Building Logistics in Urban Areas; Innovations and Solutions to Decrease GHG Emissions

Capstone

Dirk de Boer

Mentor: Dr. Jairo Garcia

section 425.800.81

May 13, 2022

Table of Contents

Building Logistics in Urban Areas; Innovations and Solutions to Decrease GHG Emissions 1

Abstract 4

Executive summary 5

Introduction 6

- Problem statement 6
- Research questions 7
- Relevance of research 9
- Framework outline 10

Literature review 11

- Material 11
- Personnel 12
- Equipment 12
- Delivery van characteristics 13
- Building plans for cities 14
- Stakeholders 14

Methods 18

- Layout 18
- Interview questions 18
  - Construction worker survey questions 18
  - Construction wholesaler questions 19
  - Municipality of Amsterdam interview 21

Results 22

Case studies 22

- Amsterdam 22
  - Current process of Material, personnel, and equipment 23
  - Innovations 23
  - Policy results 25
- London 27
  - Current process of Material, personnel, and equipment 27
  - Innovations 28
  - Policy results 29
- Stockholm 32

Current process of Material, personnel, and equipment 32
Innovations 33
Policy results 33
Discussion 36
Hypotheses testing 36
Viable logistic solutions 41
Conclusion 44
References 45

Abstract

Construction logistics in urban areas are negatively impacting the livability in city centers. Inefficient logistics are impacting the environment, causing congestion and increasing traffic accidents. Construction workers, municipalities, and construction material suppliers should work closely to modernize the construction logistic industry. This can be achieved by innovative government policies, modernizing the transportation fleet, and the consolidation of construction materials for last-mile deliveries. A condition for successful improvements is that construction workers need to change the methods of approaching renovation construction projects. The conservative behavior of construction workers will be the biggest challenge for modernizing construction logistics.

Executive summary

The current climate crisis is putting the world in danger. Although I was aware of the crisis, the Energy Policy and Climate program made me understand the crisis scientifically. It also encouraged me to think about mitigating and adaptative measures that positively impact the world from an environmental, societal, and economic perspective. Ideas should be economically viable to ensure initiatives come from the market and ensure continuity and constant innovation.

The problem discussed in this project has a potentially positive impact on these three factors. More focus is put on construction logistics as building agendas are increasingly focused on city centers. Inefficient construction logistics are visible and negatively impact the environment, impose safety hazards, and cause congestion in city centers. This study conducted surveys with construction workers, in-depth interviews with experienced people from the construction market, and did case studies of the European cities of Amsterdam, London, and Stockholm. They showed the challenges this sector has, the innovative solutions that could play a prominent role in the future, and the difficulties of those market solutions. The outcome of this research was surprising as the construction worker plays a more significant role than expected. This research adds knowledge to the (still) underdeveloped research field of construction logistics in urban areas and highlights the importance of future scientific research.

Introduction

Problem statement

The world faces one of the most crucial challenges that humanity has ever experienced. Intense droughts, severe storms, extreme heat, warming oceans, and melting glaciers are caused by climate change. As climate change will only worsen, the likelihood of these events will increase (WWF, 2022). Although the signs are evident, this increase cannot become less in the future. With very high confidence, scientists forecast a temperature increase of 2,5 to 10 degrees Fahrenheit over the next century due to greenhouse gas emitted by human activities (NASA, 2022). Global sea-level rise impacts cities across the world, and this will continue. Scientists expect an increase of 1 to 4 feet by 2100, but they are not ruling 8 feet rise out (Wuebbles, 2017). According to the IPCC, humans need to emit zero carbon emissions to minimize climate change's impact on ecosystems and society (IPCC, 2018). Policies have been implemented to encourage industries and individuals as much as possible to reduce greenhouse emissions. The Paris Agreement is the most famous climate agreement. It has been adopted by 196 countries and is a binding agreement on climate change that aims to keep global temperature rise below 2 degrees Celsius (UNFCCC, 2016). Countries have been developing their strategies and goals to decrease greenhouse gas emissions as much as possible. The Dutch government aims “to reduce the Netherlands’ greenhouse gas emissions by 49% by 2030, compared to 1990 levels” (NECP, 2019). The 2019 published National Energy and Climate Plan was based on the Paris Agreement and contained the policy and measures to achieve the Dutch goals.

One of the measures taken in that plan is to focus on ‘smarter’ logistics and zero-emission vehicles in urban areas (NECP, 2019). Currently, 30 cities in the Netherlands are committed to

only zero-emission delivery, and transporter vans are allowed in their city center from 2025 onwards (Manthey, 2021; TLN, 2021). The Netherlands is one of the frontrunners in proposing these strict regulations, but the rules are also ambiguous. At the end of 2021, only 0.76% of the transporter vans in the Netherlands were electric (NOS, 2021). Just prohibiting emitting vehicles from urban areas will therefore be challenging to implement. A more significant focus should be put on 'smarter' and more innovative solutions for logistics.

Construction logistics are currently the most prominent problem in city centers as they are large in volume and very inefficient. Dutch research institute TNO recently published two reports about the building logistics in city centers. Currently, 30% of the transport movements in cities are building-related (van Rijn, Rondaij, van Merrienboer, Kin, & Quak, 2020). Renovation projects are responsible for 80% of these transportation movements in the Netherlands (van Merrienboer, Kin, Quack, van Rijn, & de Vries, 2020). Besides this, renovation projects are well represented looking at the transportation movements since they are not bundled and carefully planned, as is the case with new construction projects. Moreover, renovation projects are often done by small or medium-sized contractors who don't have the funds or the capacity to innovate.

This problem is apparent, but there is no best practice for approaching this problem. This research will dive into construction logistics by having several interviews with stakeholders. The interviews will take place in the Netherlands, but a case study on the logistic behavior will be done in three different European cities.

Research questions

The following research question is developed to investigate the problem mentioned above.

Which innovative solutions can reduce the transportation movements and emissions in the construction sector in Europe?

To answer the research question, several hypotheses need to be tested. The first hypothesis is focused on aligning all stakeholders involved. Every stakeholder has its agenda and own goals. Stakeholders can be driven by a specific purpose and therefore don't have an incentive to change their behavior. If they can align on a common goal that improved construction logistics can facilitate, all stakeholders have an incentive to adapt to innovative logistics solutions. Hence the first hypothesis is developed.

Hypothesis 1: There is a common goal for all stakeholders in the construction delivery industry

One of the most mentioned solutions is construction consolidation hubs. These hubs collect the materials before doing the last mile delivery. Bundling materials is, without a doubt, a solution for creating more minor transportation movements. However, it is unclear whether bundling has a positive impact on the efficiency of the construction worker.

Hypothesis 2: Bundling materials can reduce the transportation movements in the construction sector and still work positively for the construction worker.

A clear trend is seen in deliveries of smaller goods, as they are delivered more often by Zero Emission (ZE) vehicles. There is a lot of discussion about whether ZE transportation solutions can be beneficial for providing heavier construction materials. Using ZE trucks to deliver heavier goods needs to be investigated. A trade-off needs to be made in defining having interests without emission and the option to do that efficiently without continuously recharging the truck's batteries.

Hypothesis 3: Zero-Emission transportation solutions are suitable for the logistic industry.

