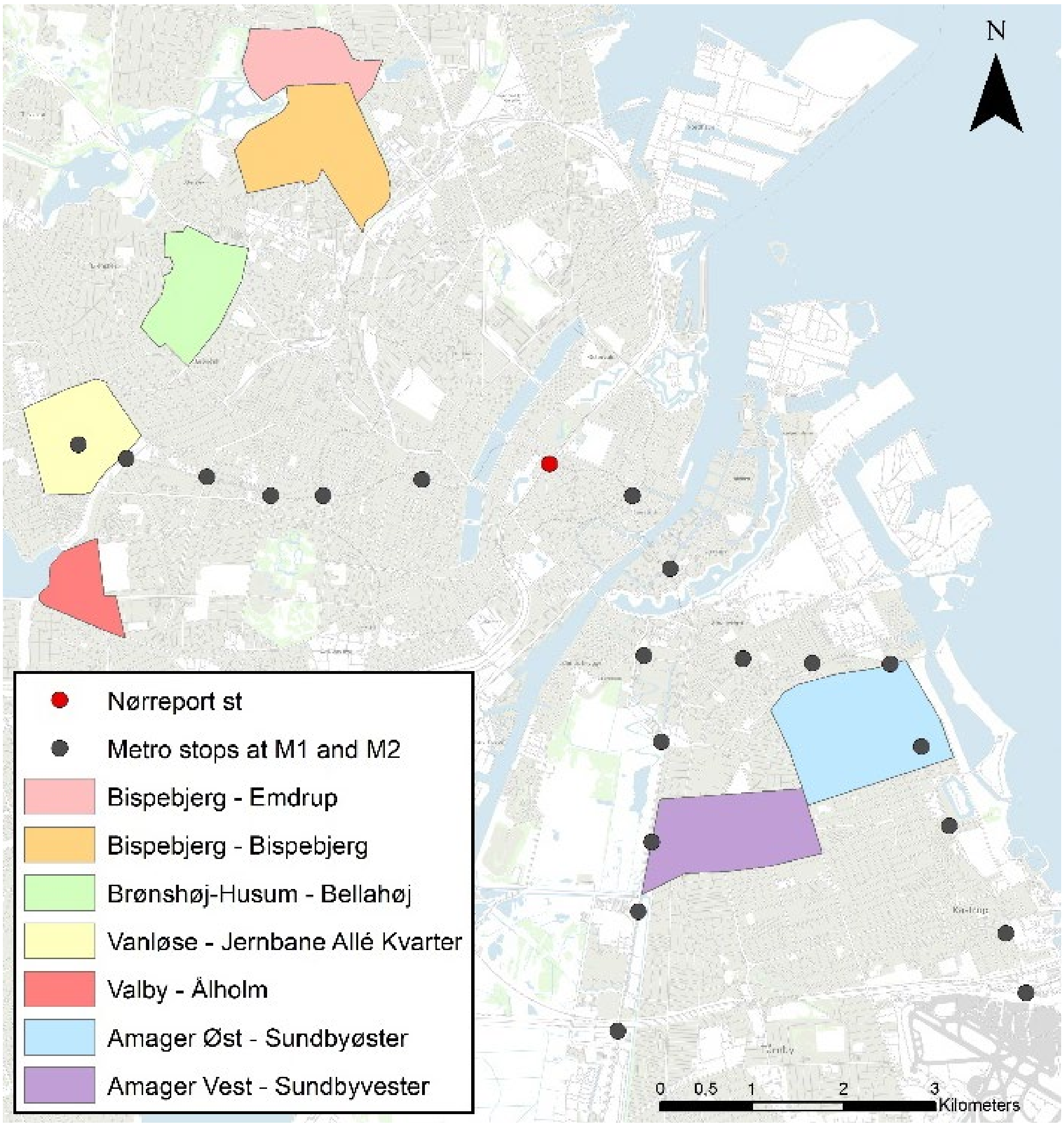


Figure 10: Map of the case districts and metro stops at M1 and M2. Self-produced.

18.2 Results

The following sections show the results in the variance of different aspects of demographics including type of housing, disposable income, age distribution, completed education, and change in economy.

18.2.1 Type of Housing

An analysis of the development in the type of housing, in the different districts, will determine if the type of housing impacts where the metro is placed. Similarly, to examine if the presence of a metro station has an influence on how the development in the type of housing changes. The proportion of housing types in different districts of Copenhagen is shown in table 4.

Different type of housing in Copenhagen

	1993	2002	2007	2012	2021
Owner-occupied home	18%	19%	21%	19%	22%
Privat rental	33%	26%	24%	26%	28%
Housing cooperative	21%	32%	33%	33%	30%
Public housing	19%	21%	20%	20%	19%
Municipal/state owned	9%	2%	2%	2%	1%

Owner-occupied home

	1993	2002	2007	2012	2021
Valby - Ålholm	29%	32%	32%	31%	31%
Vanløse - Jernbane Allé Kvarter	23%	26%	26%	24%	26%
Brønshøj-Husum - Bellahøj	0%	0%	0%	0%	1%
Bispebjerg - Emdrup	27%	29%	31%	30%	30%
Bispebjerg - Bispebjerg	6%	9%	12%	6%	6%
Amager Øst - Sundbyøster	19%	24%	26%	23%	25%
Amager Vest - Sundbyvester	35%	37%	40%	40%	43%

Privat rental

	1993	2002	2007	2012	2021
Valby - Ålholm	21%	16%	14%	14%	15%
Vanløse - Jernbane Allé Kvarter	44%	33%	27%	29%	30%
Brønshøj-Husum - Bellahøj	0%	1%	1%	1%	6%
Bispebjerg - Emdrup	41%	37%	35%	36%	36%
Bispebjerg - Bispebjerg	22%	23%	11%	16%	16%
Amager Øst - Sundbyøster	25%	18%	20%	22%	22%
Amager Vest - Sundbyvester	25%	19%	17%	17%	15%

Housing cooperative

	1993	2002	2007	2012	2021
Valby - Ålholm	30%	32%	34%	35%	33%
Vanløse - Jernbane Allé Kvarter	22%	27%	32%	31%	30%
Brønshøj-Husum - Bellahøj	1%	10%	10%	9%	9%
Bispebjerg - Emdrup	1%	1%	1%	1%	1%
Bispebjerg - Bispebjerg	10%	33%	36%	35%	35%
Amager Øst - Sundbyøster	32%	42%	42%	42%	41%
Amager Vest - Sundbyvester	18%	21%	21%	23%	24%

Public housing

	1993	2002	2007	2012	2021
Valby - Ålholm	18%	21%	21%	21%	21%
Vanløse - Jernbane Allé Kvarter	11%	15%	16%	15%	15%
Brønshøj-Husum - Bellahøj	98%	89%	89%	89%	85%
Bispebjerg - Emdrup	30%	34%	34%	34%	34%
Bispebjerg - Bispebjerg	30%	33%	38%	38%	38%
Amager Øst - Sundbyøster	17%	18%	14%	14%	14%
Amager Vest - Sundbyvester	14%	19%	18%	19%	18%

Municipal/state owned

	1993	2002	2007	2012	2021
Valby - Ålholm	3%	0%	0%	0%	0%
Vanløse - Jernbane Allé Kvarter	0%	0%	0%	0%	0%
Brønshøj-Husum - Bellahøj	0%	0%	0%	0%	0%
Bispebjerg - Emdrup	0%	0%	0%	0%	0%
Bispebjerg - Bispebjerg	31%	0%	0%	4%	4%
Amager Øst - Sundbyøster	8%	0%	0%	0%	0%
Amager Vest - Sundbyvester	7%	4%	4%	4%	1%

Table 4: Percentage of different types of housing in the case districts and Copenhagen overall. Self-produced. Data from (Københavns Kommunes Statistikbank, n.d.).

The types of housing examined are owner-occupied homes, private rental, housing cooperative, public housing, and municipal/state-owned homes. As shown above, the development in types of housing is similar in the different districts, however, Bellahøj stands out because almost all housing in Bellahøj is public housing, whereas the type of housing is diverse in the other districts and Copenhagen as a whole. Public housing is meant to be for everyone because they are affordable, therefore, they appeal especially to citizens with a lower education and income.

From table 4, it can be inferred, that districts with less public housing e.g., Sundbyvester, Sundbyøster, and Vanløse also have metro stations. Additionally, each of these districts consists of 19 % or less public housing, which, compared to the table content "*different type housing in Copenhagen*" above, means that no district with a metro station exceeds the average, of 20 %, of public housing in Copenhagen. Furthermore, when comparing the development in public housing in 1993 and 2021, there is an average increase of 2 percentage points in districts with metro, and an increase of 4 percentage points in districts without metro, except for Bellahøj. Bellahøj has a decrease in public housing, in the same period, by 13 percentage points, which is caused by an increase in private rental and housing cooperative, which most likely is due to natural urban development.

It is to be noted, that areas with a metro station, (Sundbyvester, Sundbyøster, and Vanløse) have an average increase from 1993 to 2021 in owner-occupied homes by 5 percentage points, whereas districts without metro only experience an increase of 1 percentage point in this category. The development of housing cooperative is about equal, an average of 8 percentage points. And the development in private rental has experienced a decrease for both types of districts, however, districts with metro have decreased more (8 percentage points), than districts without metro (5 percentage points). Overall, it can be seen, that districts with metro also experience an increase in owner-occupied homes which normally attracts people with higher incomes who can afford to live in these areas. At the same time, districts with metro experience a higher decrease in private rental, which affects the opportunities for people who cannot afford to buy a house.

In conclusion of the above-mentioned, the development in the type of housing shows a tendency of inequality development among districts in Copenhagen. A common denominator in these districts is, in this case, a metro station. However, it is to be noted that the development is influenced by other parameters than just a metro station.

Due to the significantly different housing structure in Bellahøj, this case district is given less priority in the rest of the analysis.

18.2.2 Disposable Income

An analysis of the average disposable income per person is made, to see if the metro has any influence on the disposable income in a district. The diagram and table of the disposable income are shown in figure 11.

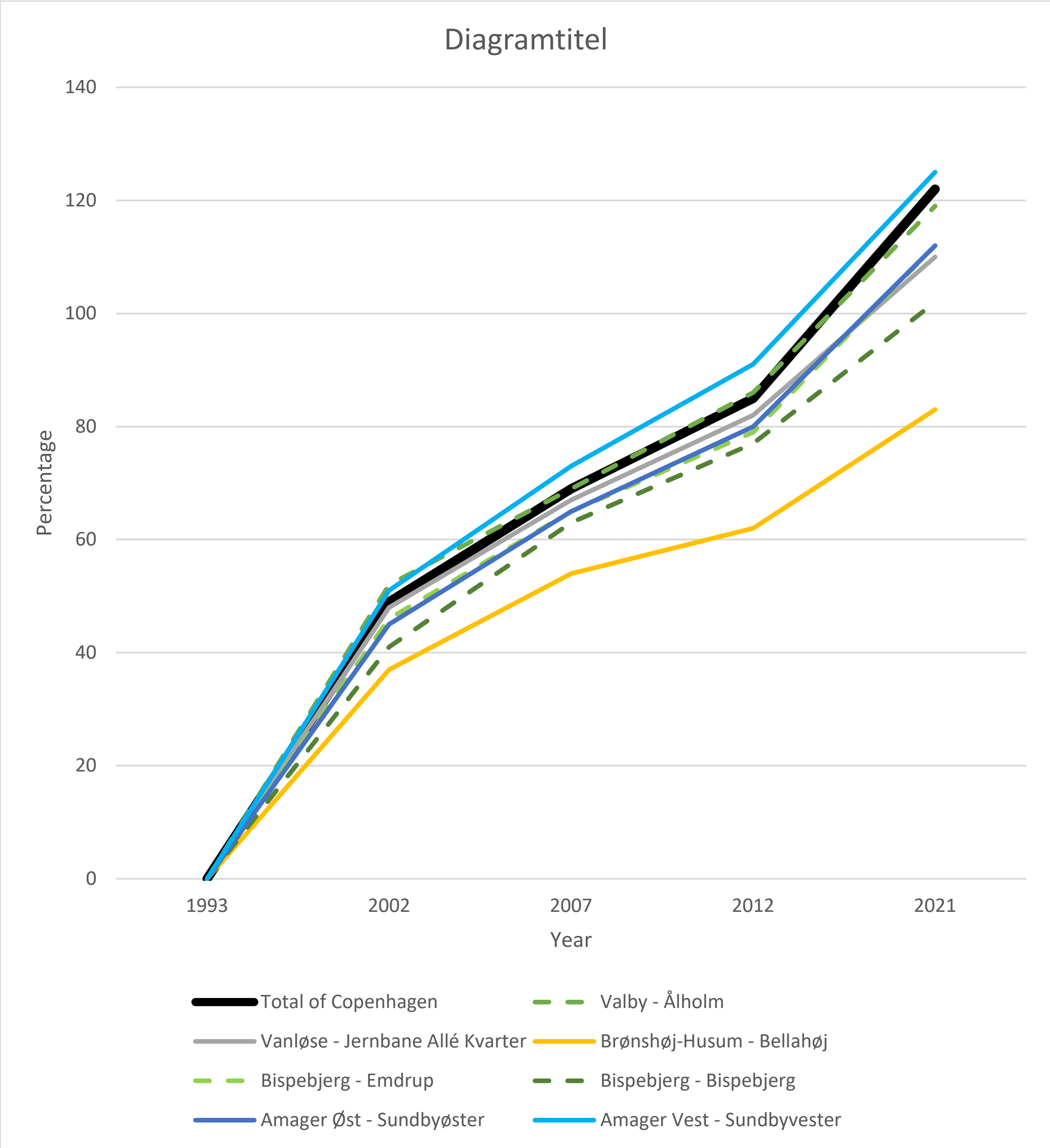


Figure 11: Overall percentage change in disposable income since 1993. Districts with metro have a bluish colour and districts with train have a dashed colour. (Københavns Kommunes Statistikbank, n.d.)

Percentage change in disposable income					
	1993	**2002**	**2007**	**2012**	**2021**
Valby - Ålholm	0%	52%	17%	17%	33%
Vanløse - Jernbane Allé Kvarter	0%	48%	19%	15%	28%
Brønshøj-Husum - Bellahøj	0%	37%	17%	8%	21%
Bispebjerg - Emdrup	0%	46%	19%	14%	33%
Bispebjerg - Bispebjerg	0%	41%	22%	14%	25%
Amager Øst - Sundbyøster	0%	45%	20%	15%	32%
Amager Vest - Sundbyvester	0%	51%	22%	18%	34%
Copenhagen average	0%	49%	20%	16%	37%

Table 5: The piecemeal percentage change in disposable income since 1993 (Københavns Kommunes Statistikbank, n.d.).

In 1993, the income in the different districts was close to each other. The population in Bispebjerg, Bellahøj, and Sundbyøster had a disposable income of about 90.000 DKK and Ålholm, Sundbyvester, Emdrup, and Vanløse had an income of around 100.000 DKK. In 2002, Vanløse, Ålholm, Emdrup, Sundbyøster, and Sundbyvester had the highest increase in disposable income from 1993 to 2002, with between 45-52 %. Sundbyvester got the M1 line in 2002, and over the next years, it was further extended to the airport and Vanløse. In 2007, the development in disposable income was similar in all areas, except for Sundbyvester and Emdrup, which had the highest increase of 22 % in disposable income, see table 5. The same tendency continued up to 2012, where all districts have a similar increase, except for Bellahøj, with the largest change of 18 % in Sundbyvester. In the period from 2012 to 2021, the smallest development in disposable income was in Vanløse and Bispebjerg, and the change in disposable income is similar in the other districts. In table 5, there is a tendency, that after 10 years of the metro in operation, 2002-2012, the high increase in disposable income over the years become more even between the districts. However, the stagnation in the disposable income can also be explained as the aftermath of the financial crisis that entered Denmark in 2008. Compared to the overall change in disposable income in Copenhagen, the change is similar from 1993 to 2012. After 2012 the change has been lower in the case districts compared to Copenhagen overall. In Copenhagen, the change in disposable income has increased 37 % from 2012 to 2021, in this period the M3 metro line was established which could explain the change because none of the case districts are placed near a metro station on the M3 line.

Based on section 18.1 “Case Delimitation” above, it is expected that the areas closest to Nørreport, will have the biggest increase in disposable income, but the analysis shows that it is not the case. Areas near the metro experience an influence in the development of the disposable income. All areas, except Bellahøj, have metro or S-train. The only public transport in Bellahøj is buses, which means that there is a tendency for districts with metro or S-train to have a bigger development in disposable income, than areas that only have buses. The significantly lower development in the income in Bellahøj could be explained by the fact that the population in the western world tries to avoid buses according to section 3.4 "Transport and infrastructure planning".

Percentage change in disposable income from 1993 to 2021		
	Disposable income (1993)	**Percentage**
Amager Øst – Sundbyøster	92.274 DKK	165%
Bispebjerg – Bispebjerg	93.385 DKK	146%
Brønshøj-Husum – Bellahøj	93.655 DKK	109%
Amager Vest – Sundbyvester	97.149 DKK	191%
Vanløse – Jernbane Allé Kvarter	97.168 DKK	157%
Bispebjerg – Emdrup	99.009 DKK	163%
Valby – Ålholm	99.128 DKK	178%
Copenhagen average	**93.071** DKK	**185%**

Table 6: Percentage change in disposable income 1993-2021.The blue districts have metro station. Self-produced, (Københavns Kommunes Statistikbank, n.d.).

It appears from table 6, that Sundbyvester has the largest increase by 191 % in disposable income among the case areas (marked in blue), however, the district also had the biggest disposable income in 1993 of 97.149 DKK. As seen above, the lowest disposable income in 1993 was 92.274 DKK. Of the districts with the lowest income, (92.000-94.000 DKK), in 1993, Sundbyøster increased the most in disposable income in 2021 with 165 %. Sundbyøster and Sundbyvester are districts with metro stations, therefore, a tendency is that it potentially is more attractive to live in these districts, justified by the higher increased development in these districts compared to those without metro. However, table 6 also shows that Vanløse has increased the least among areas with the highest disposable income in 1993 (97.000-99.000 DKK), which can be due to other factors that may affect the development.

18.2.3 Age Distribution

The age distribution in each district will be analysed to see if the implementation of the metro influences the age group of the people who live and move to a specific district. The development of the age groups in Emdrup, Sundbyøster, and Copenhagen Municipal are visualised in figure 12, figure 13 and figure 14 below.

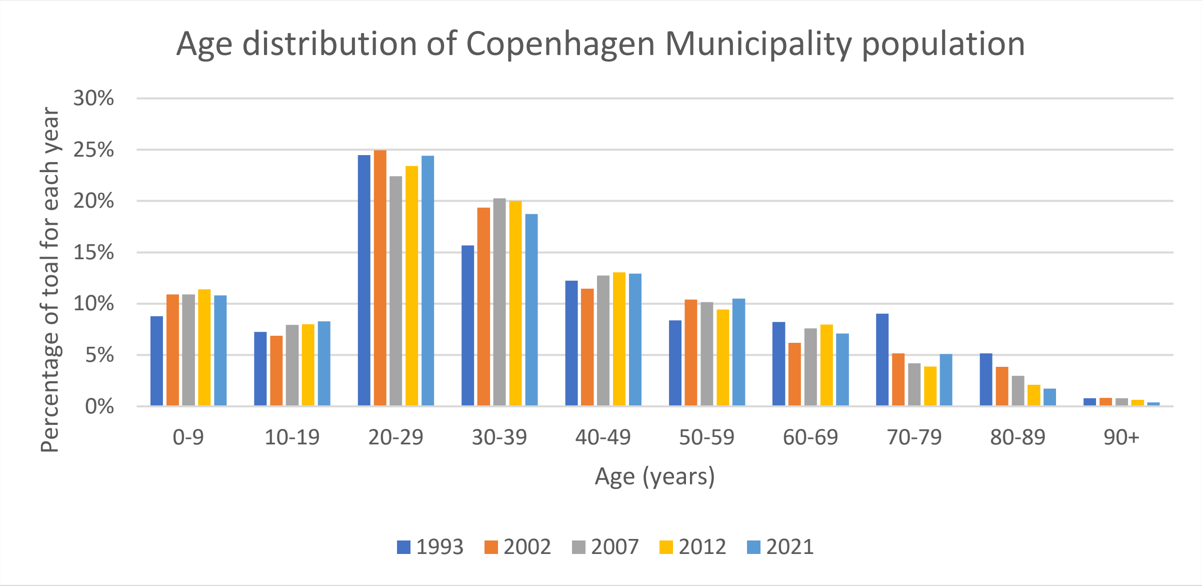


Figure 12: Age distribution in Copenhagen Municipal, data from (Københavns Kommunes Statistikbank, n.d.).

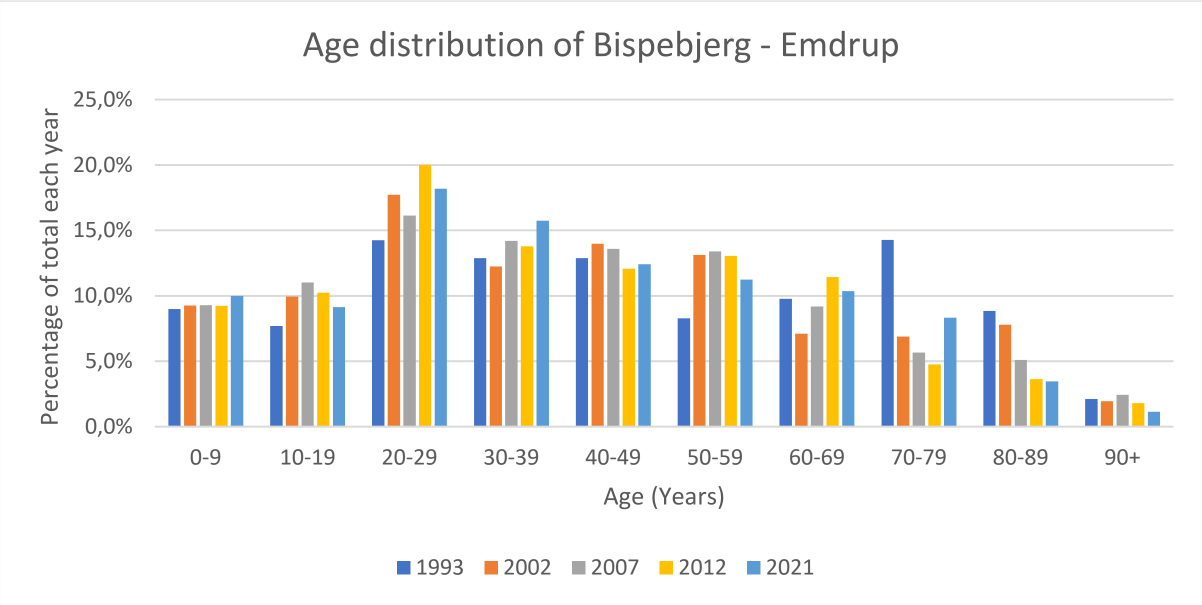


Figure 13: Age distribution of Bispebjerg – Emdrup, data from (Københavns Kommunes Statistikbank, n.d.).

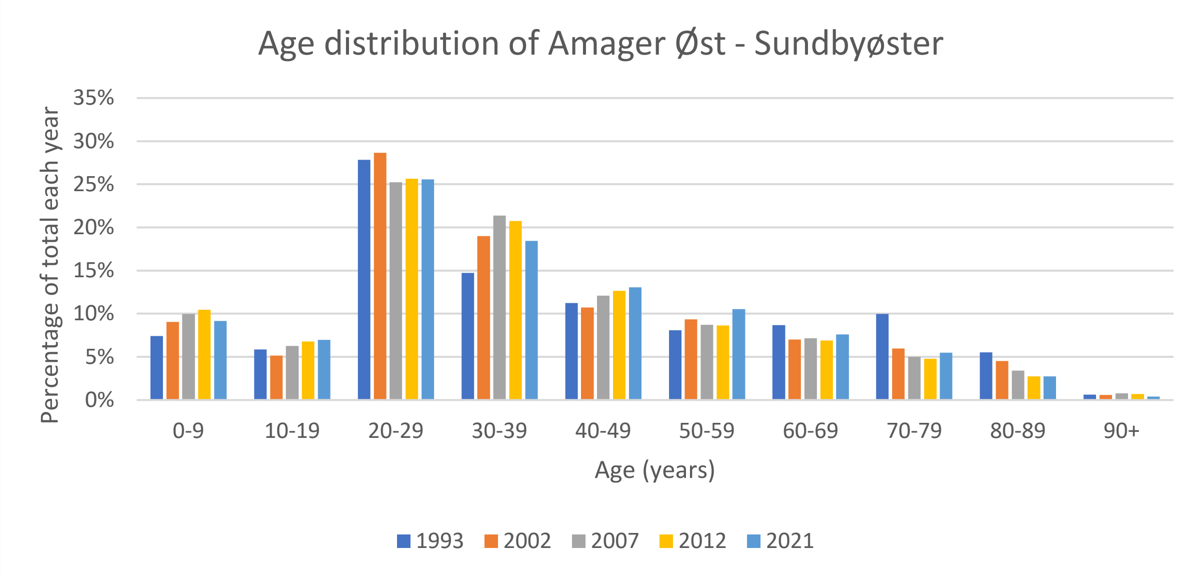


Figure 14: Age distribution of Amager Øst – Sundbyøster, data from (Københavns Kommunes Statistikbank, n.d.).

The biggest age group in Copenhagen municipal in figure 12, is the group between 20-29 years with a proportion of 24 % of the total population followed by the 30-39 age group, with around 19 % of the population. This age distribution is a sign that Copenhagen is a big student city. This trend also applies to all the selected districts, which can be seen in Appendix 2.

The two districts Emdrup (figure 13) and Sundbyøster (figure 14) have been selected to compare the age distribution in districts with metro stations and areas without. The residential areas close to a metro station, has a minor tendency to have slightly more young people than the average in Copenhagen's municipality, but is otherwise very similar to the average for the municipality.

The residential areas without metro differ to a greater extent by having a general with equal distribution of all age groups with around 5 % fewer in the age group 20-29 and 30-39 than the average in Copenhagen municipality and more aged 50-59 and 10-19. This means there are a bigger percentage of the younger population in districts with metro station, compared to districts analysed without metro stations.

In general, districts with metro stations also have the biggest amount of young people who live there, and this could affect the picture of development in personal income that is presented in figure 15.

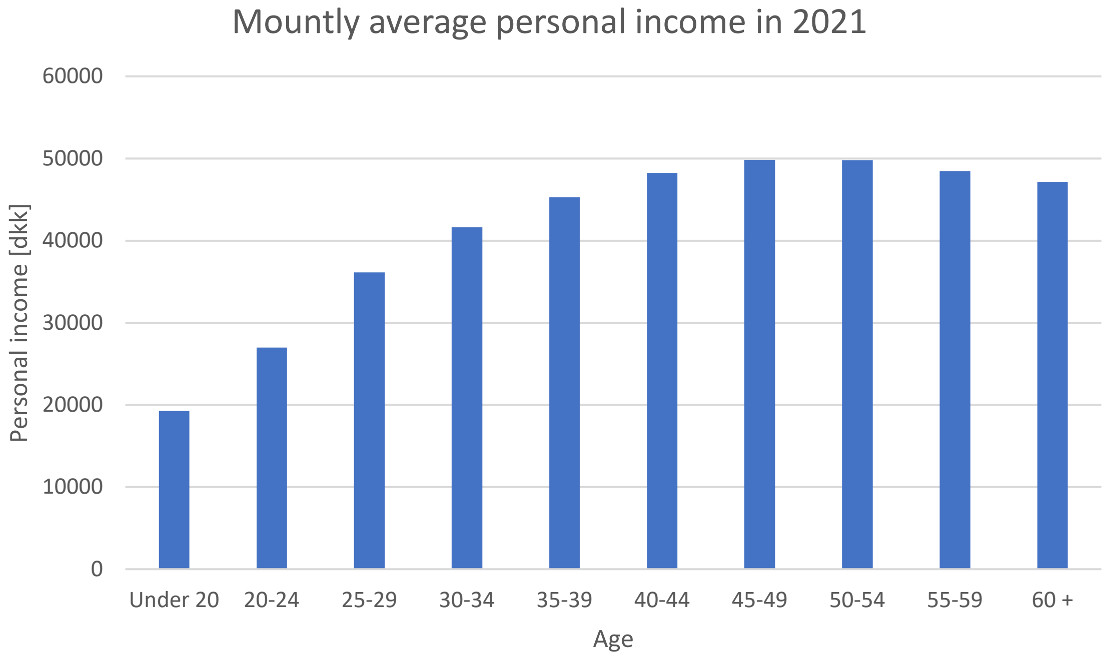


Figure 15: Average income for different age groups in Denmark. Data from (Statistikbanken, n.d.).

Figure 15 shows that it is people above 40 years old that have the highest income and young people have a lower income. It is concluded in section "Change in property value" that there is a tendency that residents are more expensive when they are close to a metro station. According to section 18.2.2 "Disposable income" the higher percentage of younger people do not affect the disposable income in a district, which means there is a tendency that the population in districts with metro are more resourceful compared to other in their age group.

It can therefore be said that the young people immediately live more in areas containing a metro than areas without, but it is not certain that this is something they choose themselves.

18.2.4 Highest Completed Education

The highest completed education will be analysed to see if the districts near a metro station have a different development in the type of highest completed education level. Primary school and longer academic educations are the educations that will be investigated, they are chosen because they are the most common types of educations in Copenhagen as the highest completed education. It is to be noted, that the graph is based on residents with an age of 15 years or older and that a large portion, estimated to be about 5-8 % based on the age distribution graphs, whom have only graduated primary school are probably teens, who are in probably in secondary education or tradesmanship school.

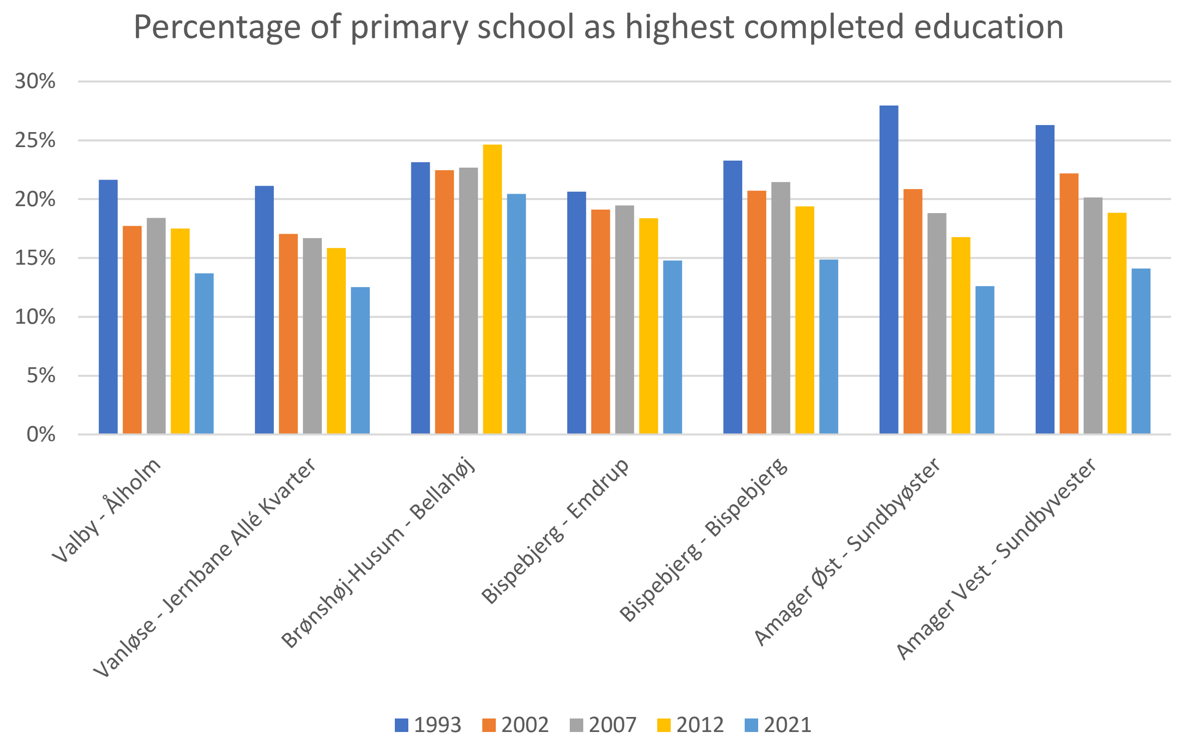


Figure 16: Percentage of residents with primary school as highest completed education in the case districts (data from (Københavns Kommunes Statistikbank, n.d.)).

Figure 16 shows the development in the number of people, who has primary school as the highest completed education. There is a clear tendency that shows that the districts near the metro, (Vanløse, Sundbyøster, and Sundbyvester) and Bispebjerg have the largest decrease of people who have primary school as the highest education level, and these districts also have the lowest percentage of population with primary school as highest completed education in 2021. The decrease is especially huge from 1993 to 2002, compared to the other districts, which is the year the metro line M1 and M2 was developed.

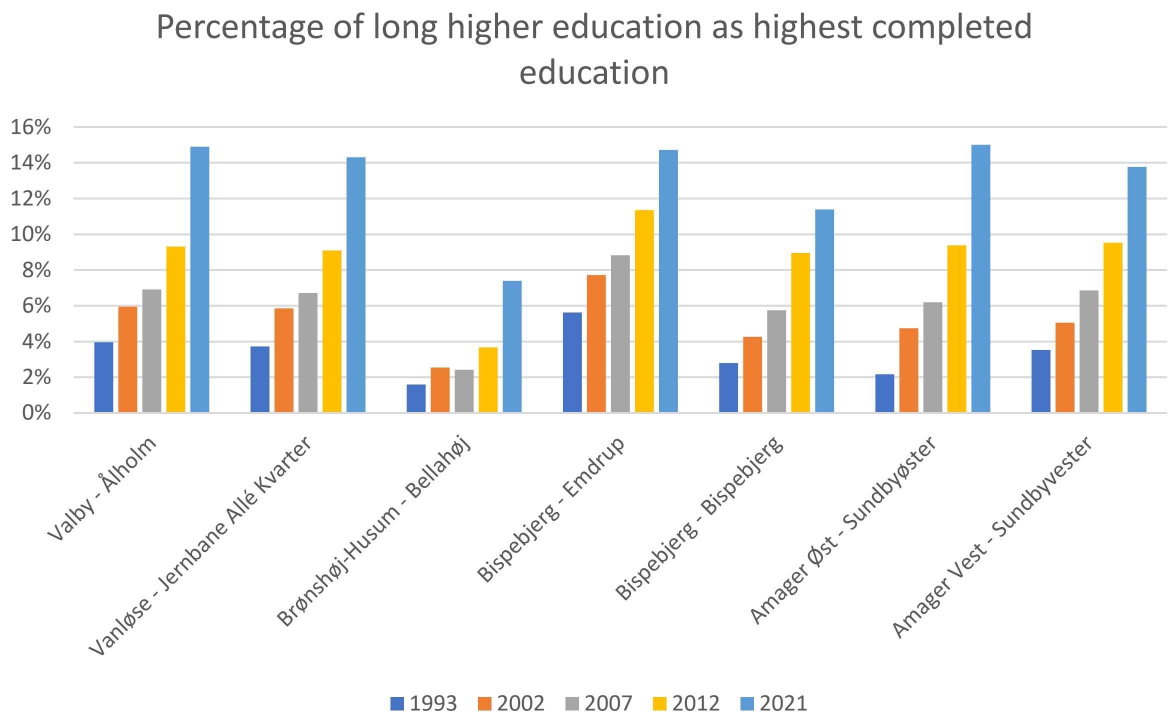


Figure 17: Percentage of residents with long higher education as highest completed education in the case districts (data from (Københavns Kommunes Statistikbank, n.d.)).

Based on the data in figure 17, there is an increase in the amount that complete a long higher education. The biggest development happened in the districts close to a metro station, especially Sundbyøster, Sundbyvester, Ålholm and Vanløse has a huge increase with an increase over 10 % of the population with a long higher education in 2021, compared to 1993. This also strengthens the conclusion in section 18.2.3 ”Age distribution”, where it was concluded that the people who live in Sundbyøster and Vanløse have a bigger income, than other people in their age group, and also a high education level, as shown in figure 17, and it is an explanation on that conclusion.

Based on the analysis of the highest completed education, the biggest development in the level of education completed happens in the districts closest to a metro station and Ålholm with 10-13 % more of the population with a long higher education. The other districts have an increase of 6-10 %.

18.2.5 Economic Status

An analysis of the change in the amount of income for each economic decile will be investigated in this chapter. Deciles are a method to divide the population into groups based on their income. The first decile is 0-10 % of the population with the lowest income, the second decile is the population who have the 10-20 % lowest income, etc. This shows the differences between the poorest and richest people, in an area, which means the analysis can show how the inequality has changed in a district. Normally there are 10 deciles, but at the statistical bank of Copenhagen Municipality there were only 9 deciles, therefore, the analysis will only be made for deciles 1-9, in the different districts. The data have been processed in index numbers, where the income for each decile in 1993, will be the basic number for the analysis. This gives an almost equal basic number, because as table 7 shows, the income in 1993 in the chosen districts is similar.

Vanløse - Jernbane Allé Kvarter

	1993	2002	2007	2012	2021
1. decile	100	136	154	163	193
2. decile	100	140	163	181	221
3. decile	100	142	166	184	226
4. decile	100	143	167	187	235
5. decile	100	143	169	191	243
6. decile	100	144	173	199	252
7. decile	100	145	174	205	260
8. decile	100	147	177	211	276
9. decile	100	149	182	224	297

Amager Øst - Sundbyøster

	1993	2002	2007	2012	2021
1. decile	100	133	147	156	200
2. decile	100	140	163	181	232
3. decile	100	140	167	187	246
4. decile	100	141	169	193	250
5. decile	100	141	172	195	258
6. decile	100	142	174	200	264
7. decile	100	145	176	205	277
8. decile	100	146	180	213	290
9. decile	100	149	185	227	309

Amager Vest - Sundbyvester

	1993	2002	2007	2012	2021
1. decile	100	146	172	179	214
2. decile	100	144	171	193	237
3. decile	100	145	169	193	247
4. decile	100	143	171	199	259
5. decile	100	146	176	211	271
6. decile	100	147	179	218	284
7. decile	100	147	180	221	293
8. decile	100	149	185	227	300
9. decile	100	151	188	234	313

Valby - Ålholm

	1993	2002	2007	2012	2021
1. decile	100	136	155	169	212
2. decile	100	140	164	185	239
3. decile	100	138	163	186	239
4. decile	100	138	163	187	249
5. decile	100	140	167	195	256
6. decile	100	144	172	206	269
7. decile	100	146	177	213	280
8. decile	100	149	184	220	296
9. decile	100	152	189	227	311

Bispebjerg - Bispebjerg	1993	2002	2007	2012	2021
1. decile	100	128	151	157	198
2. decile	100	132	158	170	209
3. decile	100	133	161	178	221
4. decile	100	135	164	183	226
5. decile	100	136	165	188	234
6. decile	100	138	169	192	242
7. decile	100	141	176	199	247
8. decile	100	144	180	208	257
9. decile	100	147	184	217	278

Bispebjerg - Emdrup	1993	2002	2007	2012	2021
1. decile	100	132	154	145	183
2. decile	100	135	156	163	201
3. decile	100	136	160	170	215
4. decile	100	140	161	175	221
5. decile	100	142	165	184	235
6. decile	100	147	172	198	257
7. decile	100	150	182	210	281
8. decile	100	151	188	225	295
9. decile	100	156	194	232	313

Brønshøj-Husum - Bellahøj	1993	2002	2007	2012	2021
1. decile	100	131	151	155	164
2. decile	100	132	156	159	176
3. decile	100	132	156	161	183
4. decile	100	132	154	163	188
5. decile	100	133	151	159	190
6. decile	100	135	152	161	199
7. decile	100	137	153	164	209
8. decile	100	137	154	165	215
9. decile	100	137	155	169	218

Copenhagen Average	1993	2002	2007	2012	2021
1. decile	100	136	151	163	203
2. decile	100	137	159	177	223
3. decile	100	138	163	185	239
4. decile	100	141	168	192	253
5. decile	100	143	171	198	264
6. decile	100	145	175	205	274
7. decile	100	147	178	212	286
8. decile	100	149	181	220	299
9. decile	100	152	187	231	320

Table 7: Index numbers for the growth in income for each decile. Self-produced. Data from (Københavns Kommunes Statistikbank, n.d.).

In the development of the deciles from 1993 to 2002 all districts, except Bellahøj, have a similar development in the deciles. Bellahøj has a lower increase, compared to the other case areas. The most equal development happened in Sundbyvester in this period because deciles 1-3 have the biggest increase, and all the other deciles in Sundbyvester have almost the same increase, as the other case areas. The tendency in the other districts is deciles 1-3 have a smaller increase than deciles 7-9, which means there has been an almost equal development in the income for the population in Sundbyvester, compared to the other districts. Sundbyvester is the only area where the metro opened in 2002.

In the period from 2002 to 2007, the development is like the period from 1993 to 2002. Sundbyvester has a high and equal development. In this period Vanløse and Sundbyøster also get a metro station, the only significant change about these two districts is that the 1st deciles especially in Sundbyøster, have a much worse development compared to deciles 2-9. This means that the poorest in Sundbyøster are getting even more poor compared to the rest of the district, and it continues until 2021. The only significant change in the inequality from 2007 to 2012 is that Emdrup gets a huge inequality in this period, and it also continues from 2012 to 2021.

18.3 Partial Conclusion

There is evidence that areas that contain metro stations in time experience a rise in the number of residents with a higher income, and therefore have the largest percentage increase in income. The development seems to happen in the first 10 years after the opening of a metro line and then evens out.

Areas near a metro station slightly tend to attract a higher share of young people, but this does not give a negative impact on disposable income, which means that the inhabitants especially in Vanløse and Sundbyøster are more resourceful compared to people of their own age group who live in districts without metro stations. This is backed up by the fact that these two districts are also some of the districts where the population is best educated.

There is a slight tendency for the metro to create more equality in Sundbyvester, but more inequality in Sundbyøster. However, this may be due to the fact that the development of public housing is more minor in districts with metro stations, which gives a picture of unequal development in the composition of the population between districts in Copenhagen.

All these trends that this analysis has emerged cannot be directly put in context with the arrival of the metro, but based on the analysis, there is an overall trend that shows that areas seem to gain advantages in development in the years after a metro line opens in them, while many of the districts that do not have metro stations seemingly get a worse and more unequal development internally.

The equality does not change in a district when it gets metro, but there is a tendency that shows an increase in the economic change in districts with metro, which gives an inequality development between the districts.

19 Change in Property Value

The following analysis are based on the hypothesis:

Planning a metro station at a certain place result in an increase in the property value within a few hundred meters of each station over time compared to the general price development of Copenhagen.

19.1 Case Delimitation

For this analysis, the general square meter price for apartments and houses in Copenhagen and in Denmark, in general, has been investigated to compare the price development with the overall growth in Denmark. Therefore, the GDP development in Denmark in the same period has been included.

The method of analysing property value is, as mentioned earlier, a GIS analysis where sales prices within a certain distance from existing metro stations will be interpolated and shown on graphs to determine a pattern in the change of price proportional to the distance from the station. To reduce the number of outliers in the analysis and thus become more certain of the result, the ideal station would be near neighbourhoods that are homogenous in size and type of properties. The analysis could also yield different results depending on the property type, as the apartments in the centre of town may have more factors determining their sales prices than the suburban villa houses. Control areas with similar property types are also needed to determine if any price changes over time can be attributed to the progress of the construction of a metro line or is more likely an overall trend of the market at that time. As any part of the centre of Copenhagen has access to metro stations, a "control" could instead exist in the shape of multiple stations, where the time of construction was different. Optimal stations as cases for this analysis would therefore be:

- Vanløse metro station
- Amager Strand metro station

19.2 Results

The results of the GIS analysis are seen in the four figures below. In figure 18 and figure 19 it is investigated if there is any relation between the distance from respectively Vanløse and Amager Strand metro stations. Around Vanløse metro station, an area of 1500 meters has been investigated as shown in figure 18. The investigated area around Amager Strand metro station is 600 meters, as seen in figure 19. Both graphs show that there is no correlation between the distance from the station and the price of the home. This could however be due to the restraints of the method of analysis. To ensure a conclusion is not made due to a lacking analysis, it will also be investigated how time has affected the Danish economy, the housing market in general and in the area around Vanløse and Amager Strand metro stations based on the GIS data from Appendix 1.