City logistics are becoming an increased point of attention. Many delivery companies, such as UPS or FedEx, are working with advanced software solutions to minimize the traveled kilometers as much as possible (Blank, 2021; UPS, 2020). They also give real-time updates about their location and expected delivery time to increase customer satisfaction. Construction workers are not likely to be average customers since they are often dependent on their supplies. This process, therefore, needs to be very reliant.

Hypothesis: 4: Software for city logistics and planning will make it easier for construction workers to adapt to changing city logistics

The hypotheses will eventually form the basis of answering the main question. The project's objective is to find out the best way to innovate this very old-fashioned, rigid sector and reduce GHG emissions in city centers as much as possible.

Relevance of research

The relevance of the research is to society. Inhabitants of cities want cleaner air, less deadly traffic accidents, and less congestion in their city center (Bruyninckx, 2017; SWOV, 2017; Manville, Taylor, & Shoup, 2022) . Urbanization is likely to continue, and cities will become more crowded than they currently are. Currently, 4 billion people live in urban areas worldwide, and it is expected to increase to 7 billion people by 2050, according to the UN (Ritchie & Roser, 2019). Intelligent solutions could increasingly play a role in achieving this.

Besides this, this capstone project could be used to increase the focus on construction logistics in general. By increasing the efficiency of transportation movements and introducing innovative

solutions, it is expected that improvements can be made in the liveability of people living in urban areas.

Framework outline

Amsterdam's current construction logistics process will be investigated thoroughly by conducting interviews with construction workers, construction material wholesalers, and the municipality of Amsterdam. This will make it possible to understand all the stakeholders' needs and behavior. Three case studies will be presented after conducting the interviews and researching the needs and problems of stakeholders in the construction industry. The three cities that will be investigated are Amsterdam, London, and Stockholm. These three cities are unique. The city center of Amsterdam was built in the 17th century. The canals and small bridges make it a challenge for construction logistics. London is fascinating, as cars, vans, and trucks are not allowed to enter the city without permission (GovUk, 2022). This forces logistic companies to find a solution to deliver their construction materials effectively. According to several lists published online, Stockholm is the capital of one of the most sustainable countries in the world (Berry, 2021). The country has more than 50% of its energy consumption produced by renewable energy sources. It focuses on electric buses, intelligent roads, and smart solutions such as urban farming and state-of-the-art recycling systems (Berry, 2021). People are very focused on the environment, and it is a great city to do a case study on.

Comparing best practices from these three cities will be done by studying papers and finding news articles to learn about innovations. An overview will be made of all these initiatives. The approach to reviewing each of the three cities will be the same. Eventually, recommendations will be made on which industries are most effective in city centers.

Literature review

Material

The most important part of construction logistics is the transportation of the materials. The materials are the most difficult to transport. Materials can be fragile, have odd sizes, or be very heavy. The material plays a significant role in what type of transportation method is needed. Table 1 provides an overview of what kind of vehicles are used in the construction market.

Table 1

Vehicle type	Transport	Used for a variety of construction
Delivery van	Personnel, equipment, ad-hoc materials	- Renovation - Sometimes, new construction
Box truck	Materials	- Renovation - Sometimes, new construction
Heavy Truck	Heavy materials and more extended materials	- New construction - Sometimes renovation
Crane Truck	Heavy and more extended materials that need to be delivered on height	- New construction - Sometimes renovation

Overview of vehicle types (own research)

Delivery vans and box trucks are primarily used for renovation construction. They are easy to drive through cities and, on average, have a capacity of 3500 kg (de Groot, et al., 2017). Box trucks and heavy trucks are used less for renovation products. Crane trucks are also not used frequently, but they are relatively more used in urban areas than rural areas. Heavy trucks

deliver mostly goods that are difficult to transport. They can transport up to 15 times as much load as a delivery van (de Groot, et al., 2017). Because of that, the operation is most of the time planned and therefore efficient. The delivery vans and box trucks can consequently make the most significant improvements.

Personnel

In the Netherlands, the construction market is highly fragmented. Around 60% of the 293K people in the Netherlands that work in construction work at companies with less than two employees (CBS, 2022). The company size is this small because of the many independent contractors that work in the construction market. They require flexibility in the way they transport themselves. Besides this, these independent contractors use their vans also in their spare time.

The smaller construction companies with most renovation work have vans available for their employees. The vans are also used to bring the construction worker to the construction site and bring the construction worker back. It gives the construction worker flexibility and saves the construction company space, as they don't need to store vans at the office.

Equipment

Equipment is brought into the city center mainly with vans (de Groot, et al., 2017). Independent contractors own or lease their equipment (Ondernemersplein, 2022). If they work on a site with multiple construction workers, they take their equipment home every day (van Merrienboer, Kin, Quack, van Rijn, & de Vries, 2020). Smaller construction companies also bring their equipment to the job with smaller vans. Their equipment is often owned by the company working on site, and they tend to leave it there (van Merrienboer, Kin, Quack, van Rijn, & de

Vries, 2020). The equipment transportation is inefficient; however, it is transported less frequently and has less volume. Therefore, the urgency to solve this inefficiency is more minor than material and personnel.

Delivery van characteristics

Most of the Vans in the Netherlands are Diesel driven. In 2022, 93% of the delivery vans are diesel-driven, and only around 1.4% of the vans are electrically driven (CBS, 2022). Since only 14.000 out of the 991.000 vans are electrically operated in the Netherlands, the number is not large enough to significantly impact (CBS, 2022). In 2022, 21% of the delivery vans were younger than three years, 29% were 3 to 7 years old, 22% were 7 to 12 years old, and 28% older than 12 years (CBS, 2022). These numbers show that construction workers buy their van, either as an independent contractor or as a company, with the idea of writing it off over many years.

As stated in the introduction, from 2025 onwards, the city centers of 25 cities will only allow ZE vans (Manthey, 2021; TLN, 2021). Electric vans have many advantages and lots of disadvantages. The benefits are clear; they are zero-emission, are less noisy, and have lower running costs (Herincx, 2022). The disadvantages are that you are dependent on available loading stations, the reach of the vans is limited, and the loading capacity is much lower than conventional vans (Herincx, 2022).

In September 2019, only 1% of the vans in the Netherlands were electric (NOS, 2021; CBS, 2022). Luckily, this number is increasing. In 2022 58% more electric delivery vans were registered than in 2021 (CBS, 2022). This amount is likely to increase because of government regulation, battery improvements, and relative price reduction of electric vans (Luman, 2019). Besides this, heavy electric trucks are expected to increase faster in the upcoming years. From

2025 to 2030, it is likely that 25% of the newly acquired heavy trucks will be electrically driven (Luman, 2019). The alternatives besides these electric vans for ZE logistics are biofuel, hybrid (Diesel-electric), and hydrogen (Luman, 2019). Hybrid trucks could be used only to turn on the electricity in specific ZE zones.

Building plans for cities

Currently, 50% of the building plan in the Netherlands is in cities, but this will increase to 80% in 2040 (van Merrienboer, Kin, Quack, van Rijn, & de Vries, 2020). This is mainly due to urbanization and the fact that current housing needs better isolation requirements. Four times as many houses are expected to be renovated in 2030 yearly compared to today (van Merrienboer, Kin, Quack, van Rijn, & de Vries, 2020). On a worldwide scale, urbanization is expected to be much more impactful than the Netherlands. In 2050 2,5 billion extra people will likely live in urban areas, all in need of a home that still needs to be built (UNPopulation, 2018). At the beginning of the century, 371 cities had more than one million inhabitants; in 2018, 548 towns had more than 1 million inhabitants, and in 2030 this number is expected to be 706 cities (UNPopulation, 2018). In 2018, 23 % of all the people lived in the city with more than 1 million inhabitants (UNPopulation, 2018). As this number increases, the houses that will be constructed will also grow significantly. The importance of good logistics for construction companies is crucial to maintain proper living standards and keep cities safe.

Stakeholders

The first stakeholder that plays a significant role is local governments. Governments can make policies on the level of municipalities or nationwide. Examples of policies made on a municipality level are city-specific rules and regulations. These regulations can be specific

vehicle requirements or when and how deliveries can be made. The main goal of the governments is to decrease emissions and reduce congestion as much as possible while maintaining high standards for the people living in certain areas.

Secondly, construction wholesalers play a significant role. Construction wholesalers have selling points outside city centers. Figure 1 shows the location of the four largest construction wholesalers in the Netherlands. These construction wholesalers are Bouwmaat (Red), BMN (Blue), Technische Unie (Yellow) and Pontmeyer (Brown).

As can be noticed from the map, construction wholesalers are all located around cities in the Netherlands, which is evident from a commercial perspective looking at the building plan.

Figure 1; Distribution of the four largest construction wholesalers (own analysis)

Figure 2 zooms in on Amsterdam. Amsterdam is an excellent example for other cities. Construction wholesalers are always located outside city centers, as more space is available for relatively less money. We notice that construction wholesalers are located close to each other in all cities in the Netherlands in certain areas. Theoretically ideal for bundling of goods.

Figure2; Construction wholesaler distribution Amsterdam (own analysis)

The last and most important stakeholder is the construction worker. The construction worker is vital since they decide how the project will be carried out.

Methods

Layout

This research consists of the following parts:

- Understanding the basis of the problem
- Compare best practices from other cities over the world
- Propose a solution based on these best practices

We conduct interviews with construction workers, construction wholesalers, and municipalities to understand the basis of the problem. If the needs and goals of all stakeholders are separately understood, it is possible to comprehend the current situation fully.

Interview questions

Construction worker survey questions

Often construction workers were approached, and an interview with them on the phone was conducted via a google survey. Also, many construction wholesalers were visited. The total number of respondents was 55. The interviews were designed to learn more about the construction worker's motivations, calculate the time consumed by supply chain-related activities, learn more about problems construction workers experience, and learn more about feasible innovations in the construction market.

The questions from the survey are:

Closed questions

1. How many times per week are you driving from the wholesalers to your construction project in the city center? A) 0, B) 1-3, C) 4-6, D) 6+

2. How much time does an average trip cost you? A) 30 min, B) 1 hour, C) 1.5 hour, D) 2 hours, E) more than 2 hours.
3. Would you use a service that bundles all your goods from the wholesaler to your construction project?

   If not, why not? – A) Not trustworthy – B) Loss of flexibility – C) Price – D) Just like to work on supply chain-related activities – E) Bad experiences in the past – F) Other

4. Before visiting the logistic construction center, how long do you know what to order? A) Same day – B) 1 day in advance – C) 2 days in advance – D) 3 days in advance
5. Is sustainability driving you?
6. Are zero-emission vehicles suitable for you? Yes / No

Open questions:

7. Do you use any kind of software to help you? If yes, what do you use?
8. What could you do to reduce your supply chain-related activities? (Open answer)
9. Are there initiatives that are currently helping to increase efficiency? (Open answer)
10. What kind of problems do you experience?

Construction wholesaler questions

Three in-depth interviews showed the needs and requirements from a construction wholesaler's perspective. The interviewees were the manager of the supply chain, the managing director, and the sustainability manager of the Bouwmaat, the Voskamp Group, and the Technische Unie, respectively.

The goal of these interviews was to learn more about the motivations of construction wholesalers, to learn more about their current delivery process, and learn about their view of construction logistics.

The interviews were in an open format, but the below questions were discussed.

I, therefore, ask mainly open questions to learn as much as possible.

- What percentage of your products is currently delivered?
- Do you offer pick & pack? (Construction worker orders online, and he only has to pick it up)
- Do you have a focus on sustainability when making deliveries?
- Do you focus on congestion in city centers while doing the deliveries?
- Are zero-emission vehicles suitable for deliveries?
- Are you satisfied with the current situation? (Construction worker picks up materials and store and drives back to the city center with partly filled bus
- Are there many urgent deliveries demanded?
- Do you think construction wholesalers are paying enough attention to the problems?
- What will be the most challenging part of optimizing this industry?
- Are there current initiatives that improve construction workers' efficiency?
- What is your thought on construction hubs?
- What role can software play in optimizing the process?
- What would you change if you had a magic wand and could change something for the current situation?

- Is there a common goal for all stakeholders in the construction delivery industry? Can you please share your thoughts?

Municipality of Amsterdam interview

The municipality of Amsterdam was more challenging to approach; hence one interview was conducted with a consultant who had been hired as project manager for construction logistics of the city of Amsterdam. The goal of this interview was to learn more about the current construction logistics initiatives in Amsterdam and learn more about policies. The following questions were used as a guideline during the interview:

- What is the main problem of the current construction logistic situation? (I.E., Safety, congestion, emissions)
- Do you work together with construction wholesalers?
- Are there initiatives to optimize this process?
- Do you look at other municipalities in solving this problem?
- What is your thought on construction hubs?
- What role can software play in optimizing the process?
- Can you describe how municipalities, construction workers, and construction wholesalers work together? Could this be optimized?
- There is a lot of research published by the municipality of Amsterdam. Why is this all researched on a local level and not on a national level?
- What would be the best solution for the municipality of Amsterdam?
- Is there a common goal for all stakeholders in the construction delivery industry? Can you please share your thoughts?

Results

Case studies

Amsterdam

As Amsterdam's oldest building dates back to 1300 and the rest city center was built around 1600, the center of Amsterdam is ancient. Transportation methods at that time were different. Horse and wagons mainly executed construction logistics through the canals. Construction logistics through the canals is gaining popularity again (PortofAmsterdam, 2020). The city center has been overloaded over the past decades, and especially the bridges and quay walls in the city center are breaking down because of the heavy loads that are transported over them. The municipality is currently restoring the 200 km of quays and 850 bridges future proof by replacing some of these historic constructions (Wolfert, 2022). The future of construction logistics will play a significant role in the livability of Amsterdam. Renovation works in Amsterdam are likely to increase in the future. First, the insulation requirements that the Dutch government imposes. The Dutch government encourages making households more energy efficient by granting subsidies for wall insulation, roof insulation, ground isolation, or high-efficiency glass (DutchHousingPolicy, 2022). These subsidies will increase the amount of home innovation. Secondly, more and more people will move to cities. Whereas currently, 50% of the Dutch building agenda is in cities, it is expected to increase to a building agenda of 80% in cities by 2040 (PloosvanAmstel, 2020).

Amsterdam is moving towards a more sustainable, efficient, and safer city center. One of the steps is to make the city center of Amsterdam car-free (GemeenteAmsterdam, 2020). Currently, the focus is on bike lanes, shared transportation methods, and public transport

(GemeenteAmsterdam, 2020). Focusing on these environmentally friendly aspects will make it impossible that an increased focus on innovative green solutions for renovation construction will be made.