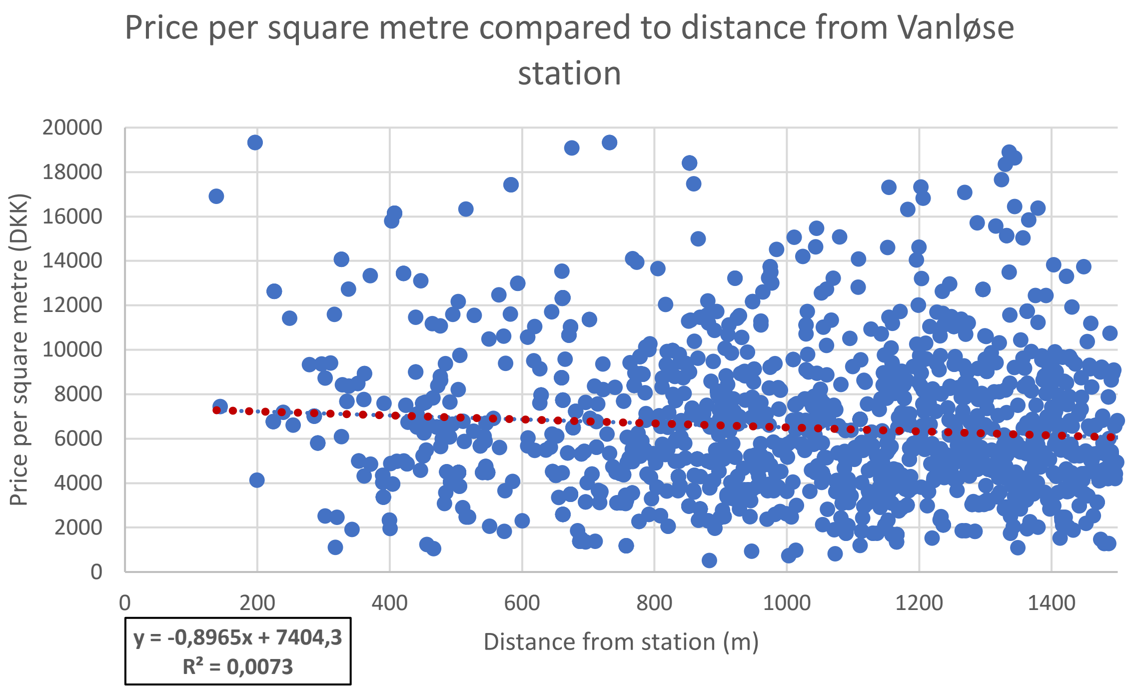


Figure 18: Price per square metre (Y) compared to distance (X) from Vanløse metro station, self-produced in ArcMap, source of data: (Skat, 2023).

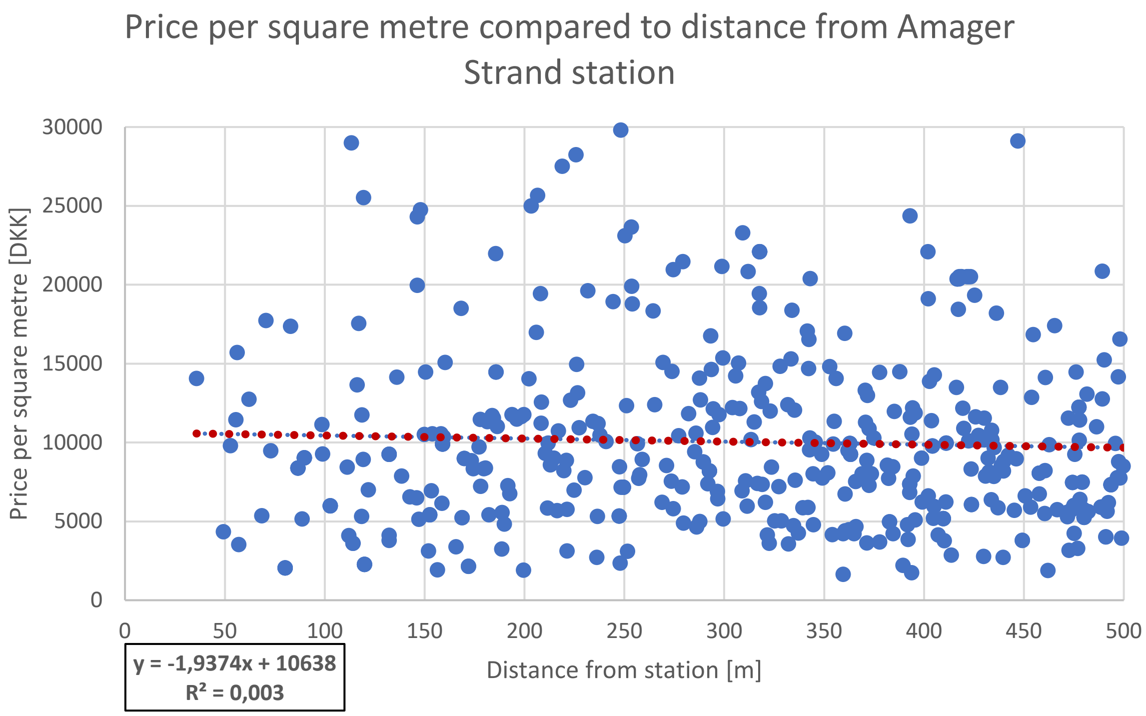


Figure 19: Price per square meter (Y) compared to distance (X) from Amager Strand metro station, self-produced in ArcMap, source of data: (Skat, 2023).

In the period from 1992 to 2022, the GDP has developed from 923 billion to 2798 billion, which is a growth of 303 %, as seen in figure 20. Except for the period after the financial crisis from 2008 to 2009, there has only been growth in the Danish GDP. This means that the economic value addition has grown, and the country has become wealthier, which also may affect the residential market.

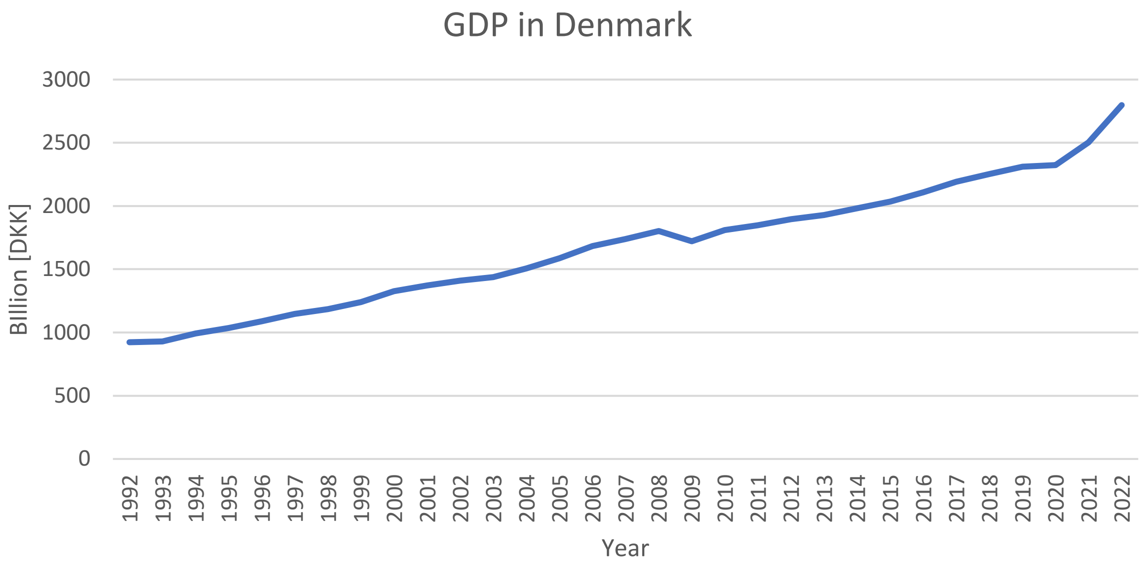


Figure 20: GDP in Denmark from 1992 to 2022. Self-made in Excel with data from (Danmarks Statistik [A], 2023) (Danmarks Statistik [A], 2023).

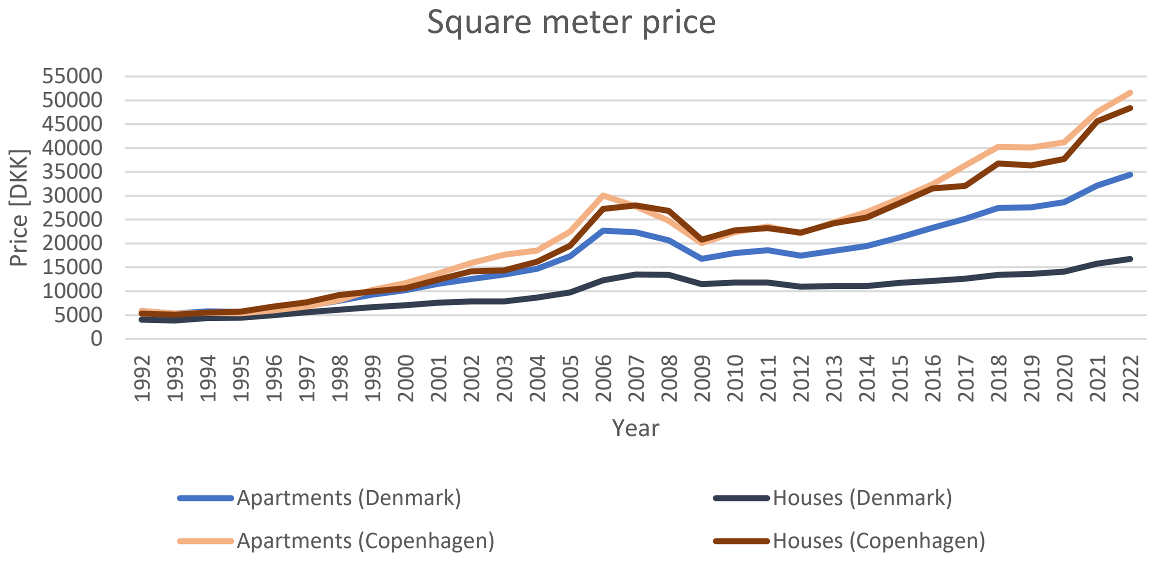


Figure 21: Average Square meter price for apartments and houses in whole Denmark and Copenhagen since 1992 to 2022 Source (Boliga, 2023).

The growth can also be seen in the residential market, as seen in figure 21, it has an average growth that looks similar to the GDP graph. In 1992, the average square meter price was significantly lower than today and the difference between Copenhagen and Denmark in general was not that remarkable. The average square meter price for an apartment was 5.820 DKK in Denmark and 5.843 DKK in Copenhagen. The square-meter price for a house in Denmark was 3.851 DKK and 5.068 DKK in Copenhagen. This shows that there was a difference between the house prices in Copenhagen and Denmark in general of around 32 % and under 1 % difference between the average apartment square meter price in Denmark and those in Copenhagen. The numbers for 2022 show a difference of 50 % between apartments in Denmark in general and Copenhagen and a difference of 189 % between the average square meter house price in Denmark and Copenhagen.

The financial crisis that hit Denmark in 2008, caused a dive in the GDP and especially the entire housing market to take a serious dive, but since then it has only increased. The apartment and house market in Copenhagen today is way higher than at the best times before the financial crisis and have doubled in price since then. It looks different with the housing market, where the average house price in Denmark has only reached the same level as the peak before the financial crisis.

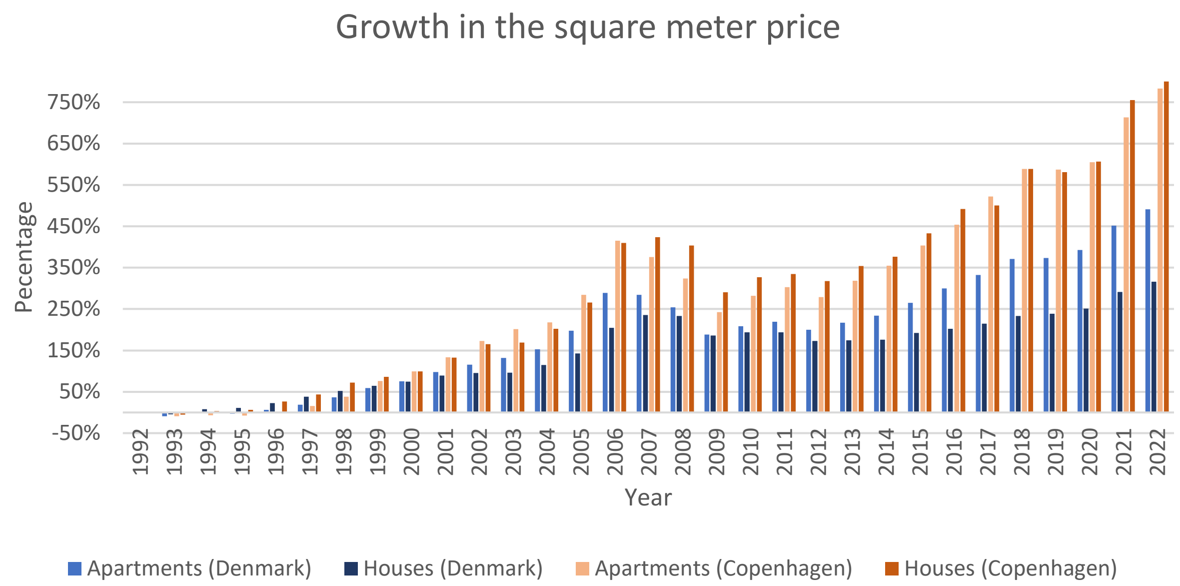


Figure 22: Percentage growth in the square meter price since 1992 to 2021 Source (Boliga, 2023).

Figure 22 shows that the square meter price for apartments in Denmark, in the period from 1992 to 2022, in general, has increased by 491 %. In comparison, apartments in Copenhagen have increased by 783 %.

In the same period, the development of the price per square meter on the housing market has increased as well by 316 % in Denmark in general and by 807 % in Copenhagen.

In conclusion, the average square meter price on the housing market in Denmark is the only market that nearly has the same development as the Danish GDP. The difference between apartments in Copenhagen and Denmark in 1992 and 2022 has increased from <1 % to 50 % and the increase between houses went from 31 % in 1992 to 189 % in 2022.

The two metro stations, Vanløse and Amager Strand, have, as mentioned, been chosen on the basis that the majority of sold properties near the stations are properties, consisting of their own cadastral number i.e., villa houses and townhouses. In addition, most buildings existed around the stations before the stations were built, even dating back to before 1992, which is the year of the earliest sales in the register used for the analysis.

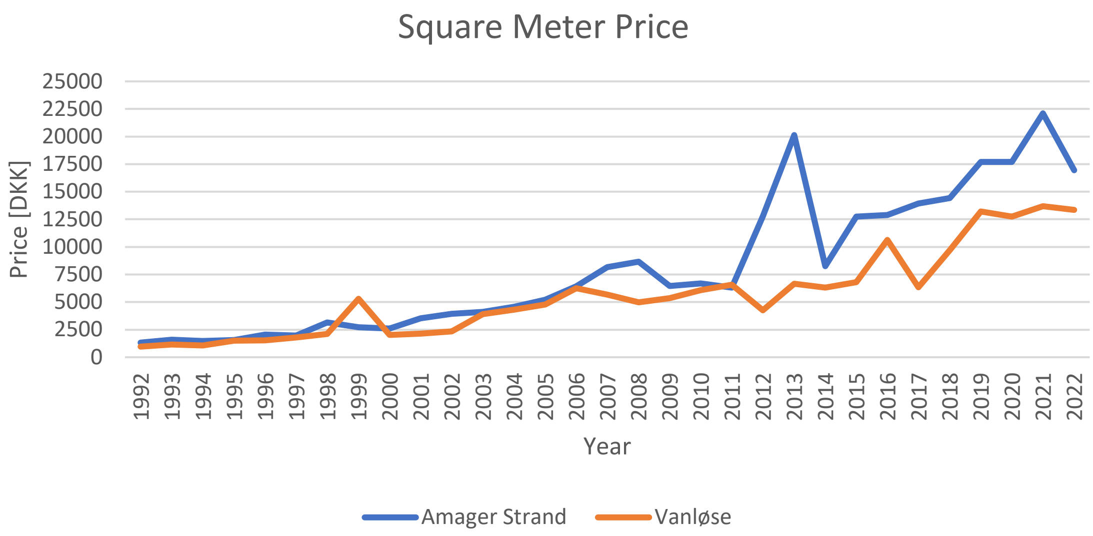


Figure 23: Square meter price of Vanløse and Amager Strand from 1992 to 2022. Source: (Skat, 2023)

The price per square meter development at Vanløse and Amager Strand station roughly followed each other until 2011, as seen in figure 23. After this, a lot of development begins with new townhouses around Amager Strand, which causes the average price per square meter to rise significantly in this area in 2012 and 2013, as seen in figure 23. The large fluctuations are due to the relatively small number of properties that are sold in the individual area per year, with an average of 59 sales in Vanløse and 40 sales in Amager Strand. For that reason, the subdivision and construction of several new homes can provide a huge impact on fluctuations.

When preparing this analysis, property data was obtained from the BBR register. This register only contains data about the size of the individual cadastral number and not the square meter size of the residential area. For this reason, the percentage development has been analysed to be able to compare the two different ways of calculating the square meter price.

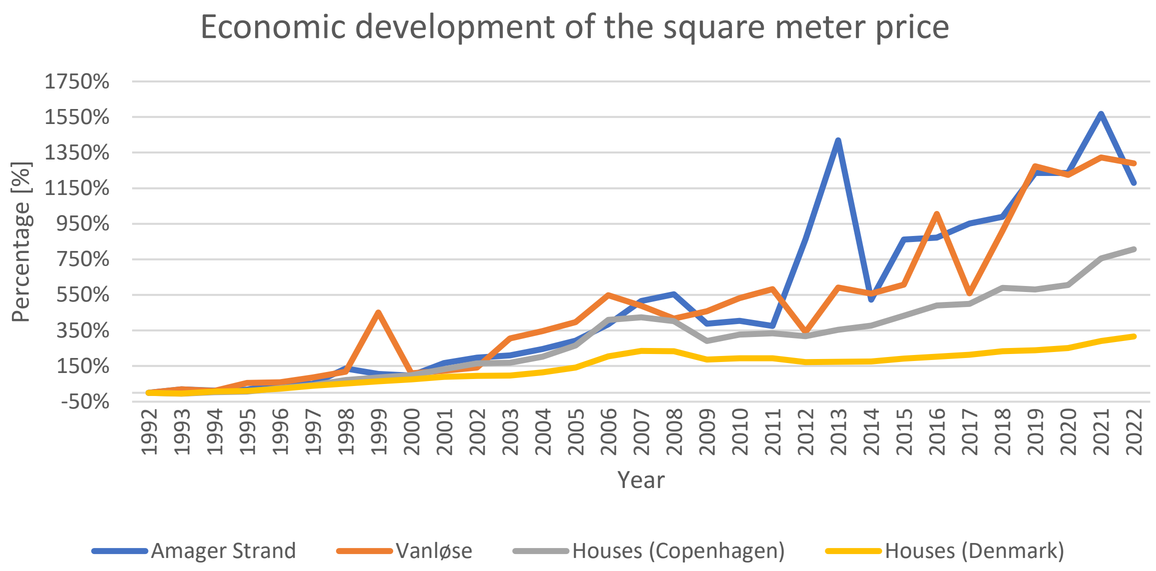


Figure 24: Comparison of the percentage development of the square meter price from 1992 to 2022. Source (Boliga, 2023) and (Skat, 2023).

Vanløse metro station opened in 2003 and Amager Strand in 2007. In figure 24, it is illustrated that there is a tendency for house prices in the two residential areas to grow more than the general house price level in Copenhagen during the periods when the two metro stations opened.

19.3 Partial Conclusion

Based on the given data it is difficult to say with certainty that the metro station has a direct impact on the property prices in the area around them in the period when they were put into use. The analysis of Vanløse and Amager strand stations showed a better growth in villa housing property value over time for houses in a radius of 500 m, than the average price of a villa house in Copenhagen. It can be seen that residential areas within 500 m from the two metro stations have increased by around 1200 % and the general price increase for houses in Copenhagen is 800 %. However, the small sample of only two stations where an analysis could be made with the limited amount of data doesn't eliminate any external potential factors which otherwise affect Vanløse and Amager Strand specifically. While it can be concluded that the house prices in the two residential areas based on this analysis have increased by 50 % more than the general housing market in Copenhagen, there is no proof that a trend that says that the metro has an impact on house prices if they are within 500 m from a station, nor whether the 50 % rise is unanimous along any station on the metro lines.

In summary of the analysis and conclusion on the hypothesis presented at the start of the analysis the following partial conclusion is made.

Planning a metro station can probably increase the property value for housing close to the stations more than residential areas that are not. But it cannot be said for sure, due to lack of data from multiple cases.

20 Complaints about the Metro

The following analysis are based on the hypothesis:

Placing stations near residents would ultimately solely provide benefits for neighbouring residents.

20.1 Case Delimitation

The analysis of the complaints will be based on the legal authority to access documents that were given from Metroselskabet I/S, cf. FL § 9. However as mentioned earlier, documents/complaints older than 4 years are deleted by Metroselskabet I/S because of the introduction of the GDPR act, which limited the company in what it was allowed to archive. The analysis therefore only contains information regarding complaints from residents about the metro lines in the last four years, all of which are situated along the M3 Cityringen line. The analysis will examine the general locations of complaints and whether or not certain places experience an accumulation of complaints, and in that case, which type of complaints. Furthermore, the analysis will contain a comparison of the state of noise before the Metro Cityringen was operating to examine if there is any tendency in the level of noise from traffic and the number of complaints in areas with high and low levels of noise.

20.2 Results

Metroselskabet I/S received a total of 3045 complaints from the period 29/09-2019 to 25/04-2023, in regard to the M3 Cityringen after its completion. The complaints are categorised into 7 different groups: Dust, Traffic, Vibrations, Noise, and Other. However, of those 3045 complaints, around 1200 are marked as “/NC.X”, which refers to interactions with a citizen about an already submitted and ongoing compliant. These complaints are thus cut from the analysis, leaving 1860 complaints.

Classification	Count
Dust	1
Lighting	5
Traffic	5
Vibrations	4
Noise	1807
Other	38
Total	**1860**

Table 8: List of complains and the classification regarding Cityringen from the period 29-09-2019 to 25-04-2023.

As seen by a significant amount of the complaints (97 %) are concerning the noise from Cityringen, with only a handful of complaints about the rest. Complaints about dust is the least frequent complaint, with only one complaint, followed by vibrations, which only consist of 4 complaints. Traffic and lightning both have 5 complaints, and complaints about other issues have 38 as seen in table 8. As mentioned in the chapter "Inclusion of residents in the pre-processing of mega projects", Copenhagen and Frederiksberg Municipality held a series of public hearings regarding Cityringen, in which the citizens could express their objections and comments, all of which were collected in the so-called "Hvidbog". During this public hearing the vibration issues concerning Cityringen when in operation only played a minor role, with only two specific cases being discussed including Frederiks Church and the citizens near Platanvej on Frederiksberg, and the noise issues were not even mentioned. On the basis of the VVM statement and the complaints and objections in the Hvidbog, it is fair to say that Metroselskabet I/S reflected on the operating phase from M1 and M2, which had no significant number of complaints regarding noise and vibration and therefore concluded that there would be no noise and vibration issues in the operating phase of M3. Furthermore, the citizens chose to trust the authority and their calculations on the construction of M3, and thus they had little or no comments on issues such as noise and vibration when the metro is operating. In addition, Metroselskabet I/S announced that "*no one would be disturbed or affected by noise from the metro*", which was said after complaints during the construction phase, and promised in regard to the operating phase. Therefore, Metroselskabet I/S indicated that there was no reason to worry when the metro entered the operating phase (Kjeldsen, et al., 2020).

Rail traffic will to a certain point make vibrations in the material the rails are made of. Since the rails are not without unevenness and the wheels are not perfectly round, the weight of the train will cause the rails to move and make vibrations. The vibrations are transmitted from the rails through the surrounding subsoil into the buildings that are placed on top of the tunnel tubes/pipes. By strong vibrations, it will create noise and be felt in the body of a human. However, less powerful vibrations will also create noise from the building construction, the walls, floors, and ceiling that can be perceived by human ears, which is the reason why the noise complaints greatly exceed the vibration complaints by far. However, the level of noise measured depends on several factors including the construction of the building, the nature of the subsoil, distance to the tunnel pipes, building materials etc. (Skov & Backalarz, 2020, p. 58).

To assess the vibrations and noises when the metro is operating, some limit values have been determined, which must be followed. As mentioned above, vibrations are caused when trains and rails are in contract, and the vibrations are converted into structural sound/low-frequency noise, that one can experience as noise in their homes. The indicative limit value for low-frequency noise or structural noise, is 25 dB during the day and 20 dB at night. In addition, the indicative limit value for “peaks”, which are defined as “short peaks of noise above the base noise”, is 40 dB at night, and there is no limit value during the daytime for “peaks”” (Metroselskabet I/S, 2021).

Furthermore, WHO has published “Night Noise Guideline for Europe”, which proposes a limit value for noise at night of 55 dB, however, approximately 1/3 of the residents in Copenhagen are exposed to noise during the night from road traffic that exceeds 55 dB (Københavns Kommune & Frederiksberg Kommune, 2008, p. 15).

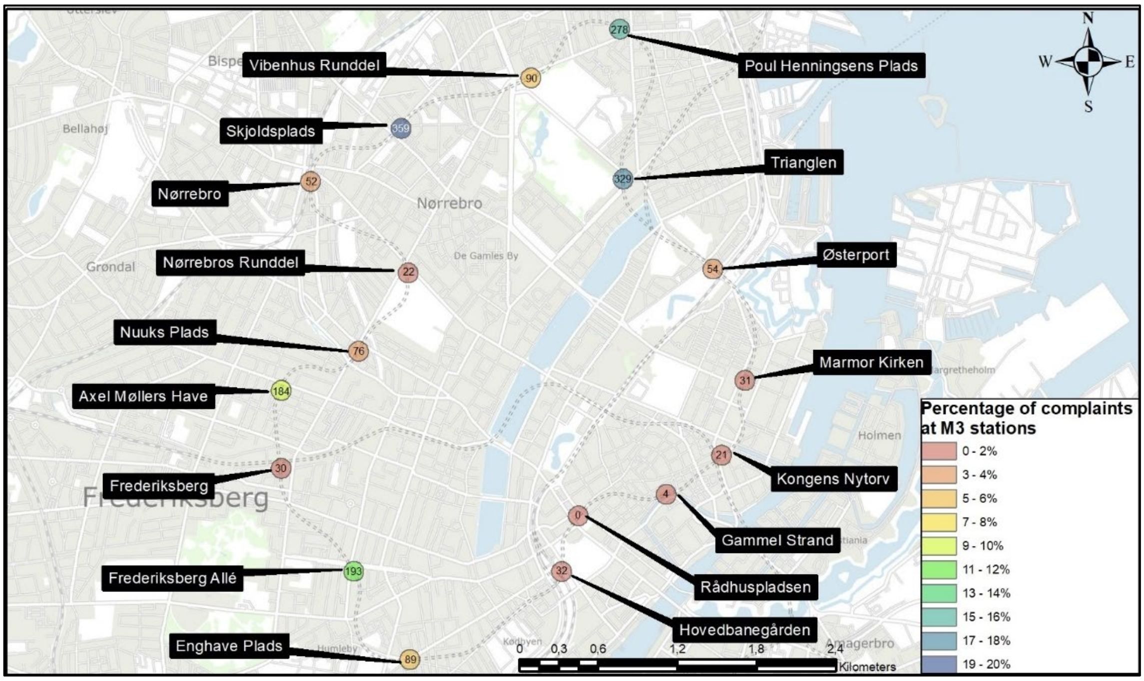


Figure 25: Illustrates the complaints at every metro station at the M3 line in Copenhagen, which were submitted after the M3 line started operating. Self-produced. Data in excel from Metroselskabet I/S.

As visualised in figure 25, the number of complaints varies at the M3 stations, where the span of complaints is from 0-359 at the certain stations. Skjoldsplads, Trianglen and Poul Henningsens Plads have a significant number of complaints when the metro is operating, which amounts to about half of the total amount of complaints. Furthermore, it is interesting that the number of complaints varies from each station, which means that in some areas it is possible to have the metro operating without disturbing the surroundings.

It is illustrated by figure 25, that the complaints follow the route of the metro which indicates that the citizens closest to the metro, even though most of the metro moves underground, are exposed to disturbances. Comparing objections from the Hvidbog concerning the operating phase and the actual operation of the metro shows that the only concerns in the past were bicycle parking, pedestrian tunnels, and vibrations that ruin a night's sleep. The combined objections collected in the Hvidbog of the operating phase were 37, which shows how unpredictable elements like noise, vibrations, traffic etc. are when dealing with mega projects.

Most complaints are clustered in areas near the metro stations, Trianglen, Skjoldplads, Poul Henningsens Plads, Frederiksberg and Frederiksberg Allé. Furthermore, the category of complaints most frequent is noise from the trains and vibrations that sound like noise when they enter the surface. In addition, most of the complaints are located where the residential areas are placed on top of the metro tracks, which is augmented when the vibrations enter the house closest to where the vibrations originate (Skov & Backalarz, 2020, p. 55).

Figure 26: Illustration of complaints compared to areas containing different amount of road noise measured in decibel. Self-produced with data retrieved from (Miljøstyrelsen, 2023).

When analysing the frequency of complaints in specific areas, it is examined how comprehensive the general noise was before the construction of the M3. By entering the noise data collected from the roads in Copenhagen, it is possible to investigate which areas that were exposed to higher levels of noise, and which areas had little or no noise before the construction of the M3.

It is illustrated in figure 26, that the largest and most trafficked roads produce the most noise. Furthermore, residential areas surrounded by buildings and nature limit the noise to reach far, which makes these areas preferable to live in or to enjoy nature. On the other hand, bare areas without trees and buildings, for example Søerne in central Copenhagen, allows the noise to reach further and a broader area, which explains the areas on the map above are covered in noise without being a road.

As mentioned above, Trianglen has 329 complaints where 97 % of these are noise, and the complaints are gathered in clusters in residential areas near the metro station in areas where there was no significant noise in 2018, before the metro was constructed. Furthermore, the areas around the metro stations, Skjoldsplads and Poul Henningsens Plads, have submitted a total of 637 complaints about noise, and it is illustrated in figure 26, that the complaints are submitted in areas where the level of noise was low in 2018. The same pattern can be seen at Frederiksberg and Frederiksberg Allé station with a total of 377 complaints in areas with faint noise, see figure 25.

Similarly, Rådhuspladsen, Gammel Strand and Kongens Nytorv have received a total of 25 complaints. In 2018, these areas were already exposed to high amounts of noise due to H.C Andersens Boulevard, the canal that meanders by Gammel Strand and the road and traffic constantly surrounding Kongens Nytorv. In summarisation, it can be inferred that there is a tendency that areas already exposed to noise before the metro started operating in 2019, seem less affected by M3 and the noise and vibration that follows. It can also be seen that areas with no or little noise are more likely to notice the change in noise brought about by the M3 line. Furthermore, the tendency shows that most of the complaints are located just above the tracks of the Metro line on the surface, which is where the vibrations and noise have the highest impact.

The legislation of complaints related to the construction of a metro in Denmark is examined to determine the reason for the different frequency of the complaints at the metro stations. It is stated in the expropriation procedure act § 21, that there is a 1-year deadline for submitting complaints or cases to the commission after the construction has been put into operation or declared completed. In comparison to the operating phase of M1/M2, there were only a limited number of complaints in general, and therefore the issues of noise and vibrations were not dealt with then. The legislation and the process of complaining were the same in both construction periods, which assumes that there was no change in the way of submitting the complaints or the transparency in the process of complaining when the M3 was constructed. Due to the interview with the surveyor, Karsten L. Willeberg-Nielsen, the difference in noise and vibrations comparing M1/M2 to M3 is the choice of making a metro ring system, that necessitates a specific angel of the tracks for the trains to make the turns most efficiently which increase the friction between the rails and the train, that cause an increase in noise and vibrations (Kjeldsen, et al., 2020).

The above-mentioned road noise analysis shows the impact on the number of complaints when living in a quiet neighbourhood versus living in a busy residential area receiving constant noise from traffic. However, there might be a different angle to determine the frequency of the complaints. In the interview with Karsten L. Willeberg-Nielsen, he states:

"*It is solely residential apartments who have been allowed to complain - businesses or office apartments have not been able to complain.*".

Therefore, the complaints received during the operating phase were only submitted by residential apartments and not by companies or commercial residence that is registered e.g. ground floor and first floor. Areas such as Rådhuspladsen, Gammel Strand and Kongens Nytorv are all in the centre of Copenhagen and are hugely represented by companies and commercial residences. In figure 25 it appears that 1 % of the total amount of complaints are submitted from Rådhuspladsen, Gammel Strand and Kongens Nytorv, and the complaints submitted at Trianglen and Skjoldplads are all placed in clusters in residential areas. Thus, the frequency of the complaints at certain stations can also be explained by the type of complainant.

20.3 Partial Conclusion

In conclusion, the analysis above and the related hypothesis shows that the construction of a mega project, like the M3 Cityringen, can risk entailing some sort of ignorance that ultimately negatively affects its closest surroundings. As mentioned in section 8 "Inclusion of residents in the pre-processing of mega projects", the mega-project paradox states that mega projects in general are not well received by the public and often, in some way, are controversial. In regard to the M3 Cityringen, Metroselskabet I/S announced that "*no one would be disturbed or* *affected by noise from the metro*", however, as shown in the analysis, Metroselskabet I/S received above 1800 complaints from noise. According to Bent Flyvbjerg, the reason for the poor decisions throughout the process of planning a mega project, is a tendency to underestimate the costs, the environmental impact, and in general consequences of actions. However, it is fair to argue that they underestimated the extent of vibrations and noise following the operating phase of the M3 line.

The conclusion of the road noise shows that most of the residents in Copenhagen are exposed to traffic noise during the day and at night. The examination of the noise levels before the M3 was operating, shows that areas close to metro stations, that are used to noise from large roads with traffic, have a significantly low number of complaints, e.g., Rådhuspladsen and Kongens Nytorv. Compared to areas surrounding the metro which are not used to road noise have a significantly higher number of complaints, e.g. Trianglen, Skjoldsplads and Frederiksberg Allé. Furthermore, it is only residential areas that had the opportunity to submit a complaint, while companies and commercial residences were not able to submit complaints. In other words, a tendency in the complaints can also be seen where clusters of complaints are submitted in residential areas like Trianglen, and nearly no complaints are submitted in areas consisting of companies and commercial residences like Rådhuspladsen and Kongens Nytorv.

Therefore, it can be concluded that the construction and mostly the operating phase of M3, as a mega project, affects citizens, both the users in general and more important the neighbours to the metro. The noise and vibrations are a constant disturbance that enters the residential areas during the day and at night. These disturbances are negative effects, and the processing of the complaints shows that Metroselskabet I/S, Copenhagen, and Frederiksberg Municipality have assessed the complaints to be below the tolerance limit expected for noise in the city. However, Metroselskabet I/S are open to reducing the noise as much as possible, which is seen by grinding and greasing the rails more often to reduce vibrations.

In summary of the analysis and conclusion on the hypothesis presented at the start of the analysis the following partial conclusion is made.

Placing stations near residents do not solely benefit the surrounding areas, but also entail inconveniences for the neighbouring residents when the metro is operating.

21 Potential Time Saved

The following analysis are based on the hypothesis:

The main objective of constructing a new metro line is to improve the mobility of the transport network.

21.1 Case Delimitation

To see how the metro gives a more sustainable and equal city, a network analysis is made in GIS. This analysis will investigate how the new metro line will help specific areas in Copenhagen to be connected with the rest of Copenhagen, as the given dataset only contains modern day public transport routes, which can be assumed to remain largely unchanged when the new metro line is introduced. This means that any areas that will be pointed out should be near areas where a future planned metro stop on the M5 will be located. Areas at Refshaleøen and Lynetteholmen will be interesting to make a network analysis at, because Lynetteholm does not exist yet, and Refshaleøen has a big potential to increase the population if it will be developed. However, a network analysis to see a change in travel time would only work for areas that are already accessible, eliminating Lynetteholmen. Another way to see if any major changes happen would be to examine already heavily travelled areas by the future M5 line, using already existing stations that will be connected by M5 could be useful in determining so. Other future stations which are not already served by a metro line are also heavily used through bus traffic. Investigating the improvements of a metro line over bus lines could also be interesting. Thus, the most suitable locations for case studies of an analysis of potential time saved are:

- Refshaleøen bus stop (nearest bus stop to the future Refshaleøen metro station)
- Smyrnavej bus stop (nearest bus stop to the future Amagerbrogade metro station)
- Lergravsparken metro station

21.2 Results

The following section introduce the analysis of the effects of the M5 line and Cityringen based on the potential time saved.

21.2.1 The Effects of the M5 Line

As mentioned above, the GIS analysis of potential time saved is made for the following future stations at Amagerbrogade, DR Byen and Refshaleøen. The GIS analysis shows a comparison of today's reachable distances within 15 minutes and reachable distances within 15 minutes after the implementation of M5. Furthermore, the analysis shows time saved in reachable areas today with an estimate of the travel time that will be saved when the M5 is operating.

The GIS analysis, shown by figure 27, illustrates starting a trip at the future Amagerbrogade metro station. Comparing today with when the M5 is in operation shows that it will be possible to reach areas such as Refshaleøen and Lynetteholmen as well as the M3 metro stations at Østerbro and Frederiksberg in 15 minutes. The implementation of the M5 shows no significant change in reachable areas within 15 minutes in the south of Amager, as seen in figure 27, which presumably can be seen as the consequence of the M5 line that stops no further south than Amagerbrogade, which is the starting point of the analysis.

On the other hand, there are a lot of positives to take from the new stop at Amagerbrogade, which allows the traveller to reach areas of West Amager by a faster shift to the M1 line via DR Byen station, as seen in figure 27, which makes it about 7 minutes faster to reach the station at the M1 line. Most east-west travel between Amager is handled by bus line 18; a route which the switch to the use of M5 will improve the travel time. Furthermore, the GIS analysis shows that from the starting point at Amagerbrogade station, it becomes faster to reach M2 to smaller areas of eastern Amager, which includes a high number of residents by Amager Strand station and Lergravsparken station, the future transportation hub.

Ultimately it is also seen in figure 27 that key areas in the centre of Copenhagen become faster to reach when the M5 is operating, namely Copenhagen Central Station and any area close to stations operated by the M3 Cityringen line. It can be concluded that the areas that are optimised with M5 are areas around already existing metro stations M1, M2 and M3. However, it can also be seen that some areas see no effect from the implementation of M5, which does not affect the transportation time more effectively than the opportunities existing. The main reason is that the transportation opportunities within Copenhagen's centre are already well-developed and supported by the combination of M1/2 and M3 Cityringen and public buses such as 5C that drive directly to the central station (DOT, 2023).

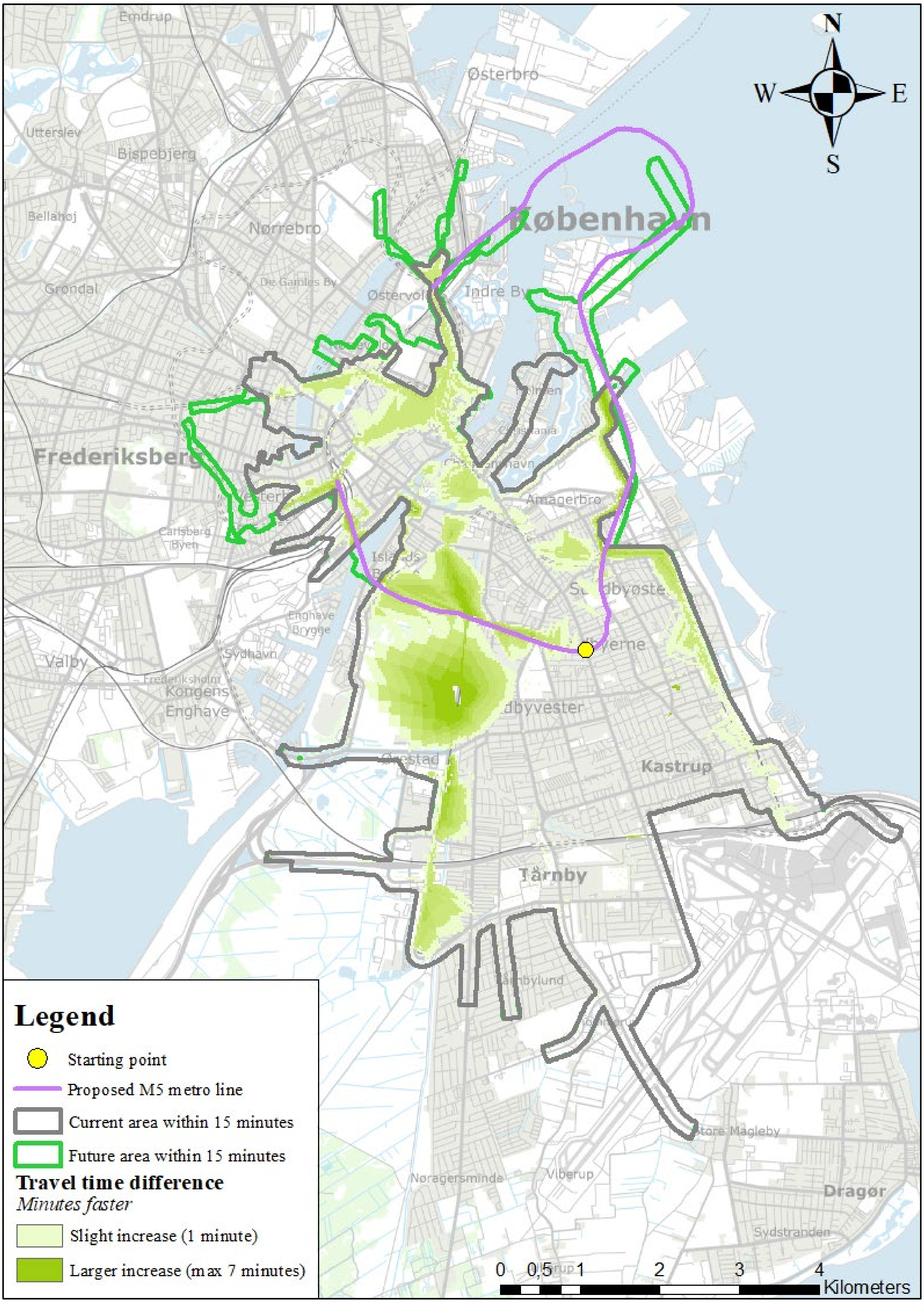


Figure 27: The reachable areas today and when the M5 is operating with the starting point at Amagerbrogade station as well as the calculated improvement in travel time when adding the M5 line. Self-produced. Data retrieved from traffic data by Movia and DOT.

The GIS analysis of the future M5 station at DR Byen as well can be seen in figure 28. The pattern of improvement in the eastern and western sides of Amager is repeated when the starting point is DR Byen. Furthermore, the implementation of M5 means that it will be possible to reach further areas within 15 minutes than today. The change in the starting point from Amagerbrogade to DR Byen makes it possible to reach areas of Valby, Frederiksberg and Sydhavnen which allows the traveller at DR Byen station to get to Aalborg University within 15 minutes. Additionally, it will be possible for the traveller to reach Copenhagen airport and a broader area of Tårnby within 15 minutes.

The GIS model starting at DR Byen station shows that the M5 allows the traveller to reach Copenhagen Central Station easier and within a shorter period than today. Therefore, it becomes up to 7 minutes faster to reach areas at Vesterbro, Frederiksberg and Valby because of the S-train lines and other regional trains. It is illustrated that the southeast of Amager will be significantly faster to reach. Therefore, it stands out that time improvements from 1 to 7 minutes can be reached in areas where well-developed shifting opportunities allow travelling more efficient and streamlined. In conclusion, the improved time to reach Copenhagen Central Station are the reason for the improvement of reachable distance in the West, and the opportunity to reach Lergravsparken is the reason in the southeast.

At last, the model in figure 28 the network suggests that it is faster to switch from M1 to M3 via Kongens Nytorv and from there switch to M5 at Østerport if you want to go out to the northern end of Lynetteholmen. It can be argued that this is one of the weaknesses of the model as it doesn't make up for the time spent on shifting between stations with the same stop-ID, as mentioned in the methodology of the model in section 13.2 "Analysing the saved time with current and future metro lines - Network analysis", which in practice also would require time. This leads to single cases like in figure 28, where the model can suggest that a shorter distance with more interchanges between the same type of transportation is faster than a longer distance with fewer shifts.