Current process of Material, personnel, and equipment

Large quantities of goods and construction materials are transported by water into the city center (PortofAmsterdam, 2020). This is a significant improvement since it significantly reduces the amount of traffic on the road. Currently, materials for renovation construction are picked up with vans at wholesalers at the edge of the city. Large orders for renovation constructions and newly built homes are delivered by large box trucks or heavy trucks. Personnel and equipment are also going to their job with the van. Also, when large deliveries are made and the equipment is already on the project side, construction workers tend not to use public transportation or car-sharing initiatives.

Innovations

At this moment, logistical hubs are increasing in popularity in Amsterdam. One of the biggest hubs is the Amsterdam Logistic City Hub. The seat is ideally located on the outskirt of the city and thereby easily accessible by water and land as they state that their “electric Canal Cruisers and van parking facilities make it possible to transport bulky materials and equipment together with personnel in one go, wherever they need to be” (AmsterdamlogisticCityhub, 2022). This hub is the largest site in the Netherlands since it has 220 loading docks, 180m private quay, and a total area of over 220,000 m2 (AmsterdamlogisticCityhub, 2022).

The most significant innovation is currently consolidating and transporting construction materials over water. Although this method has been used for ages, the current deck barges

used for large construction projects are very effective. This hub allows suppliers to bring the goods by ship to the hub, where the cargo of the different suppliers is combined and brought to the construction site as one load on electric of green fueled barge (Theunis, 2020).

Consolidating effectively is also done on a smaller scale. Instead of barges, it is done using small electric vehicles. These vehicles are ideally suited for city logistics in Amsterdam as cars can pass these electric vehicles on the narrow canals in Amsterdam, having a very positive impact on the congestion in the city center. One of the interviewees from this study was working for the Technische Unie (Santos, 2022). Technische Unie is the biggest wholesaler in the Netherlands focused on installation materials. The Technische Unie completed a pilot in Utrecht with Light Electric Vehicles (TechnischeUnie, 2021).

Figure 3 source: Technishe Unie (2021)

Besides the fact that this setup navigated much quicker through the city center, the Technische Unie is also testing doing white label deliveries. They are used by their competitors to positively influence the cities and be able to identify themselves as an absolute front runner in the

Netherlands (Santos, 2022). This means different construction suppliers can deliver products at the Technische Unie for consolidation purposes (Santos, 2022). Technisch Unie will provide all these materials in one run. By doing this, the Technische Unie is the first party involved in white label constructions.

Another evolution that is about to take off is the flash delivery of building supplies. Flash delivery is gaining popularity in the grocery industry in Western Europe with companies such as Gorilla's, Zapp, and Gettir. This on-demand delivery promises to deliver groceries within a specific timeframe in many cities in Western Europe. In recent months, the first party connected to many different wholesalers started in Amsterdam. They have a promise to deliver materials to city centers within 1 hour (Foremoresupplies, 2022). The rapid delivery of building materials can positively impact electric cargo bikes that could be used instead of vans. Recently, this party started with conventional vans to define the impact on the city centers.

Policy results

The results of these innovations can be significant. In Amsterdam, 80% of the freight movements transport 20% of the freight volumes (van Merrienboer, Kin, Quack, van Rijn, & de Vries, 2020). Reducing the number of rides by using consolidation will have a significant impact. Precise results are not yet published, but expectations based on similar initiatives in London show a possible ride reduction of 75% (Frazer, 2021).

Sustainability

Construction logistics by water have been investigated for specific projects in 2018 and 2019 by the municipality of Amsterdam. A clear result was that 37% less CO2 was emitted on the transportation side of the project (AmsterdamVaart, 2020). Many larger projects were

researched with the use of construction hubs. Experiences with building construction hubs are very positive. Three large projects that the Dutch Research institute TNO thoroughly monitored had a CO2 emission reduction of 40, 50, and 85% (TNO, 2021).

Congestion

Arranging construction logistics by water is very effective in looking at congestion in the city center. Research from 2018 and 2019 showed that 40% of the intercity construction transportation movement by road with large trucks could be reduced per building project (AmsterdamVaart, 2020). Currently, 20,000 freight movements for construction logistics are occurring daily in the city center of Amsterdam (Frazer, 2021). The use of the Amsterdam logistic hub significantly increased the loading capacity of the trucks.

Safety

In November 2021, two fatal accidents occurred with cyclists and heavy trucks in one morning. This led to the discussion of removing heavy trucks from rush hours (Parool, 2021). Removing trucks from rush hours will likely reduce fatal accidents in the city center by 25% (Parool, 2021). Amsterdam has several initiatives running to increase traffic safety awareness among people, but there is no emphasis on the construction sector.

London

London is an interesting case to analyze. London is currently the world's most expensive city regarding the construction (ConstructionIndex, 2022). Also interesting because construction vehicles are not allowed to enter the city without permission (GovUk, 2022). This makes the logistical operation of building construction a challenge. The focus in the UK on emissions by the construction sector is increasing. Besides that, the focus on transportation is rising. Currently, 23% of the building sector emissions are assigned to transportation (GLobalAllianceReport, 2020). As the UK aims for a net-zero building construction sector by 2050, focusing on a more sustainable solution for construction logistics is crucial (GLobalAllianceReport, 2020). The city of London created a roadmap on how to achieve this and make London a zero-carbon city by 2050. As of 2025, the GLA car fleet, which includes all the cars from municipalities, will be net-zero (Odedun, et al., 2021; GLAFleet, 2022). Besides the roadmap to becoming a zero-carbon city by 2050, London has developed a construction playbook that aims to improve the performance, profitability, and sustainability of the construction sector (HMGovernment, 2020).

Current process of Material, personnel, and equipment

Finding effective methods for transporting materials will be crucial in net-zero construction (Odedun, et al., 2021). The most significant focus there is that London wants to 'break silos' by manufacturing and assembling different components outside the city. After that, they transfer the assembled pieces to the town and build with just a single "kit of parts" (Odedun, et al., 2021).

Like Amsterdam, London uses the Thames River for light freights to the city center of London (Ploos van Amstel, 2022). Unfortunately, this is not common. Still, almost all freights are transported by road resulting in that one-third of the vehicles in the morning peak in central London are trucks and light commercial vehicles (TfL, 2019).

80% of the personal trips in London are made on foot, by cycle, or using public transport (TfL, 2019). Construction workers can easily take public transportation to the construction project, and they tend to do that more often because of vehicle restrictions. Their equipment is brought there by other vans while deliveries are made.

Innovations

Small and medium-sized enterprises play a significant role in the innovations in the construction sector. They have the experience and flexibility to contribute mainly to improving projects but often lack the capacity and funds to engage in projects more often than larger companies (HMGovernment, 2020). The UK government increased its attention to smaller and medium-sized enterprises to involve them in projects. Innovations play a more prominent role, especially in projects' preparation and planning phase. Platforms are digitalizing the software, and sound measurement and modeling tools make it easier and faster to manufacture parts abroad. The UK government has also developed a UK BIM framework that enables secure, resilient data sharing across sectors (HMGovernment, 2020). More tangible, several government reports state that construction companies should use digital twins to be more effective in the construction process (Sutton, 2021). "A digital twin is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation,

machine learning, and reasoning to help decision-making" (IBM, 2020). Digital twins can be ideally suited for renovation construction.

Policy results

London uses a construction consolidation center that has been very successful. For the specific projects that use the consolidation center, 68% of the transportation movements can be reduced, 25% of accidents can be diminished, and 75% of the CO2 emission can be concentrated (Frazer, 2021).