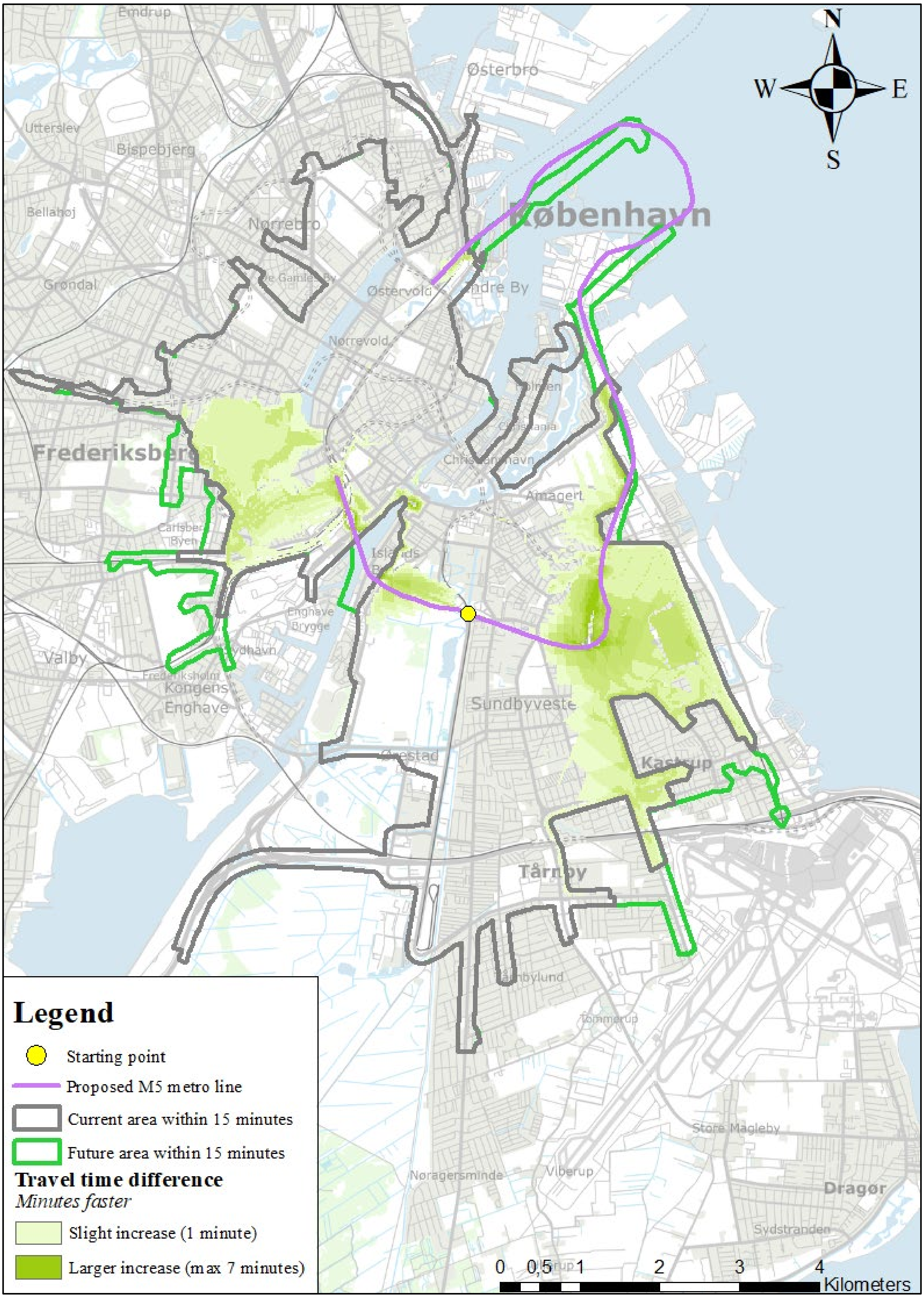


Figure 28: The reachable areas today and when the M5 is operating with the starting point at DR Byen, as well as the influence of improvement in time when adding the M5 line. Self-produced. Data retrieved from traffic data by Movia and DOT.

The last model that shows the effects of the M5 line has its starting point at Refshaleøen, as illustrated in figure 29. In general, Refshaleøen is known for its current weak connection with the rest of Copenhagen, as the area has only become a residential area and an attraction in recent years. The lack of connections makes it difficult for citizens in Copenhagen to reach the northeast of Amager today. The main way to reach Refshaleøen with the existing public transport is by bus 2A or the Copenhagen Yellow Harbor Bus which has 9 stops and is one of the slowest transportation modes on average with the capacity of transporting 80 people per boat (VisitCopenhagen, 2023).

As seen in the model, transportation from Refshaleøen is very limited and the implementation of the M5 has a huge impact on areas that today are reachable within 15 minutes compared to the model of Amagerbro S and DR Byen above. The model shows that the areas along the future M5 line become far more reachable, which include Østerbro, the city centre and the future Lynetteholmen can be reached within 15 minutes. The M5 line streamlines the infrastructural transportation from Refshaleøen to Copenhagen Airport, because the introduction of M5 makes it faster to reach the M2 line that enters the south of Amager via Lergravsparken station. After the introduction of the M5, it will be possible when travelling from Refshaleøen, to reach far more of Amager, especially along Amagerbrogade station where the M5 connects to the main bus lines, 5C and 250S, and by DR Byen station where a connection to the M1 line can be made (DOT, 2023).

The time spent reaching areas within 15 minutes today also become much faster. Figure 29 illustrates that most of Christianshavn and the northern end of Amagerbrogade become 1-5 minutes faster than today. Especially the areas closer to where the M5 stations overlap the M1 and M2 stations will have the improved time, e.g., Amagerbro station.

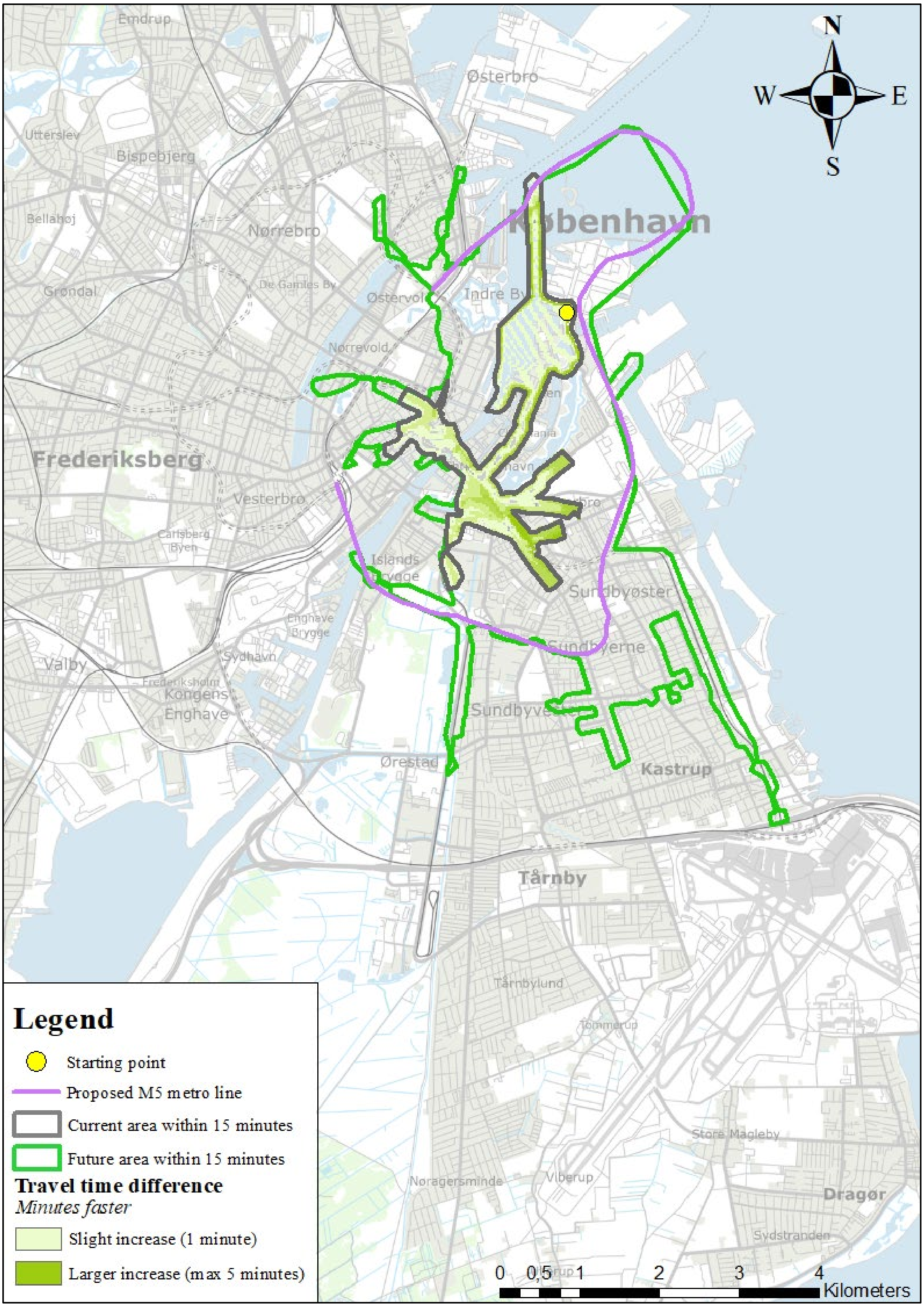


Figure 29: The reachable areas today and when the M5 is operating with the starting point at Refshaleøen, as well as the influence of improvement in time when adding the M5 line. Self-produced. Data retrieved from traffic data by Movia and DOT.

21.2.2 The Effects of Cityringen

As the only difference between today's network and the future network in the model above is the introduction of the M5 line, the results would naturally paint an overall improvement in the network. This is however an unrealistic viewpoint, as the introduction of a larger network such as a metro line has historically always entailed a restructuring of the entire network. For instance, the M3 metro line opened along with the restructuring of 39 bus lines (DOT, 2023). It is therefore interesting to examine whether the M3 line contributes to a faster infrastructure network or not to substantiate the general conviction that the primary objective of a metro line is to directly increase mobility.

When the travel starts at Frederiksberg metro station, general improvements can be seen in Frederiksberg and Vesterbro, especially along the metro line with an optimized travel time of up to 6 minutes. Furthermore, the M3 line makes it faster to reach most of Frederiksberg, Valby, CPH Central Station, Vesterbro and Nørrebro as well. It is illustrated in figure 30, that the M3 line also negatively impacts some areas. The time reaching areas in the middle of Copenhagen has become slower e.g., around the lakes of Copenhagen and Østerbro. However, it is 1-2 minutes slower to reach the middle of Copenhagen. A plausible reason for this might be that the bus lines in 2019 are calculated on an average speed, as their actual average speed is unknown. Therefore, an uncertainty of a minute leading to most of the negative impact being negligible is not far-fetched. Some of the slower areas close to Østerbro and Kongens Nytorv can also be explained by the restructuring of the routes 350S and 1A, which used to drive passengers directly through the city, but have instead become rerouted to connect suburbs around the city centre with each other (DOT, 2023).

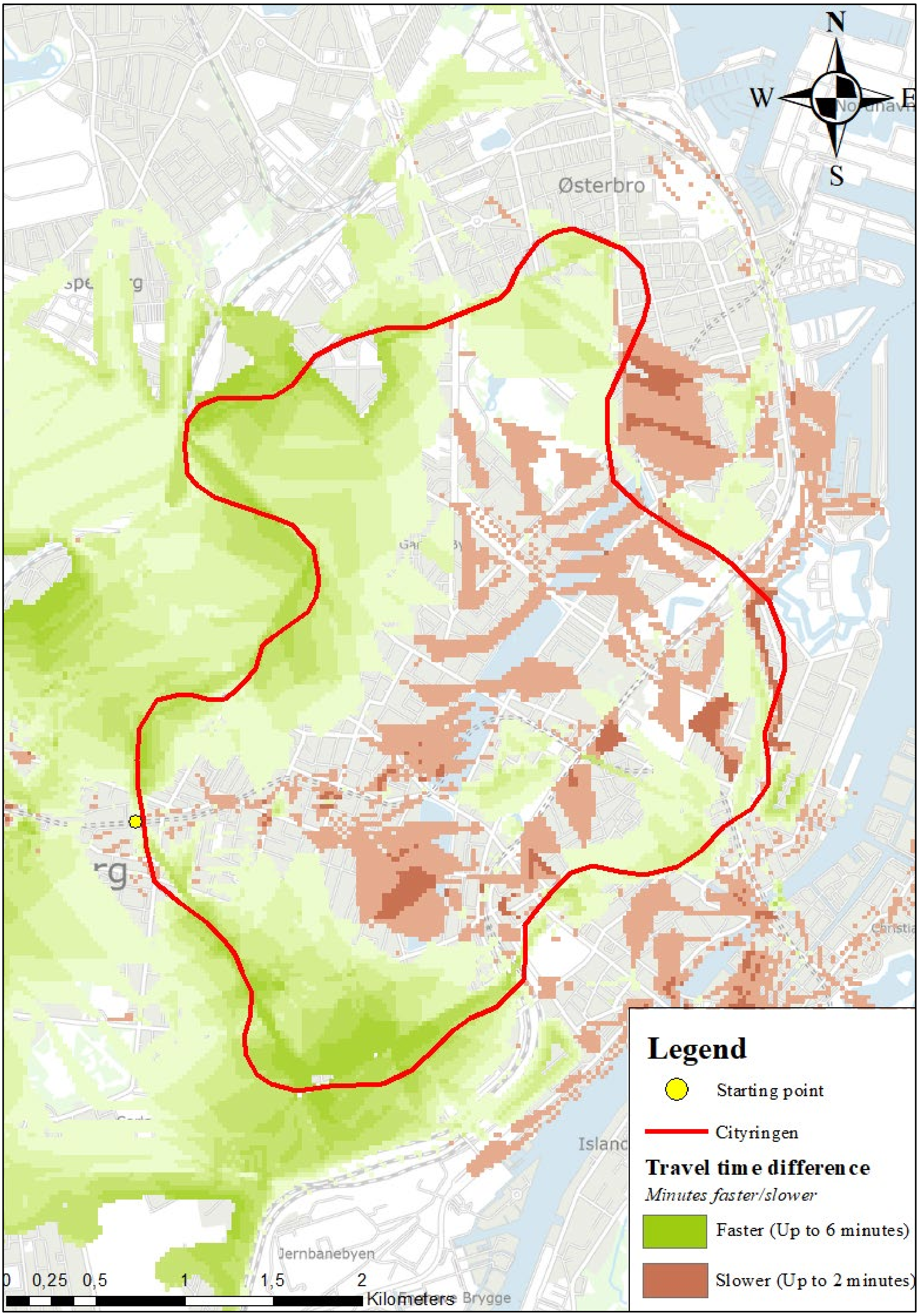


Figure 30: Shows the effects of the M3 Cityringen when one starts a travel from Frederiksberg station. Self-produced. Data retrieved from traffic data by Movia and DOT.

The same model is made for Nørrebros Runddel as illustrated in figure 31. The impact of M3 can be seen in the direction of Nørrebro station which becomes up to 6 minutes faster to reach. This extends the reach along the closest suburbs around Bispebjerg, Ryparken and Svanemøllen station, which coincides with the route of the S-train line F. Furthermore, the introduction of M3 makes it faster to reach Frederiksberg station, which in turn makes it possible to change faster from M3 to M1 or M2, thus making it up to 6 minutes faster to reach some of the stations along M1 and M2 located closest to Frederiksberg station. To sum up, Nørrebros Runddel makes it faster to travel away from the city towards destinations that can be reached by other train and metro lines. However, when travelling towards the centre of Copenhagen, Christianshavn, Kongens Nytorv and Amager, the newer network with the M3 line is considerably slower to reach these destinations. The reason for the slight delay in the travels toward the city centre may partly be explained by the realignment of the 350S bus line that used to drive the passengers from Nørrebro to the city centre and further out to Dragør in southern Amager. This direct line served as a more express version of todays 5C bus line in the centre of town and would directly connect Nørrebros Runddel through the centre of town (DOT, 2023). Removing this line changes the fastest route to taking the M3 Cityring around the city, which according to the model results in a 3-4-minute detour. This finding suggests that improving travel time is not the sole objective of a new metro line.

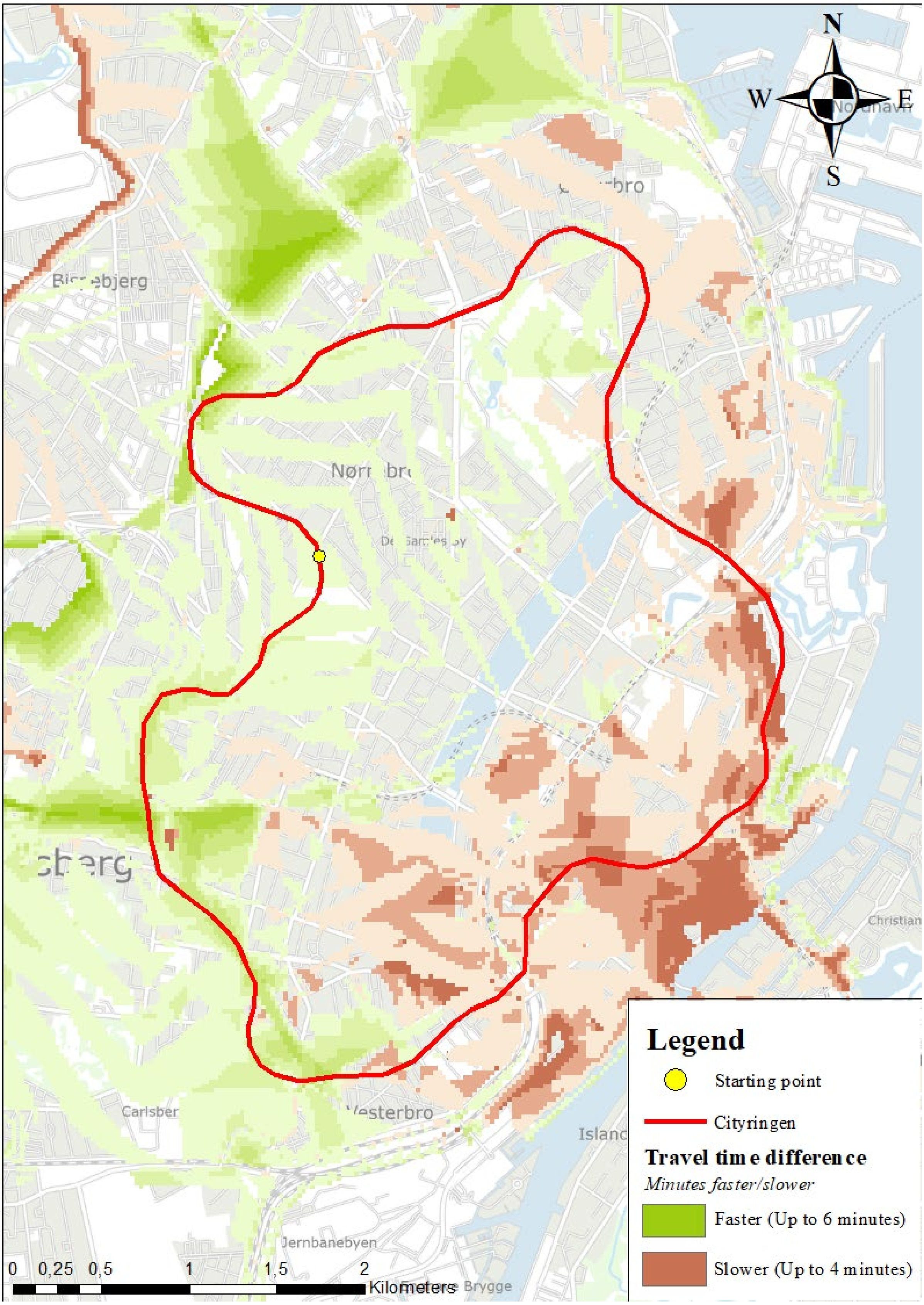


Figure 31: Shows the effects of the M3 Cityringen when one starts a travel from Nørrebros Runddel. Self-produced. Data retrieved from traffic data by Movia and DOT.

21.3 Partial Conclusion

The three models that illustrate the effects of the M5 line, including starting points at Amagerbrogade, DR Byen and Refshaleøen, show that implementing the M5 line will improve the general area of Copenhagen that can be reached within 15 minutes. Common for the three models is that the existing areas that will be overlapped by the M5 line will improve the travel time and the passengers may save up to 7 minutes compared to today. Furthermore, introducing the M5 line will expand the total reachable area within 15 minutes regardless of the starting point.

The model starting at Amagerbrogade station allows the traveller to reach the airport within 15 minutes without the impacts of M5, which is explained by bus 5C that drives directly to the Airport. When starting from either DR Byen or Refshaleøen it is not possible to reach the Airport within 15 minutes before the introduction of the M5 line. Furthermore, M5 connects Refshaleøen to Østerport, improving the free infrastructural flow through Copenhagen and streamlining the infrastructural opportunities for those working, living, and exploring.

In general, the effects of the M3 Cityringen are mainly positive in the way of saving time as a passenger. This can be seen when starting a trip at Frederiksberg or Nørrebros Runddel and the travel time is reduced when the M3 overlap with M1 or M2, also, at Nørrebro station where the passenger can shift from Metro to S-train and thus reach outlying areas of Copenhagen. On the other hand, not all areas could be reached faster, with some routes' travel times being increased by several minutes; some of which could be explained by the limitations of the model, but could also be explained by the rerouting of bus lines, which formerly provided a direct route through the city for select areas. Bus routes that were noticed to be the most impactful in travel time changes were A-line and S-line bus routes, which respectively aim to serve high amounts of passengers and travel quickly through areas with fewer stops. These bus lines are some of the most frequently travelled lines and are prone to congestion.

Therefore, while it can be concluded that the construction of a metro line directly improves travel time and by extension, the mobility in which reachable opportunities are expanded, the construction of metro lines has also resulted in rescheduling of other transportation modes e.g. the bus lines. In some cases, this can make some destinations marginally slower to reach but can improve other factors such as the number of passengers that can be served at the same time or the general congestion on roads. The model does not however give a direct answer to what other objectives were sought as a change of the bus lines. In general, the implementation of a metro contributes to improving mobility but can also be used to improve other factors in combination with other transport planning.

In summary of the analysis and conclusion on the hypothesis presented at the start of the analysis the following partial conclusion is made.

The construction of metro lines can directly improve the mobility of the transport network, but transport planning such as rerouting bus lines can alter the main objectives.

22 Environmental Analysis

The hypothesis of the environmental analysis is as follows.

The construction of the metro lines will have a measurable positive effect on the CO_2 emission in Copenhagen with regard to the mobility of the people.

22.1 Case Delimitation

To determine whether or not the metro has an actual measurable effect on the CO_2, it is necessary to calculate and visualize the evolution of the CO_2 emission in Copenhagen as a whole before the metro was introduced in Copenhagen, preferably as far back in time as the available data allows and compare it with the evolution after the metro have been introduced.

22.2 Results

The following chapters will examine the evolution of the CO_2 emission from a series of modes of transportation.

22.2.1 The CO_2 Emission from Vehicles

As seen by the graph in figure 32, the vehicle-activity had a downfall from 1989 to 1995 of 1,6%. The reasoning for the slight downfall is unknown. From 1995 to 2022, the municipality of Copenhagen had an increase of 16 %.

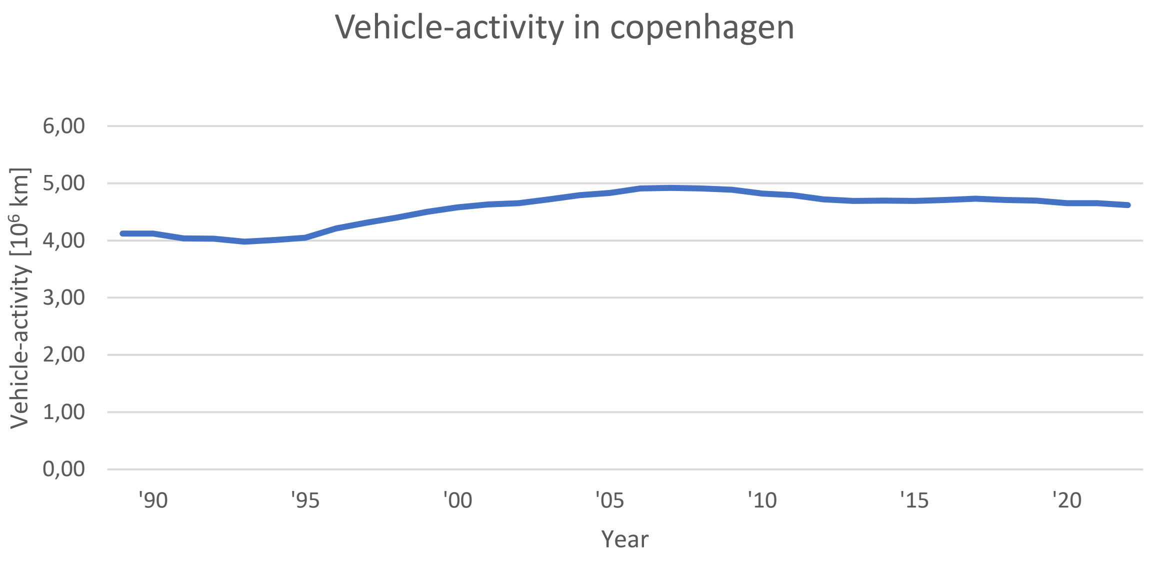


Figure 32: The vehicle-activity in Copenhagen measured in millions of kilometres per day from 1993 to 2022 (Data retrieved from the municipality of Copenhagen.

Furthermore, Copenhagen has experienced a downfall of 32 % regarding vehicles detected in city centre cross sections but an increase of 39 % regarding vehicles travelling in and out of the municipality, which results in an overall increase of every vehicle detected in Copenhagen by only 4 % from 1970 to 2022, as seen by the graph on figure 33. The city centre cross section gives an overview of the traffic within the city centre of Copenhagen, whereas the municipality border gives an overview of how many citizens travel in and out of the municipality on a daily basis. In other words, the total number of vehicles in Copenhagen has not increased by much, rather the traffic has shifted towards the purpose of accessing Copenhagen instead of navigating inside Copenhagen. This also explains the previous graph, which illustrates only a small increase in the total vehicle activity in Copenhagen since 1992.

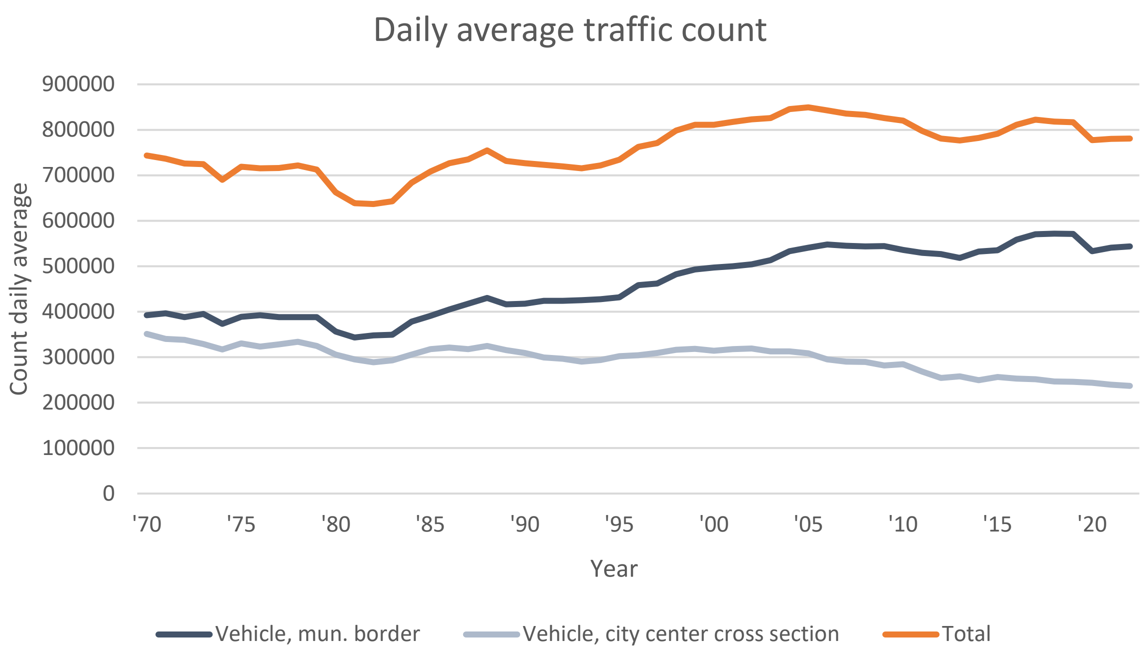


Figure 33: Copenhagen daily average vehicle-traffic per year from 1970 to 2022 (Data retrieved from the municipality of Copenhagen).

In 1993 petrol was the dominant fuel type with 95 %, with electric vehicles only having a percentage of 0,004 % and diesel of 4,7 %. However, in 2022, 20 % of newly registered vehicles are electric (Danmarks Statistik [B], 2022), with the total amount of electric vehicles being 2,8 %, which is an increase of 58868 % in comparison to 1993. On the other hand, the number of petrol vehicles in Denmark has decreased by 30 %, with diesel vehicles experiencing an increase of 71 % since 1993, as seen by the graph on figure 34.

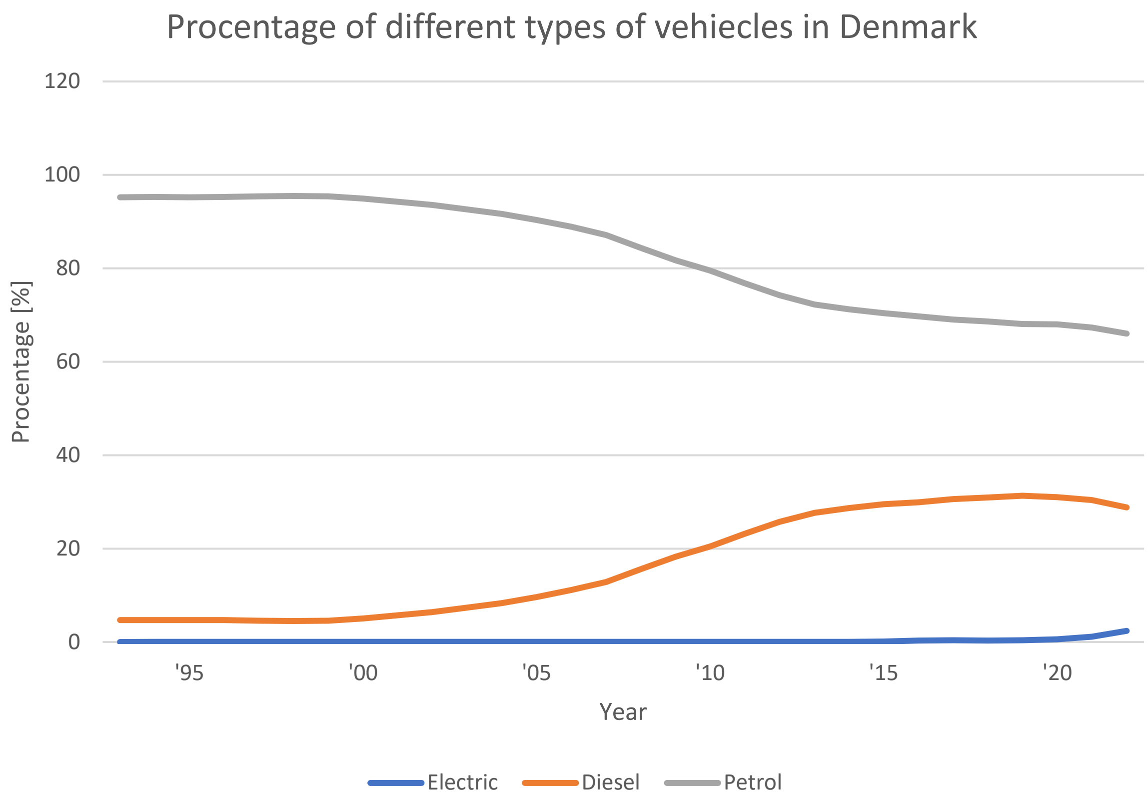


Figure 34: The of percentage of vehicles in Denmark with different propellent type, including electric, diesel and petrol, from 1993 to 2022 (Data retrieved from Statistikbanken).

The CO_2 emission of vehicles per passenger has risen and fallen periodically from 1993 to 2022 but has overall decreased by 13 %, as seen by the graph on figure 35. Given the fact that Copenhagen has experienced an increase in vehicle activity during the same period, the reasoning behind the evolution is the greater numbers of electric vehicles and that the effectivity of both diesel and petrol vehicles regarding the emission rate, has improved throughout the years.

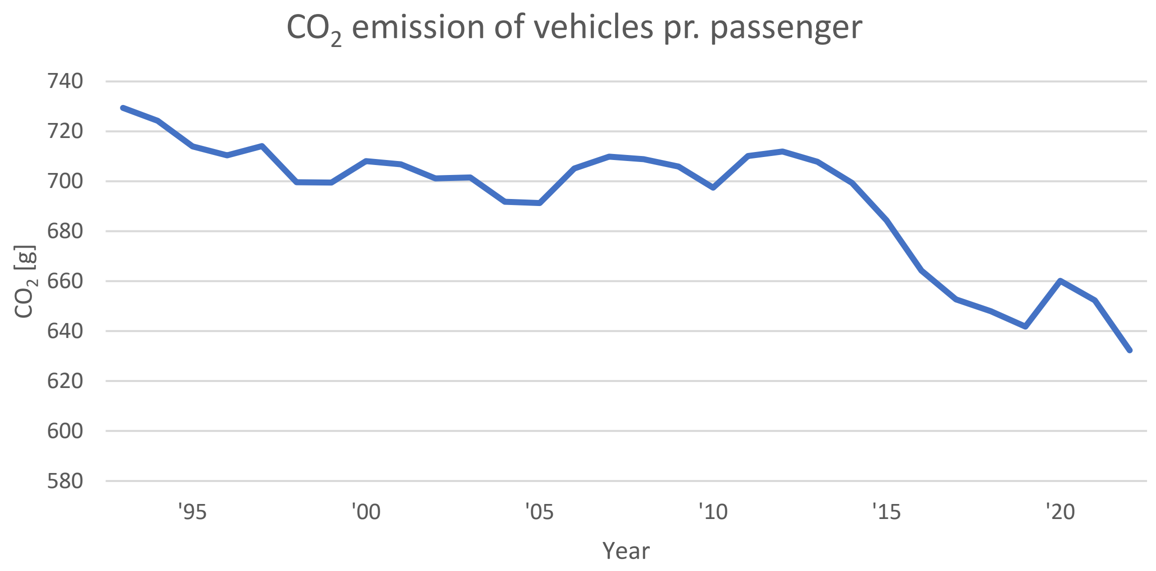


Figure 35: The CO_2 emissions of vehicles per passenger in Copenhagen from 1993 to 2022 (The numbers are calculated in Excel).

22.2.2 The CO_2 Emission from the Metro

The passenger numbers of the metro can be seen in figure 36. As the metro opened in late 2002, the low total number of documented passengers that year is not to be confused with a low daily average. The construction of the current metro lines spanned four stages, which all correspond to a spike in the number of passengers. In 2003 the M1/M2 line was expanded from Nørrebro station to Vanløse station (stage 2), in 2007 M1/M2 was expanded from Lergravsparken station to The Copenhagen Airport (stage 3), and in 2019 Cityringen was constructed (stage 4) (COWI A/S, 2023). From 2019 to 2020 the number of passengers travelling the metro declined by 34 %, which can be explained by the outbreak of COVID-19, resulting in the shutdown of large parts of Denmark, as well as more people preferring private over public transportation.

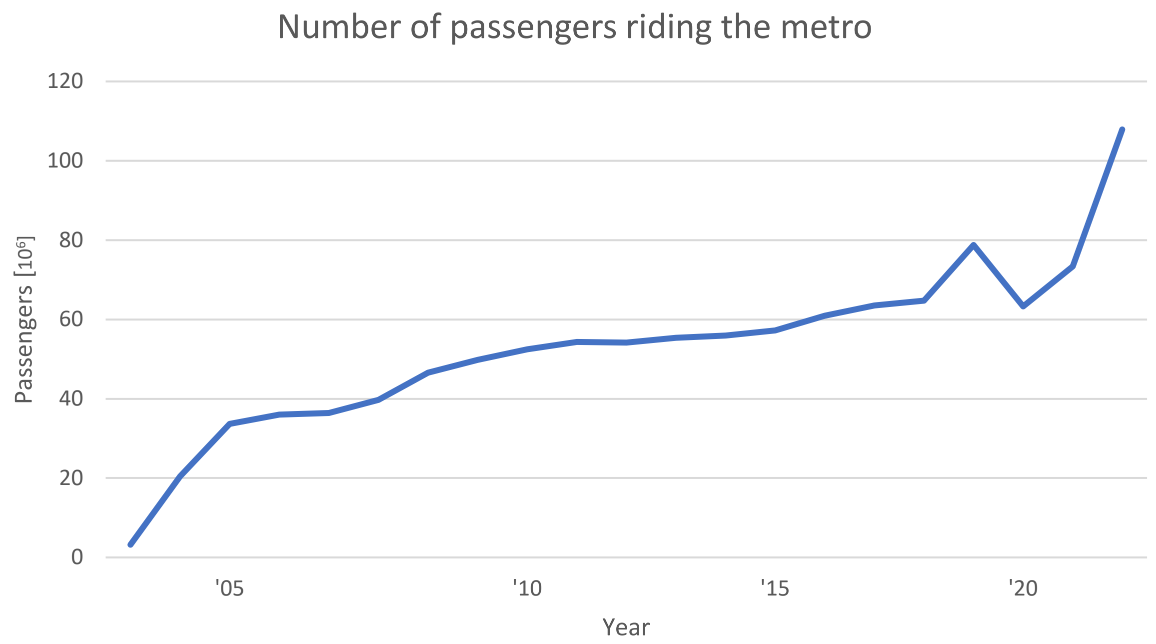


Figure 36: The number of passengers riding the metro in Copenhagen from 2002 to 2022 (The numbers are retrieved from the Metroselskabet I/S).

As seen by the graph in figure 37, the metro has experienced a decrease in the total CO_2 emission by 47 % from 2010 to 2020, which according to Metroselskabet I/S can be explained by them optimising the energy consumption (Metroselskabet I/S, 2022).

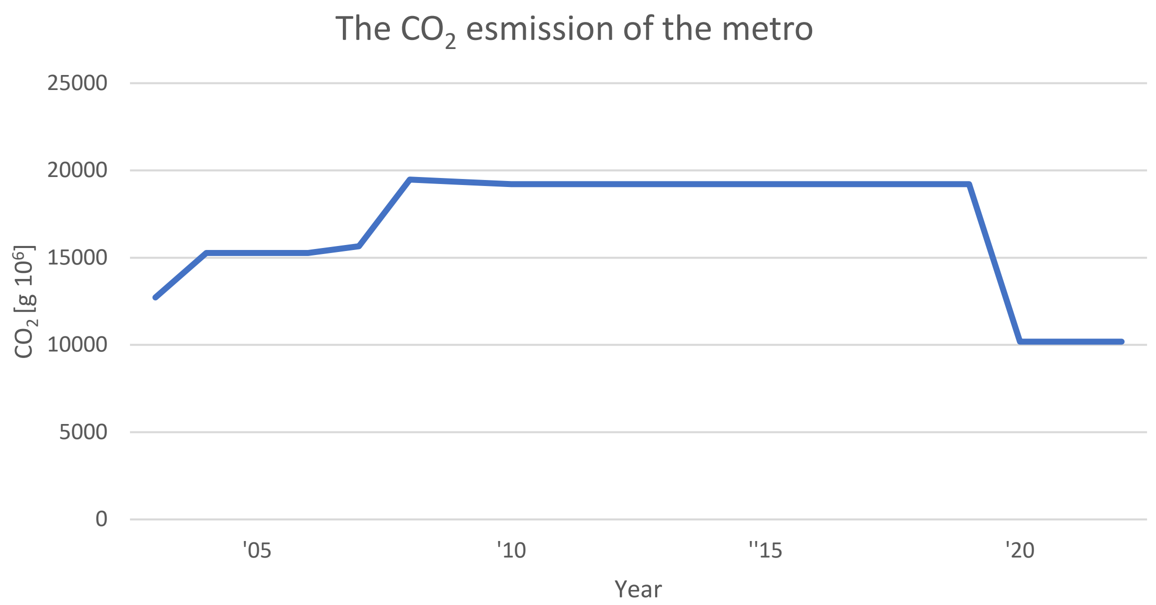


Figure 37: The CO_2 emission from the metro in Copenhagen from 2003 to 2022 (Metroselskabet I/S, 2010, p. 29) (Metroselskabet I/S, 2020, p. 10).

The CO_2 emission of metros per passenger has risen and fallen periodically from 2003 to 2022 but has overall decreased by 84 %, as seen by the graph in figure 38. This can be explained partly by the fact that more people are using the metro each year, resulting in an average higher occupancy rate on every ride and Metroselskabet I/S has been optimising the energy consumption of the metro lines.

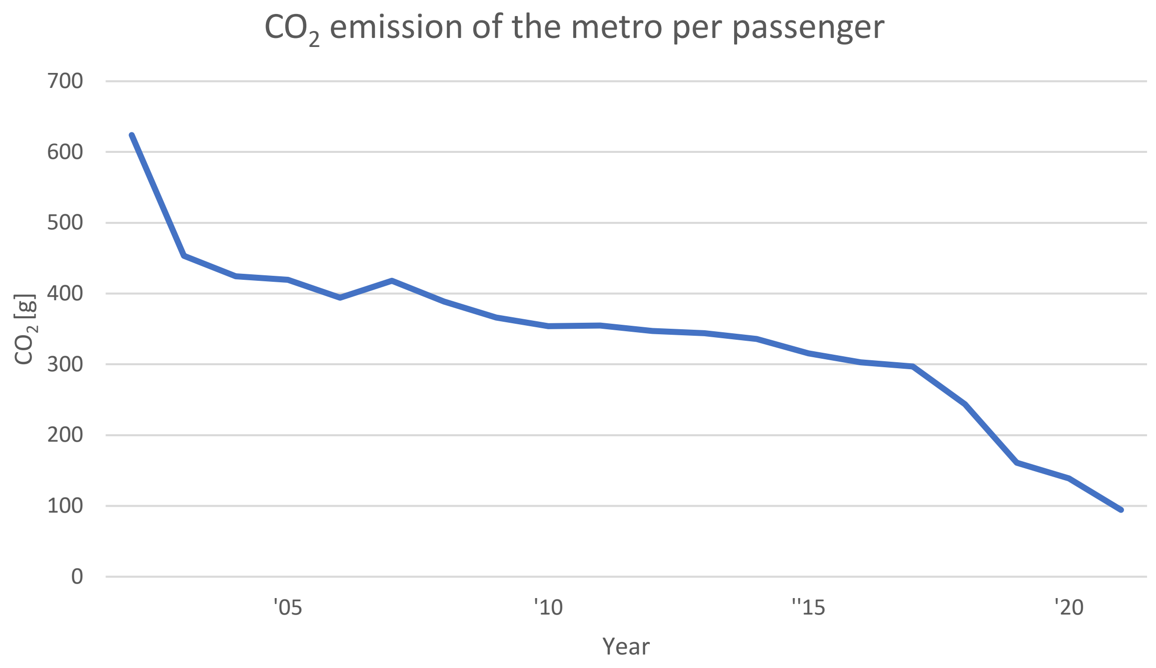


Figure 38: The CO_2 emissions of the Metro per passenger in Copenhagen from 2003 to 2022 (The numbers are calculated in Excel).

22.2.3 The CO_2 Emission from Buses

As seen by the graph in figure 39, the number of passengers riding the bus has slowly been declining every year, with an overall percentage of 50 %. 2002/03 marked the year, in which the Metro was introduced in Copenhagen, which had a visible impact on the number of passengers riding the bus, with a decline of 15 % from 2001 to 2003. The introduction of Cityringen in 2019 coincided with an increase of 20 % in bus passengers, however the numbers declined the following year.