Combining and assembling the different parts outside the city and only "kit of parts" inside the city has been successful. According to research, this "kit of parts" method improved productivity by 55% compared to a traditional construction site (Odedun, et al., 2021). Besides this, the time it took to install the building was reduced by 30%, and this technique achieved 33% cost savings (Odedun, et al., 2021). This platform technique and "kit of parts" method look promising and significantly transform the construction sector. The amount of work suitable for this 'kit of parts' approach is also large. In 2020, an analysis showed that "£35bn worth of the £50bn pipelines of public works" was suitable for London's kit of parts approach (CIOB, 2020). A significant impact could also be made by replacing road kilometers by transferring freights to water. Currently, 265,000 heavy truck movements per year are replaced by water freights; this could be increased to 400,000 movements in 2025 (TfL, 2019).

Sustainability

As mentioned, London has a strong focus on reducing the Greenhouse gas emissions of the construction sector. The 'kit of parts' method reduces the number of movements by the industry. The construction sector in the UK had to adopt identical emission reductions as the national

targets of 68% in 2030 and 78% in 2035 compared to 1990 levels (Sutton, 2021). A report from 2019 showed that 23% of road-related CO2 emissions in London came from freight vehicles (TfL, 2019). To reduce these emissions, the municipality partners with electric distribution companies. Subsidies and regulations force distribution companies to shift to Low Emission Vehicles.

Congestion

Reducing the number of movements positively affects congestion in the city center. Congestion in London is diminished because of the limited availability of vehicles allowed to enter the city. However, materials still need to be transported. 90% of the goods handled in London are transported by road (TfL, 2019). The total number of kilometers traveled by road is increased by 39% over the past 25 years (TfL, 2019). This is because industrial sites are pushed towards the city's edge as there are less expensive locations. This seems evident economically, but it increases the congestion as more kilometers must be traveled for the same materials. The municipality has a system that manages all the 6,300 traffic signals in London, which updates every 15 minutes (TfL, 2019). People are investigating the option to optimize this system by helping the vehicles on crucial freight routes in the city. These extra services could include new traffic signal strategies to reduce delays for freight vehicles at certain times (TfL, 2019).

Safety

Heavy trucks that transport materials in London significantly impact the fatalities. Although they make up less than 5% of the total vehicle kilometers driven in London, they were involved in 25% of the pedestrian fatalities and 63% of the cyclist fatalities (TfL, 2019). The busiest walking and cycling times overlap with freight vehicles' peak times. The municipality created a program that emphasizes safe vehicles, safe speeds, safe streets, and safe behaviors to improve these numbers. The city will issue permits to heavy trucks and ban trucks that have too many

blind spots (TfL, 2019). An example is that logistic construction plans will prevent left-turning maneuvers when vulnerable people, such as in school areas and cycling paths.

Stockholm

As mentioned in the introduction, Stockholm is the capital of one of the most sustainable countries in the world, with more than 50% of its energy consumed by renewables and a strong focus on intelligent solutions and electric buses (Berry, 2021). Stockholm uses 100% of its energy from its operated renewable sources, has 99% of its solid waste recycled, and consists of 1/3 green area, 1/3 water, and 1/3 built area (VisitStockholm, 2022). Stockholm is, without doubt, one of the leading cities in the world from a sustainability perspective.

The city center of Stockholm has a medieval part, which is relatively small. The more significant portion of the city center went through a radical transformation between 1955 and 1980. Older buildings were replaced by newer architecture, and this was again modernized in 2007 (Olgarsson, 2009). As the more significant part of Stockholm's city center is relatively modern, it is perfectly suitable for developing green city logistics. The focus on construction logistics will also play a more critical role in the future, as in 2019, 140,000 extra homes need to be built by 2030 (StockholmCityPlan, 2019).

Current process of Material, personnel, and equipment

39% of the total greenhouse gas emissions within the city of Stockholm's boundary were created by road transport. Out of this, 39% was 66% emitted by cars, 15% by light trucks, and 13% by heavy trucks (Landahl, et al., 2020). Since about 75% to 80% of commuting is currently done by cycling, foot, or public transport, Stockholm has successfully reduced car use over the past 25 years (Landahl, et al., 2020). However, the increased demand for housing and renovation enhanced the need for proper construction logistics. More than 50% of the goods transported in Stockholm buildings are materials such as gravel, sand, stone, and soil.

Innovations

Streets are equipped in Stockholm with loading and unloading spots for transportation companies to reduce the impact of logistics on the quality of life (StockholmCityPlan, 2019). A requirement for doing this is that sufficient space in a city center is needed. Another initiative that Stockholm has successfully implemented is the congestion tax. The congestion tax is a tax that needs to be paid per timing interval that you are in the town with your car. Dynamic pricing lets you pay more to drive around during rush hours compared to nighttime (TransportStyrelsen, 2022). Dynamic pricing was introduced in 2007 and led to a 20% reduction in traffic to and from the inner city. It also reduced traffic in the town by around 10-14%, while Stockholm's population grew by 20% at the same time (Landahl, et al., 2020). Dynamic pricing positively impacts the logistic construction sector, encouraging construction companies to plan their logistic stream carefully to make their projects more profitable.

Like other cities, Stockholm has an increasing focus on transport on the water as it is environmentally more efficient (StockholmCityPlan, 2019).

Policy results

Transporting building materials such as gravel, sand, stone, and soil over water could reduce the amount of CO2 emission by 2,000 tons CO2 per year throughout the construction period (StockholmCityPlan, 2019). This drastically reduces the amount of transport by road but managing the materials at the waterfronts will compete with other uses at the shoreline locations, such as residential buildings and recreational areas. This trade-off still needs to be made.

Sustainability

Looking at regulations, Stockholm is a frontrunner from an environmental perspective. An example is that public transport is required fossil accessible vehicles for many years now and has occupancy levels (StockholmCityPlan, 2019). Besides that, the goals of Stockholm are more extreme than other cities. The local government aims to be climate positive and entirely fossil-free by 2040 (Landahl, et al., 2020). One of the methods is the clean vehicles program of Stockholm, which a local government body has led since 1994 (Civitas, 2020). The program introduced monetary incentives for clean vehicles by providing tax discounts and subsidies.

Congestion

To optimize the traffic flow, Stockholm has a two-sided approach. Firstly, high-capacity modes of transport are prioritized in areas where private cars cause congestion. Secondly, the overall number of transportation movements needs to be reduced, especially short journeys in dense urban areas (StockholmCityPlan, 2019). Innovative digital solutions will give priority. Another initiative that will reduce congestion is the creation of the 'Stockholm Bypass,' an additional highway that will connect the Northern and Southern parts of the city to reduce traffic in the city center (StockholmCityPlan, 2019).

Safety

Besides the Swedish front running status on emissions by traffic, they already implemented a 'Vision Zero' initiative in 1997, intending to reduce traffic accidents and fatalities to zero (Kristianssen, Andersson, Belin, & Nilsen, 2018). The project has been successful, as the fatalities by road accidents have been halved since its implementation (GOS, 2019). The initiatives taken to decrease the number of deaths are the creation of more roundabouts, many

roads that have central barriers to prevent head-on accidents, many speeding cameras, and redesigning cities with a stronger focus on vulnerable road users (GOS, 2019).

Discussion

Hypotheses testing

The hypotheses have been tested by thoroughly studying the city-specific behaviors of Amsterdam, London, and Stockholm and by the survey of construction workers and interviews with the municipality of Amsterdam and the construction wholesalers.

Hypothesis 1: There is a common goal for all stakeholders in the construction delivery industry

Interviews with the construction workers showed that they are not driven by sustainability except for a few exceptions. Sustainability and congestion are closely linked, as many extra Greenhouse gas emissions are emitted indirectly by city congestions. Both are therefore equally important for municipalities. In general, according to the survey conducted in Amsterdam, construction workers are not interested in sustainability. A remark should be made that a similar survey has not been conducted in London and Stockholm. Construction workers in London and Stockholm might have different views on this, but this is a confounding variable since no interviews were conducted there. Overall, it can not be assumed that sustainability is a common goal for all three stakeholders. Similar answers came upon the open question 10 about the problems construction workers experienced. Many construction workers mentioned: 'too much time spent on logistics,' 'shortage of employees,' 'difficulties to reach the construction work.' This is also shown in the other answers. Around 60% of the interviewees are 1 to 3 times a week at construction wholesalers, and about 25% of the interviewees 4 to 6 times. Around half of them state that they spend 30 minutes, but 25% state that it costs them more than 1,5 hours. It can be said that many construction workers are eager to increase their effectiveness by achieving logical efficiencies. The municipality is against the many different

vans that drive through the cities. Construction wholesalers are not opposing the idea of making the cities more efficient. They just want to offer optimal service to their customers. ‘If the need of our clients (the construction workers) is that they need help with their logistical efforts, we can help them’ (Bouwmaat, 2022).

A common goal for all stakeholders is that they want efficiency improvements. First, municipalities want to reduce congestion in the city centers by reducing the number of rides. Besides that, construction workers want to reduce the time spent on logistical efforts to devote more time to their work and earn more. Lastly, construction wholesalers just want to make as much as possible. They see that they can earn more by providing extra service to their customers; if increasing efficiencies manage that, the wholesalers are eager to jump on board. One of the interviewees mentioned that they are already testing by ordering materials online and arranging a smooth pick-up to arrange for an improved process for the construction worker. Besides the extra service for the customer, it makes planning for the wholesaler easier because the workload can be divided between peak and non-peak times. Hypothesis 1 is accepted.

Hypothesis 2: Bundling materials can reduce the transportation movements in the construction sector and still work positively for the construction worker.

As discussed in the case studies of Amsterdam, London and Stockholm, construction hubs are often used. Construction hubs' goal is to reduce transportation movements by optimizing the last mile delivery and delivering the materials bundled. The municipality is giving subsidies and providing strategically good places to construction hubs. The interviews with the construction

wholesalers showed that a distinction needs to be made to make a proper evaluation here. Construction hubs are ideally suited for larger new-build projects since the ordering of materials happens carefully, adequately planned, and extensively. Independent contractors and less planned often perform renovation construction, on the other hand. The interviewed construction workers mainly worked for renovation construction and stated that bundling goods would take too much time. However, they are open to helping with their supply chain-related activities and improving efficiency.

Undoubtedly, bundling materials are beneficial for the number of transportation movements in city centers. Results from several cities showed the positive impact they can make. They can also positively impact the construction worker, as bundling materials can be attractive economically. Construction workers, specifically in the renovation sector, need to improve their planning capabilities. Without proper planning and timely notification, construction wholesalers will not be able to prepare pick-up orders in an orderly manner.

From the perspective of the party that will pick up, bundle, and delivers the goods, they must do that for an economically attractive price and trustworthy. The stakes in construction projects are high, and sometimes, missing a specific component can delay a project, which possibly costs more than many deliveries. The efficiency of the construction worker can thus be improved by bundling goods. However, there are some confounding variables. An example is the type of construction work the construction worker has. The benefits of bundling goods can vary. A second confounding variable is the timing need of the products. If a speedy delivery is crucial, consolidating materials will not benefit the construction worker. Nevertheless, hypothesis 2 is also accepted.

Hypothesis 3: Zero-Emission transportation solutions are suitable for the logistic industry

The case studies and interviews showed a clear outcome. Construction workers almost all say 'no' to whether Zero-emission vehicles could work for them. The reasons are loading capacity, reach, and price. However, the interviews and case studies showed many different outcomes. Stockholm has much more experience with ZE transportation, and especially the interview with the Technische Unie from Amsterdam showed extraordinary results. They recently ordered 14 Light Electric Vehicles for inner-city building material deliveries, and they have planned to order 14 more for another large city in the Netherlands. The pilot showed that these vehicles move faster through the city because of their narrow size, causing less congestion as other cars can easily pass on small streets, and their reach is good enough (Santos, 2022). Also, heavy equipment is successfully transported by electric trucks as more and more construction wholesalers are replacing their diesel trucks with electrically driven trucks. Some variables that play a significant role in defining whether ZE emission vehicles are suitable are the distance needed to travel, the charging time of the vehicle's battery, and the vehicle's loading capacity.

Zero-Emission transportation solutions are suitable for the logistic industry in city centers. Governments should promote the use of ZE vehicles just like cities such as Stockholm are doing. Outside city centers, ZE emission vehicles do have limitations since a heavier load drastically impacts the reach of the vehicles. Loading times are still relatively long, concluding that electrically driven vehicles are not always optimal. However, the results from the Netherlands show that ZE vehicles can work very efficiently in city centers (Santos, 2022). Although several limitations, zero-emission vehicles are suitable for construction logistics. Hypothesis 3 is also accepted.

Hypothesis: 4: Software for city logistics and planning will make it easier for construction workers to adapt to changing city logistics

Software is a more complex subject. The interviews with the construction workers showed that only a few used software for back-office activities, but none used software for planning logistics. The only software they used was their navigation app to bring them to the project. The observation that construction workers did not use the software was confirmed in the interviews with the construction wholesalers and the municipality's view on construction workers.

The example from the UK that the government developed a BIM framework for data sharing across sectors was not known in Amsterdam. Also, the use of digital twins was not used by construction workers to increase their effectiveness in the renovation sector.

This was surprising since many delivery companies, such as UPS or FedEx, are working with advanced software solutions to minimize the traveled kilometers as much as possible. They also give real-time updates about their location and expected delivery time to increase customer satisfaction (Blank, 2021; UPS, 2020). Sketching a delivery company to the construction worker that delivers supplies driven by software did not seem to make them happy. Possible reasons for that are that construction workers don't like change, are not familiar with digitalization, or have negative experiences from the past with missing components that make them skeptical. Eventually, the construction sector will change, but the construction industry is not ready for digitalization. It should be taken into account that only Dutch construction workers were interviewed. Cultural differences could impact the ability to adapt to software quickly. Hypothesis 4 is rejected.

The hypotheses will eventually form the basis of answering the main question. The project's objective is to find out the best way to innovate this very old-fashioned, rigid sector and reduce GHG emissions in city centers as much as possible.

Viable logistic solutions

The main question - *Which innovative solutions can reduce the transportation movements and emissions in the construction sector in Europe?* - can be answered by the case studies and interviews. The tested hypotheses lead to the answer

1. Innovative government policies

Government policies play a significant role in the speed of market change (govUK, 2009). The municipality of Amsterdam is waiting on initiatives from the market, but when construction workers are not forced to adjust their behavior, they will not change it. A good example is Stockholm, where dynamic pricing actively promotes driving outside rush hours and could cause market parties to develop innovative solutions. This will become an economic driver to change the behavior of the construction worker. As Stockholm has focused on environmental regulations since 1997, a better look should be taken to other governments. A passive stance is not practical.