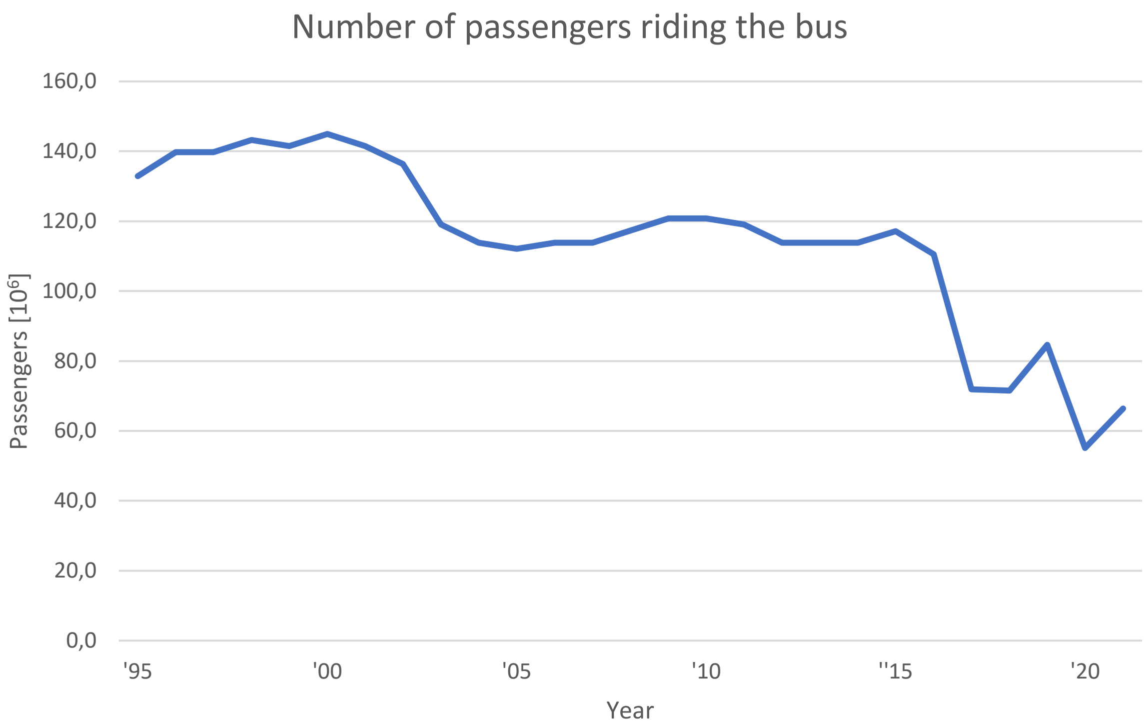


Figure 39: The number of passengers riding the bus in Copenhagen from 1995 to 2021 (Københavns Kommune , 2022, p. 81) (Københavns Kommune , 2015, p. 44).

The CO_2 of the buses in Copenhagen per passenger can be seen in figure 40. As seen by the graph, the numbers have until recent years been relatively constant, with an overall decrease from 1995 to 2016 is only 2 %. After the year 2016, the balance started shifting, with the peak occurring in 2020, the year after Cityringen was introduced. The reasoning behind this inconsistency is a combination of fewer passengers leading to a rise, while more energy-efficient buses lead to a fall.

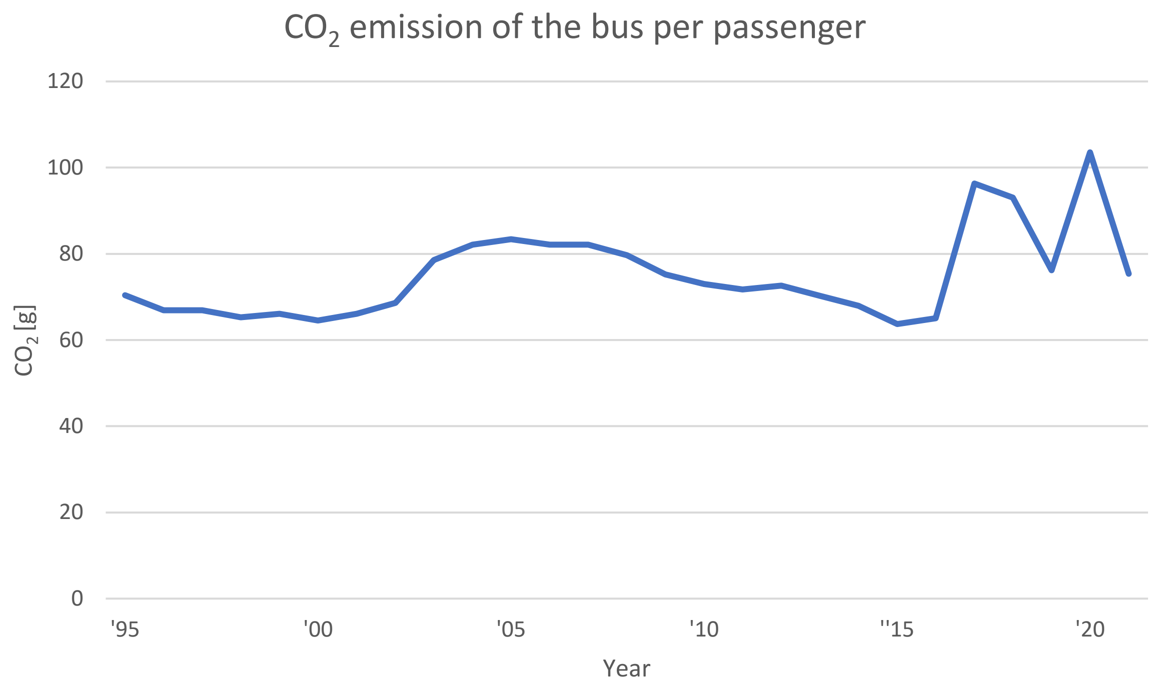


Figure 40: The CO_2 emissions of the bus per passenger in Copenhagen from 1995 to 2021 (The numbers are calculated in Excel).

22.2.4 The CO_2 Emission from Bikes

A bike doesn't emit any CO_2, when in operation, however, the extent to which people use their bikes is still important when calculating the evolution of the CO_2 emission in Copenhagen. As seen by the graph in figure 41, the municipality of Copenhagen has experienced an increase of 21 % regarding bike travelling in and out of the municipality, but an increase of 140 % regarding bikes detected in city centre cross sections, which result in an overall increase of 100% from 1970 to 2022. These numbers confirm the narrative surrounding Copenhagen as a bike city.

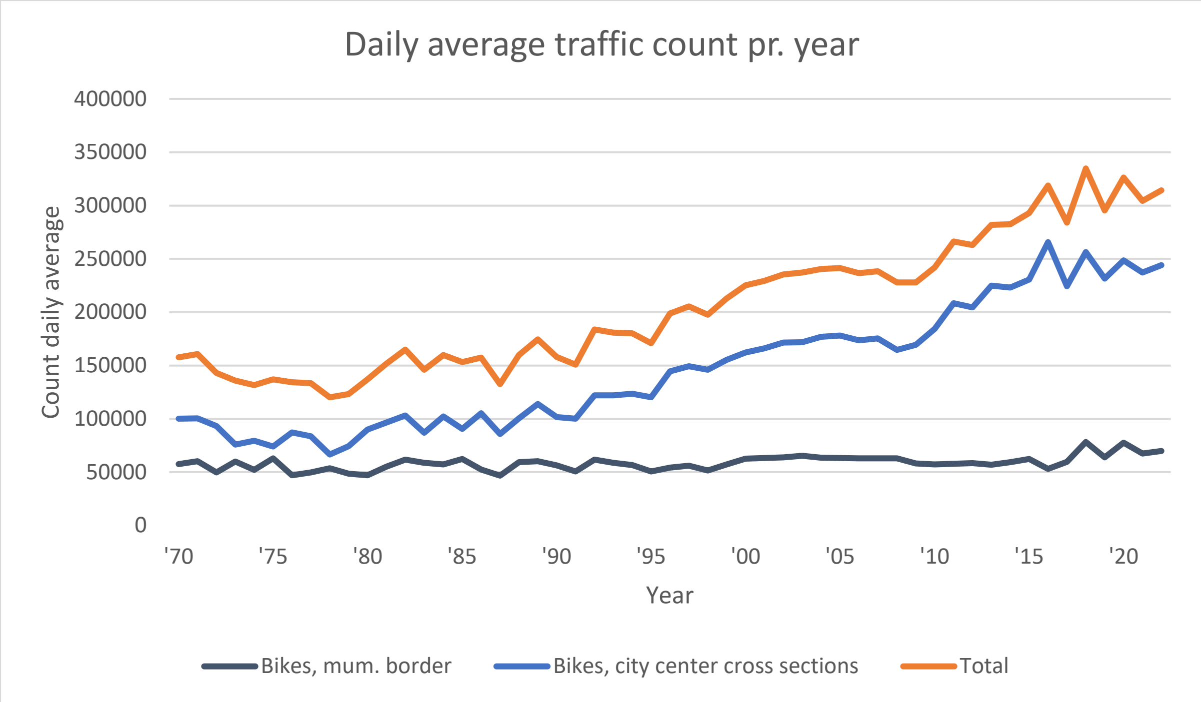


Figure 41: Copenhagen daily average bike-traffic per year from 1970 to 2022 (The numbers are retrieved from the municipality of Copenhagen).

22.2.5 Partial Conclusion - Weighted Average

As a conclusion to the analysis, the evolution of the CO_2 emission per passenger for each mode of transportation will be combined. To do so, a weighted average must be used, as a different number of passengers are using the four modes of transportation each year. It is to be noted, that the weighted average will only be conducted over the period of 1995 to 2021, as this is the period in which data exist for all four of the modes of transportation.

As the mode of transportation of vehicles on average has more passengers each year since 2002 with 355.036.230 passengers, than the rest of the modes of transportation combined with 269.237.142 passengers, it results in vehicles having the most influence on the weighted average. As seen by the graph on figure 42, this is illustrated with the weighted average closely following the evolution of the vehicles by being also proportional to it. Additionally, the mode of transportation of vehicles has a significantly higher emission of CO_2 per passenger, which results in a weighted average which is also higher than that of the three other modes of transportation.

The weighted average increased when the metro was introduced to Copenhagen in late 2002. This is due to the limited number of passengers riding the metro in the first couple of years, which resulted in a very high CO_2 emission per passenger in comparison to the already established mode of transportation in the form of buses. However, the passenger numbers have since been rising, resulting in the CO_2 emission per passenger declining. Anno 2021 the CO_2 emission of the metro per passenger is 25 % higher compared to its counterpart, however, if the trends of recent years are to continue, with the metro increasing in passengers and the bus declining, the metro is set to overtake the bus around 2023 or 2024 as the most environmentally means of transport.

The weighted average has an overall decline of 13 % from 1995 to 2022, however, it only declined 3 % before the metro was introduced in Copenhagen (1995 to 2002), but 10 % after the metro was introduced (2002 to 2022). It cannot be concluded that the metro is solely responsible for this, as both the bus and vehicles have experienced an increase in regarding energy efficiency combined with the fact that bikes have seen an increase in the number of passengers of 75 % in the same period. However, the result shows a correlation that the metro partly must have an impact on the overall CO_2 emission.

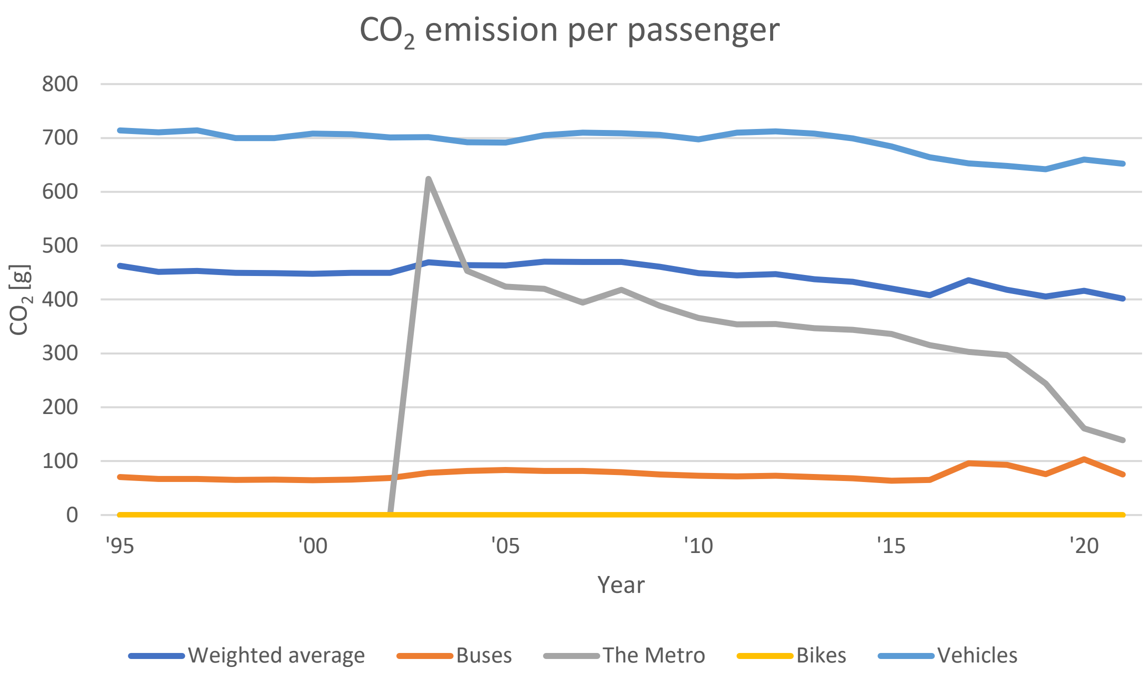


Figure 42: CO_2 emission per passenger in Copenhagen from 2003 to 2022 (The numbers are calculated in Excel).

In summary of the analysis and conclusion on the hypothesis presented at the start of the analysis the following partial conclusion is made.

The construction of the metro does have a positive measurable impact on the environment as of today, regarding CO_2 pr. passenger.

Evaluation

23 Discussion

The various methods used to come to the conclusions of the analyses are subject to discussions on the accuracies of their results and what elements were missing in order to improve them.

The analysis of demography attempted to find changes near metro lines - the best information available was grouped in seemingly arbitrary districts, some of which had a metro line in the centre. These various districts were not made with a focus on metro stations, and any results made from them are therefore not perfectly tailored for drawing indisputable conclusions. Findings did however show there was a pattern in districts that were supplied with metro stations which opens up the question, if some of the findings have happened as an effect of the opportunities made by a metro, or if other causes have developed the area in a direction, that made planning the metro another effect of these causes. However, as mentioned above, there may be other reasons behind the changes. No known theory supports the notion of a younger populace being attracted to public transport more than other population groups, nor does the finding regarding income change drastically enough from the Copenhagen average nor is specific enough to be linked directly to the metro network, however, it is expected to be slightly changing in order to follow the argument that property values should have an impact on this.

A deeper analysis of the structure in chosen districts could have been made, before the analysis, and a general analysis of more different districts could have been made, to see if there were some other districts that were more suitable, to give a strong analysis. The selection of the districts is only made based on the distance to Nørreport and the disposable income in 1993, which should be similar. The type of housing could have been investigated before the analysis, because it can give a different development, if there is a lot of the same type of housing, as in Bellahøj, which are difficult to compare to the other districts, in the analysis that are chosen to make. When the districts are compared, there has also been a focus on, which connections there have been between the districts with metro stations, compared to the other districts, this could give a biased analysis in some cases.

In the analysis of whether a metro station has an impact on the value of the surrounding property, it seems that the hypothesis is confirmed. However, the problem with this analysis has been the limitation in obtaining BBR data on the housing square meters and has therefore had to use the area of the cadastre and thus it has only been possible to look at areas with houses and townhouses. This is why the percentage development of the average housing square meter price in Copenhagen is compared with the percentage development of square meter price for the entire property, in the two case areas. This means that the data cannot be compared 100 per cent. This is also the most plausible explanation for the disproportionate increase in the value of properties near the Copenhagen metro in comparison to the level of increase expected from known theory. In addition, the lack of housing square meters of data has made it impossible to analyse other areas in Copenhagen consistent of mostly apartments. The restriction means that this analysis is based on a relatively weak collection of data, with only two case areas and two different ways of calculating the property value. So, despite the fact that the analysis shows that in the two cases, there is a piece of evidence that the metro stations have a positive impact on the property value, the coat of evidence is not strong enough to conclude anything.

Examining the fact of placing a metro near a residential area taught that adding a metro station benefits the area but entails inconveniences as well. Based on the complaints of the M3 line, the analysis only focused on the operating phase due to limitations caused by GDPR. This only allowed for the analysis to determine whether the metro benefits or detriments areas receiving the addition of a metro station when in operation. The analysis of complaints showed that the only disadvantages of a metro station are noise and vibration due to the operation phase of the metro. However, the analysis does not examine the construction phase, which could have contributed to a different view of the matter. This might have shown that the construction phase would have had such comprehensive consequences in terms of noise, vibrations, dust, and traffic in interaction with the duration of the project (approx. 10yrs), which in the end may have forced people to vacate the area before they get the benefits of the metro station in the operating phase. Therefore, the impact of the complaints during the construction phase would have contributed to a more expanded analysis, which could have shown other categories of complaints than the operating phase, for example, the addition of more citizens in the residential areas as a consequence of a metro station. This could also have been approached in practice by contacting the citizens living near the metro to get a different view of the matter.

The matter of the chosen methods and way to develop the model for travel time was heavily dependent on the way GTFS networks are structured. The standardized GTFS networks allowed for building a model that could expand a case study from examining single travels between two points to being able to examine with the cost of accepting biases that would inevitably occur through the model. The most influential of these biases is assessed to be the issue of transferring between two different routes at a stop which both routes serve. In reality, a few minutes of time would be used to step off one bus or train line and change onto another. The model takes this into account if the transfer requires transferring between two stops, but not if two different lines stop at the same stop, which is the case of train and metro stops along with a number of bus stops. Effects of this bias could be seen in the size of areas that are calculated to be within 15 minutes of travel as well as routes that solely use trains or metros. This bias however is not easily fixed; The time schedule data is available, but like the rest of the GTFS network data set, it is seemingly not designed for use in network analyses like the one for this project. To incorporate the data, a way must be found to convert the time schedules for each of the millions of travels made into a way that tells the network that it is only possible to move from certain stop-IDs at given times. With our current knowledge, it is deemed to be beyond the limits of the network analysis tools of the programs supplied by Aalborg University.

The analysis of the environmental impact attempted to illustrate whether or not the construction of the metro had a visible impact on the CO_2 emissions in Copenhagen. To do so, the evolution of CO_2 emission was to be investigated both before and after the construction of the metro. The analysis was conducted as an equation in the form of a weighted average, meaning the data was the foundation of the analysis, with each of the investigated modes of transportation having to have a number representing the total CO_2 emission by that transportation each year, as well as a number representing the total number of passengers utilizing that mode of transportation. However, the limited amount of data and the quality of said data in all most all of the cases, meant that many assumptions were to be made, in order to fill out the blanks created by the data. In the case of S-trains and regional trains, there were no available data regarding the CO_2 emission of those modes of transportation, meaning they were left of the equation. Since the data was the foundation for the analysis, the quality of the result will reflect the quality of said data. Having said that, all of the assumptions were necessary and backed with logical explanations, but it doesn't change the fact that they are assumptions and thus don't reflect the true reality, meaning the result is not of the highest quality. Furthermore, the analysis doesn't include the emission in regard to production and maintenance, which would make the bike even more favourable. Lastly, the analysis only takes the CO_2 emission of the modes of transportation into account and excludes other types of pollution, including NOx gasses, meaning the modes of transportation which utilize the fuel type diesel or petrol, seem more environmental than they actually are.

Concerning the citizen involvement used during the construction and operating phase of the M3 line, it is to be discussed whether an increase in citizen involvement could avert the number of complaints regarding the metro. The complaints are mostly regarding noise in the operating phase which was promised by the metro not to be an issue, however, the calculations were made on former metro projects, which had never seen such issues. In relation to the theory section 8 “Inclusion of residents in the pre-processing of mega projects”, it is mentioned that mega projects often are criticized by society, therefore, the introduction of utilizing participatory governance removes the barrier between citizens and the state and adds the opportunity of interactions between the actor, and conclude that the more involvement the better. However, in this case, an increase in citizen involvement would not positively affect the number of complaints due to the unpredictability of the complaints. As the issue regarding noise was first found after the completed construction, it could be argued that no single element of rational planning, process planning, communicative planning nor a combination of such could have changed the outcome.

Another argument could be made that if all five analyses were made for the same stations, it would result in conclusions that could extend further as links between the different effects observed easier could complement one another and even be used as causes for one another. An example could be whether the results of the demographic and property analyses could have a connection with one another. It would be easier to examine this precisely within the same areas as one another. This has been attempted to be achieved by selecting Amager Strand station, which is in the Amager Øst district, and Vanløse station in the Jernbane Alle Kvarter district. However, selecting the same stations for all analyses increases the risk of worsening some of the analyses due to the restrictions placed by the limited amount of data that is available. The same example with the demographic and property analyses can also be made here, as the limitations of what can be concluded by the analyses also prevent much from being able to be concluded as a cause or effect of one another. A balance has to be found between focusing on the quality of each singular analysis and focusing on the ability to connect all the analyses into one; a heavier emphasis was placed on the former to gain a better ability to give in depth conclusions for each hypothesis.

The majority of the results produced by the five analyses either supported or could not disprove the original theory that was used to formulate the hypotheses. However, there were a few cases where the analysis seemingly without any explainable flaw or limitation disproved elements of the hypothesis backed by theory. This was the case namely surrounding the findings of demographic change in combination with changes in property value and the analysis of time saved. In the case of demographic changes, minor changes in disposable income were noticed, which is an understandable effect of what both theory and analysis showed that property value does rise. However, theory regarding demographic changes due to infrastructure was scarce, maybe due to the fact that disposable income may arguably not be considered a metric that is fully demographic in nature. Theory stating the rise of property value also does not delve deeper into the impact it will have on which residents will live there as a result of the increase in value. A further examination towards studies regarding income as a keyword rather than demographics may have given relevant theory to determine whether the findings of the analyses were purely circumstantial or if it supports other studies and theory; the latter may be indicated by figure 6 in section 6 shows that groups with larger income move to Copenhagen as a whole rather than to specific pockets of the city that are necessarily close to a metro station. The findings of the analysis of time saved gave a clear contradiction to the established theory mentioned in section 3.4: there must be other objectives that are equal to or more important than mobility. While the hypothesis may be disproved, the theory does also state that the objective of mobility can be altered with heavy use of land-use planning and/or traffic policies, which the alteration of the entire bus network safely can be categorized as (Tumlin, 2012, pp. 246-249).

24 Conclusion

The metro projects have many various elements that need to be considered when planning and require vast amounts of analysis both before and after the construction to create a successful transport network. This project has highlighted how various planning theories have been incorporated in the metro planning, and how the planning has affected demographics, properties, the number of complaints, mobility, and the environment.