2. Vehicle innovations

Vehicles play a significant role in changing the logistic construction sector. Delivery vans are used to transport personnel and ad-hoc equipment. Box trucks, heavy trucks, and crane trucks are heavier loaded and more often adequately planned. As delivery vans are currently the

smallest commonly used vehicle, there is room for a modern, smaller, and lighter vehicle for construction logistics. A vehicle that has shown to be practical and well suited for construction logistics in urban areas is the Light Electric Vehicle that the Technische Unie in the Netherlands uses. Electrically driven vehicles are well suited for delivering these materials.

Another excellent innovation for heavier vehicles is the system placed in vehicles in London to reduce waiting times on crucial freight routes in the city. Environmental improvements can be made by adequately equipping heavier trucks with software that facilitates waiting times at traffic signals.

3. Bundling of construction materials

Bundling materials have shown to be effective in Amsterdam, London, and Stockholm. However, this mainly focuses on new build construction logistics and less on renovation construction logistics. Finding a method to involve all three stakeholders must come from an efficiency point of view. This is a common goal for all stakeholders involved. The solution could be to bundle goods at the construction wholesalers and deliver them to city centers. To make this a success, the following two factors are crucial.

First, the planning process of construction workers in the renovation construction sector should be improved. Currently, the decisions on what materials are needed are made in a late stadium. That decision needs to be made earlier. It is not likely that software solutions could have a role in this in the short term.

Second, no mistakes can be made in the process at the wholesaler. The stakes for construction workers are high, so the cancellation of deliveries or missing specific components could have

high indirect costs. The process should function properly, and an emergency express delivery service should serve as a backup in particular scenarios.

If these two factors can be solved, market initiatives make efficiency steps possible.

Conclusion

Attention to construction logistics is increasing. The construction market is not as mature as other markets from an innovation perspective. The research showed that all stakeholders in the construction industry want to improve their efficiency, and generally, bundling materials could facilitate this. Logistic solutions are much easier for new build projects than renovation projects. The behavior of construction workers plays the most significant role in this. Future research could be done on the behavior of construction workers. Focusing on their needs, pain points, and experience with current construction logistics could potentially lead to a solution that helps the planning. Proper government regulations can stimulate the eagerness to change their current behavior. Vehicle innovation will improve the logistic experience for the construction workers and people living in city centers experiencing congestion problems daily. This research confirmed that zero-emission vehicles are suitable for this. But the biggest challenge remains how to change the construction workers' behavior. Digital planning tools are available but not widely used by the interviewed construction workers. Solving the lack of planning capabilities for construction workers in the renovation sector could potentially lead to a market transformation. Besides additional research on the construction worker, more case studies could be done in other cities in Europe.

References

AmsterdamlogisticCityhub. (2022, April 2). *A logistical dream come true*. Retrieved from Amsterdam Logistic City Hub: https://www.amsterdamlogisticcityhub.nl/en/construction/

AmsterdamVaart. (2020, November 4). *Logistiek over water*. Retrieved from Port of Amsterdam: https://www.portofamsterdam.com/sites/default/files/2020-07/Amsterdam%20Vaart%21%202020%20Infographic.pdf

Berry, I. (2021, October 21). *Top 10 Greenest Countries*. Retrieved from Sustainability Magazine: https://sustainabilitymag.com/top10/top-10-greenest-countries-2

Blank, Z. (2021, February 22). *How FedEx Drivers Optimize Their Routes (And Their Biggest Hurdle)*. Retrieved from Get straight away: https://www.getstraightaway.com/blog-posts/how-fedex-drivers-optimize-their-routes-and-their-biggest-hurdle

Bouwmaat, J. (2022, January 22). Manager supply chain and technology. (D. d. Boer, Interviewer)

Bruyninckx, H. (2017, December 15). *EEA*. Retrieved from Cleaner air benefits human health and climate change: https://www.eea.europa.eu/articles/cleaner-air-benefits-human-health

CBS. (2022, Januari 1). *Hoeveel bestelauto's zijn er in Nederland?* Retrieved from Centraal Bureau voor de statistiek: https://www.cbs.nl/nl-nl/visualisaties/verkeer-en-vervoer/vervoermiddelen-en-infrastructuur/bestelautos

CIOB. (2020, December 20). *Construction Management*. Retrieved from £35bn of public projects 'suitable' for kit-of-parts approach: https://constructionmanagement.co.uk/35bn-of-public-projects-suitable-for-kit-of-parts-approach/

Civitas. (2020). *Making urban freight logistics more sustainable*. Retrieved from https://civitas.eu/sites/default/files/civ_pol-an5_urban_web.pdf

Collier, C. (2015). Construction's complete logistics solution: an idea that is just in time. *Logistics & Transport focus*, 30-32.

ConstructionIndex. (2022, April 8). *The construction index*. Retrieved from London returns to being world's priciest place to build: https://www.theconstructionindex.co.uk/news/view/london-returns-to-being-worlds-priciest-place-to-build

de Groot, C., Verweij, K., Hoen, A., Otten, M., Den Breejen, J., & Verbeek, M. (2017). *Gebruikers en inzet bestel auto's Nederland.* Delft: TU Delft.

DutchHousingPolicy. (2022, April 1). *Ministry of the interior and Kingdom Relations*. Retrieved from Sustainable Households: https://www.dutchhousingpolicy.nl/topics/sustainable-households

EEA. (2022, Februari 22). *EEA greenhouse gases - data viewer*. Retrieved from Greenhouse gas emissions: https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

Foremoresupplies. (2022, April 13). *Construction material delivered within 1 hour*. Retrieved from Foremore: https://www.foremoresupplies.com/

Frazer, R. (2021). *Volker Wessel*. Retrieved from Bouwmaterie,l: https://www.dinalog.nl/wp-content/uploads/2016/04/Ron-Frazer.pdf

GainPro. (2021). Infrastructure construction Benelux. *Gainpro*.

GemeenteAmsterdam. (2020, April 1). *Maatregelen Amsterdam Autoluw*. Retrieved from Amsterdam: https://www.amsterdam.nl/parkeren-verkeer/agenda-amsterdam-autoluw/maatregelen-amsterdam-autoluw/

GLAFleet. (2022, April 16). *London Assembly*. Retrieved from Mayor of London: https://www.london.gov.uk/questions/2019/19811

GLobalAllianceReport. (2020). *Global Status report for buildings and construction*. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/34572/GSR_ES.pdf

GOS. (2019, October 14). *Government offices of Sweden*. Retrieved from Vision Zero - no fatalities or serious injuries through road accidents: https://www.roadsafetysweden.com/about-the-conference/vision-zero---no-fatalities-or-serious-injuries-through-road-accidents/

govUK. (2009). *Government in market. Why Competition matters - a guide for policy makers*. Retrieved from UK government: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/284451/OFT1113.pdf

GovUk. (2022, April 4). *Planning and construction contacts*. Retrieved from Transport for London: https://tfl.gov.uk/info-for/urban-planning-and-construction/urban-planning-and-construction-contacts

Herincx, G. (2022, April 29). *Pros and cons of running an electric van*. Retrieved from Admiral: https://www.admiral.com/magazine/guides/van/pros-and-cons-of-running-an-electric-van

HMGovernment. (2020, December). *The Construction Playbook*. Retrieved from Cabinet Ofice: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/941536/The_Construction_Playbook.pdf

IBM. (2020, Devember 4). *IBM Think*. Retrieved from Cheat sheet: What is Digital Twin?: https://www.ibm.com/blogs/internet-of-things/iot-cheat-sheet-digital-twin/#:~:text=%E2%80%9CA%20digital%20twin%20is%20a,to%20help%20decision%2Dmaking.%E2%80%9D

IPCC. (2018). *pecial Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and effo*. Retrieved from IPCC: https://www.ipcc.ch/sr15/chapter/glossary/#:~:text=The%20zero%20emissions%20commitment%20is,surface)%20and%20carbon%20cycle%20inertia.