Analysis of demographics showed that areas that received metro stations over time experienced slight changes in demographics compared to neighbouring areas and the average change in Copenhagen: Areas with metro stations have a slightly higher concentration of young adults and also become areas with a faster-growing income than other neighbourhoods without the metro, arguably creating inequalities between neighbourhoods enjoying nearby metro stations and the ones that have been overlooked. This correlates with the findings of property values that showed a significant increase in the growth of property value regarding properties closest to the metro over time - as properties become more valuable, they will most likely be purchased by people with a higher income. These analyses agree with the theory they were based on, stating that a strengthening of infrastructure and an increase in mobility has an effect on the value of the properties that stand to gain the most. While the percentage of the increase vary somewhere between 2,5-10 % within theories and reviewed literature, none state the growth of up to 50 % which was found in this analysis of property value; this is believed to be an effect of a limited amount of data to use for the analysis. For the same reasons, there were no clear indications of how close to a metro station a property needs to be - a distance that seemingly also fluctuated in various theories and documents from the literature review, ranging from “a couple of hundred” to over a kilometre.

Analysing the complaints received by local residents of the metro after the time of construction showed what seemed to be a pattern of noise complaints arising in areas that according to measurements before the metro were relatively quieter areas of the city. The expert interview and additional underlying reviewed literature revealed that these complaints were not expected as a certain level of communication between property owners and Metroselskabet I/S had been held throughout the completion of the project. This lead both residents and Metroselskabet to believe that no issues, especially regarding noise, would arise once the new metro lines had opened. The interests that were both shown directly by nearby residents and indirectly by the bigger companies owning the properties were taken into consideration before the construction of the metro, leading to the conclusion that no further inclusion of residents nor a change in the type of democracy could have prevented the wave of complaints experienced following the construction.

As previously mentioned, one of the key reasons for the increase in property value was the mobility increase according to theory. The analysis of potential time saved by the newly suggested metro line quantified the increase in mobility and showed that the new metro line will increase the mobility of neighbourhoods along every station of the planned route. Areas that are already well connected would also experience faster travel times along the route, but not on as big a scale as areas with less current public transport options. These findings agree with the theory stating the importance of mobility increase for new infrastructure, yet analysis of the M3 Cityringen line showed that when taking future changes of the entire public transport network into account, mobility may actually decrease in some areas, standing in contrast to the theory stating that mobility was the main purpose.

Ultimately the environmental impact of a new metro line was also quantified through a separate analysis concluding on the evolution of the CO_2-output of various modes of transportation in Copenhagen. The analysis showed that the number of vehicles driving through the centre of Copenhagen, where the metro has operating, has decreased, as well as the number of citizens riding the buses. Furthermore, the analysis showed that the CO_2 emission per passenger has decreased more after the construction of The Metro in comparison to before. While these effects connection to the opening of the metro remains circumstantial, along with the fact that the analysis only focuses on CO_2-output and excludes other types of pollution, the conclusion does not oppose the theoretical statements, that building public transportation such as metros significantly decrease the overall pollution.

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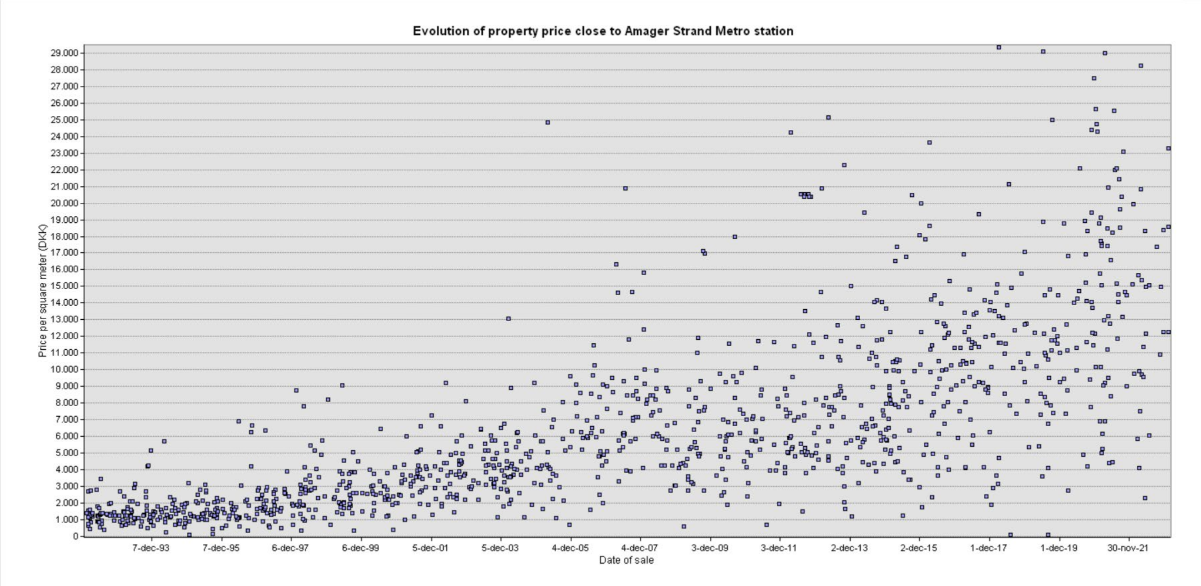
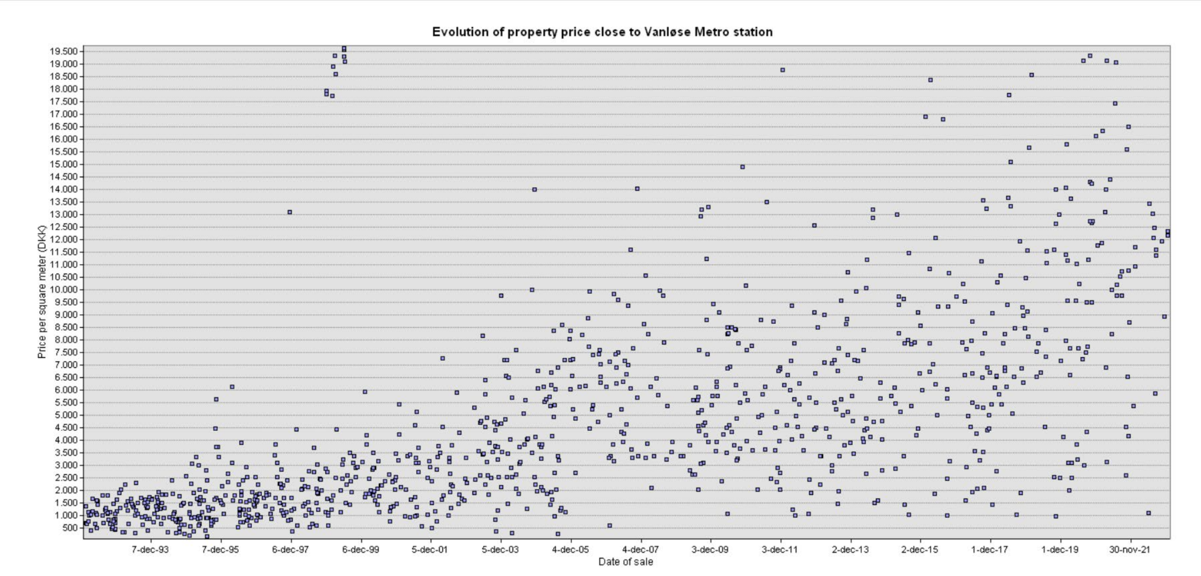
Appendix

Appendix 1

The following two graphs evolution of property price close to Amager Strand metro station and Vanløse metro station, respectively, were created in ArcMap using the dataset of (Skat, 2023).





Appendix 2

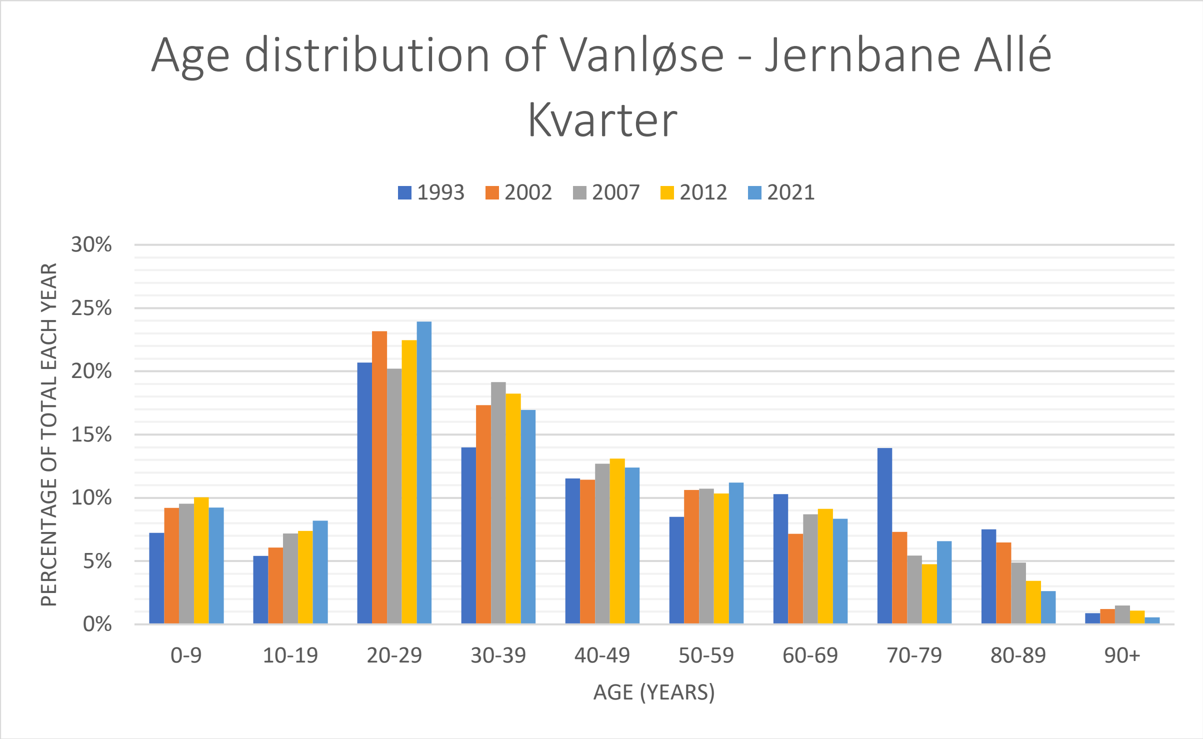


Figure 43: Age distribution in Vanløse - Jernbane Allé Kvarter, data from (Københavns Kommunes Statistikbank, n.d.).

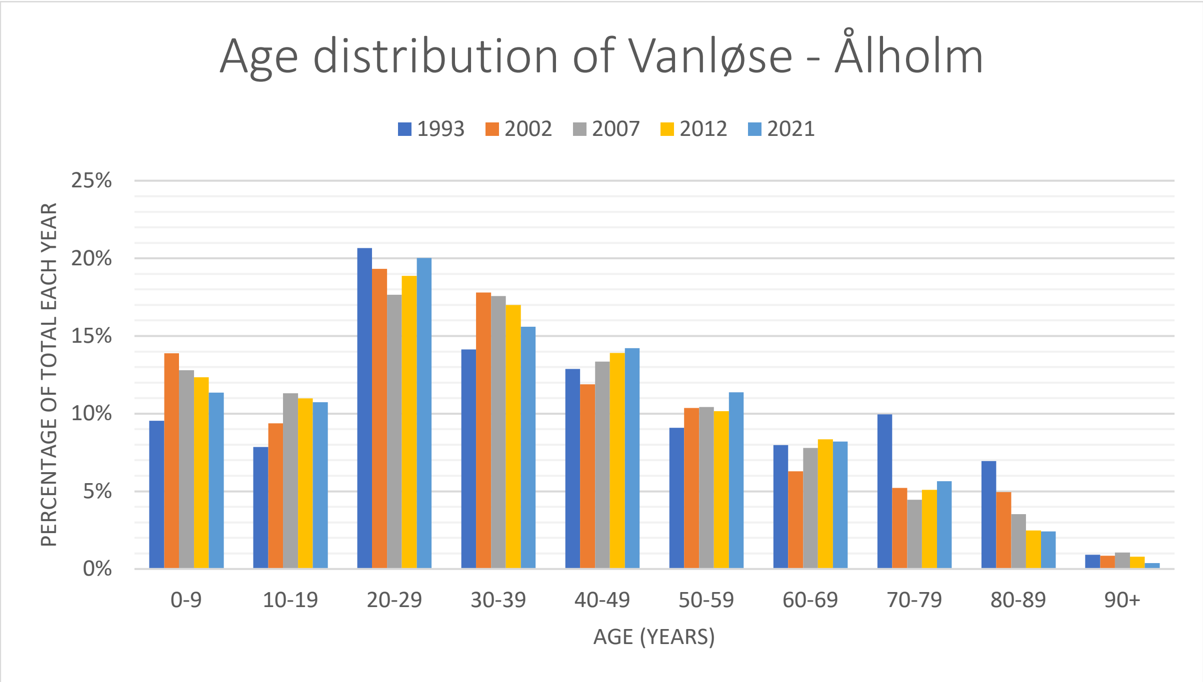


Figure 44: Age distribution in Vanløse - Ålholm, data from (Københavns Kommunes Statistikbank, n.d.).

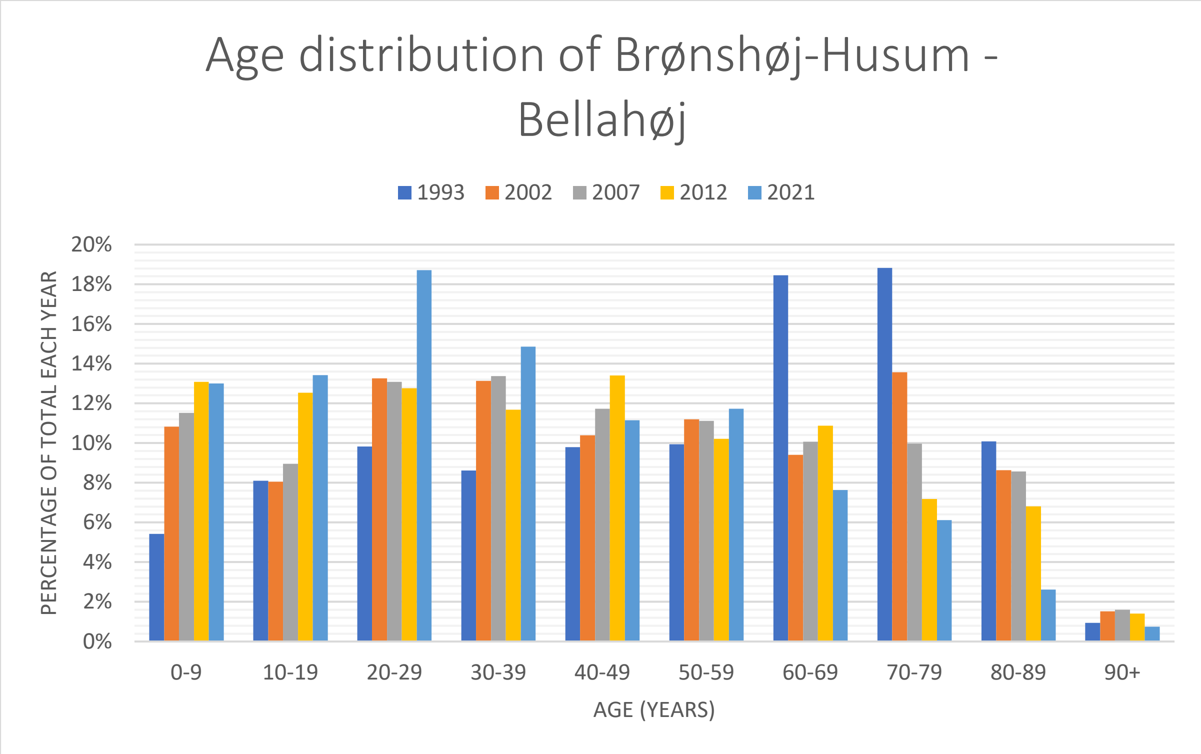


Figure 45: Age distribution in Brønshøj-Husum - Bellahøj, data from (Københavns Kommunes Statistikbank, n.d.).

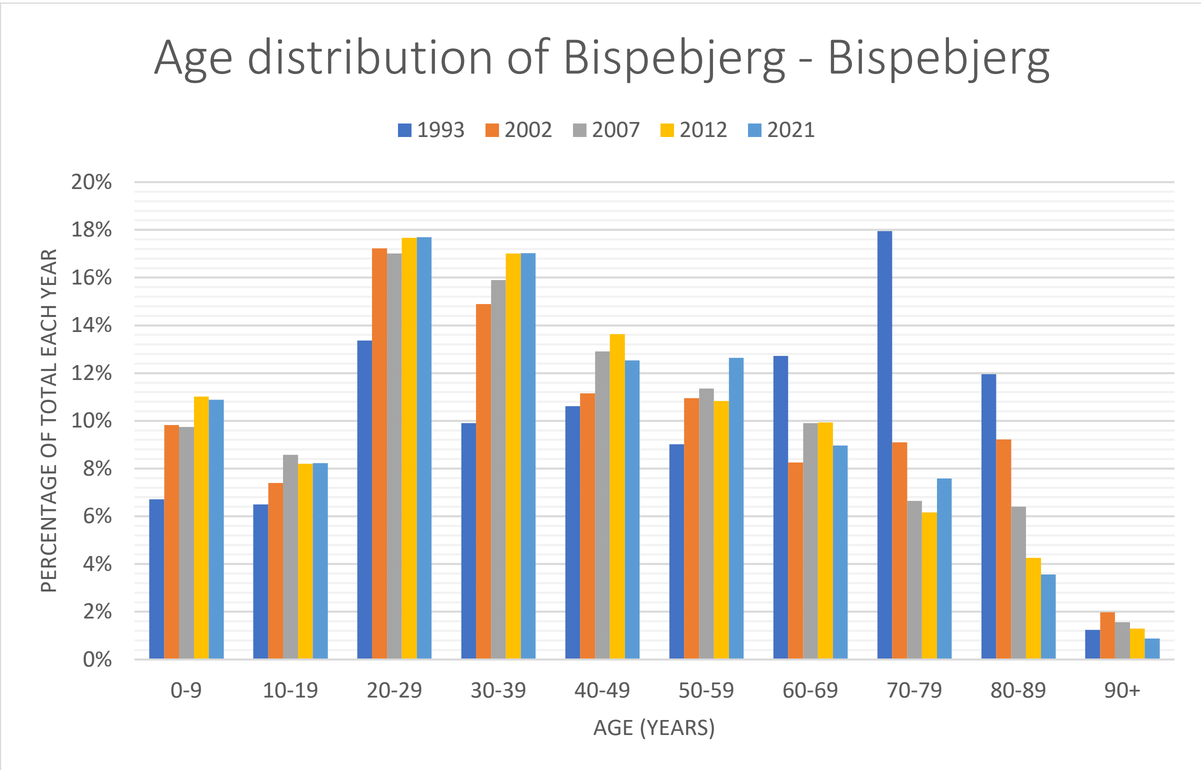


Figure 46: Age distribution in Bispebjerg - Bispebjerg, data from (Københavns Kommunes Statistikbank, n.d.).

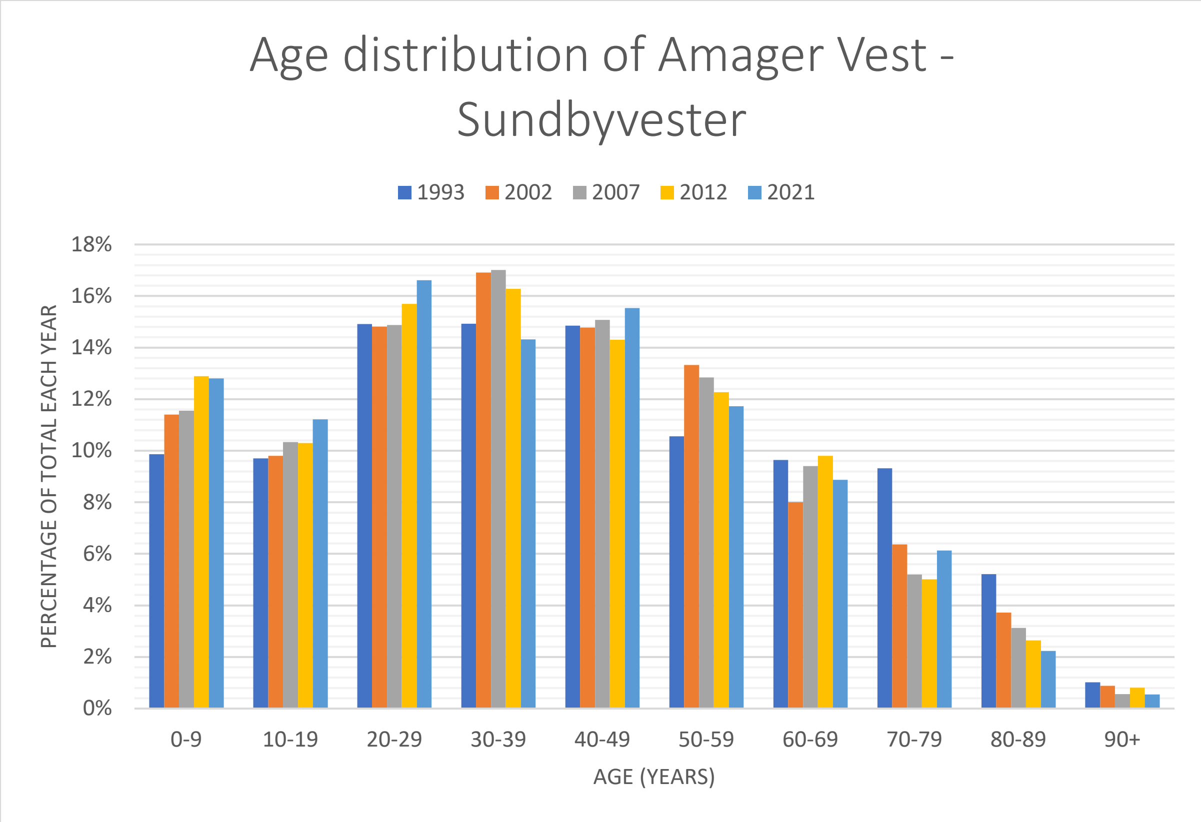


Figure 47: Age distribution in Amager Vest - Sundbyvester, data from (Københavns Kommunes Statistikbank, n.d.).