Kristianssen, A.-C., Andersson, R., Belin, M.-A., & Nilsen, P. (2018, March). Swedish Vision Zero policies for safety – A comparative policy content analysis. *Safety Science*, pp. Volume 103, March 2018, Pages 260-269.

Landahl, G., Tolf, J., Sunnerstedt, E., Porso, C., Lonngren, O., Rydstedt, T., & Ericsson, J. (2020, May 25). *Climate action plan*. Retrieved from https://international.stockholm.se/globalassets/rapporter/climate-action-plan-2020-2023_ta.pdf

Luman, R. (2019). *Tijdperk van zero-emissie breekt aan voor trucks.* ING.

Manthey, N. (2021, February 15). *Electrive*. Retrieved from Dutch municipalities to set-up zero-emission zones by 2025: https://www.electrive.com/2021/02/15/dutch-municipalities-to-set-up-zero-emission-zones-by-2025/

Manville, M., Taylor, B., & Shoup, D. (2022, May 3). *Traffic Congestion: Three Big Questions, Three Short Answers*. Retrieved from UCLA: https://www.its.ucla.edu/news/for-the-press/traffic-congestion/

Moran, D., Pichler, P.-P., Zheng, H., Muri, H., KLenner, J., Kramel, D., . . . Gurney , K. (2021, September). *Estimating CO2 emissions for 108 000 European cities*. Retrieved from essd.copernicus.org: https://essd.copernicus.org/articles/14/845/2022/essd-14-845-2022.pdf

NASA. (2022, March 15). *Global Climate Change Vital signs of the planet*. Retrieved from The effects of Climate Change : https://climate.nasa.gov/effects/

NECP. (2019, May 28). *Climate Policy* . Retrieved from Government of the Netherlands: https://www.government.nl/topics/climate-change/climate-policy

NOS. (2021, November 28). *VvE's soms bang voor elektrische auto in garage, weren mag niet*. Retrieved from NOS: https://nos.nl/artikel/2407360-vve-s-soms-bang-voor-elektrische-auto-in-garage-weren-mag-niet

Odedun, A., Nellis, S., Mathers, N., Nomoto, K., Nermond, O., Gibbs, H., & Nelson, T. (2021, March). *Achieving net zero*. Retrieved from Future of London : https://www.futureoflondon.org.uk/wp-content/uploads/delightful-downloads/2021/03/Achieving-net-zero-report-1.pdf

Olgarsson, P. (2009). *Recording and characterizing the modern city centre of Stockholm.* Stockholm: The Stockhol city Museum.

Ondernemersplein. (2022, May 6). *KVK*. Retrieved from Starten als zzp'er in de bouw in 5 stappen: https://ondernemersplein.kvk.nl/starten-als-zzper-in-de-bouw-in-5-stappen/

Parool. (2021, December 3). *Op 1 dag 2 doden: wanneer verdwijnt de vrachtwagen uit de spits*. Retrieved from https://www.parool.nl/amsterdam/op-1-dag-2-doden-wanneer-verdwijnt-de-vrachtwagen-uit-de-ochtendspits~b6cbc6e0/

Ploos van Amstel, W. (2022, March 31). *London: using the river Thames for light freight*. Retrieved from City logistics: http://www.citylogistics.info/uncategorized/london-using-waterways-for-light-freight/

PloosvanAmstel, W. (2020, Januari 27). *Bouwlogistiek gebaat bij strengere regelgeving*. Retrieved from BNR nieuwsradio:

https://www.bnr.nl/vanonzepartners/bouwenaandetoekomst/10400780/slimme-logistiek-in-de-bouw

PortofAmsterdam. (2020, November 4). *Local construction logistics by water*. Retrieved from Port of Amsterdam : https://www.portofamsterdam.com/en/business/cargo-flows/local-construction-logistics-water

Ritchie, H., & Roser, M. (2019, November). *Urbanization*. Retrieved from Our World in Data : https://ourworldindata.org/urbanization

Robbins, S. (2017). The need for London's Construction Consolidation Centre. *Logistics & Transport Focus*, 44.

Santos, T. (2022, April 5). Sustainable Business Development Manager Technische Unie. (D. d. Boer, Interviewer)

StockholmCityPlan. (2019). *Stockholm City Plan.* Stockholm: Stockholms Stad.

Sutton, J. (2021, September 24). *Construction sector must move further and faster to curb carbon emissions, say engineers*. Retrieved from Royal Academy of Engineering: https://www.raeng.org.uk/news/news-releases/2021/september/construction-sector-must-move-further-and-faster-t

SWOV. (2017, April 18). *Manifesto: 'Make road safety a national priority'*. Retrieved from Institute for road safety research: https://swov.nl/en/nieuws/manifesto-make-road-safety-national-priority

TechnischeUnie. (2021, May 10). *Emissievrije stadlogistiek in onze binnensteden*. Retrieved from Duurzaamheid: https://www.c.technischeunie.nl/duurzaamheid/emissievrije-stadslogistiek-binnensteden.html

TfL. (2019, March 12). *Freight and servicing action plan*. Retrieved from TFL: https://content.tfl.gov.uk/freight-servicing-action-plan.pdf

Theunis, R. (2020, Septemner 9). *"Amsterdam Vaart": Port as a hub for construction logistics*. Retrieved from Amsterdam Economic Board: https://amsterdameconomicboard.com/nieuws/amsterdam-vaart-port-as-a-hub-for-construction-logistics/

TLN. (2021, November 18). *Stads logistiek*. Retrieved from TLN: https://www.tln.nl/thema-stadslogistiek/

TNO. (2021, November 5). *Duurzame bouwlogistiek leidt tot aanzienlijke vermindering kosten, bouwtijd, hinder en schadelijke uitstoot*. Retrieved from Dinalog: https://www.dinalog.nl/slimme-bouwlogistiek-leidt-tot-aanzienlijke-vermindering-kosten-bouwtijd-hinder-en-schadelijke-uitstoot/

TransportStyrelsen. (2022, April 5). *Hours and amounts in Stockholm*. Retrieved from https://www.transportstyrelsen.se/en/road/road-tolls/Congestion-taxes-in-Stockholm-and-Goteborg/congestion-tax-in-stockholm/hours-and-amounts-in-stockholm/

UNFCCC. (2016, November 4). *The Paris Agreement*. Retrieved from United Nations Climate Change: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

UNPopulation. (2018, April 11). *The Wold's Ctities in 2018: data booklet*. Retrieved from UN digital Library: https://digitallibrary.un.org/record/3799524

UPS. (2020, January 29). *UPS To Enhance ORION With Continuous Delivery Route Optimization*. Retrieved from UPS: https://about.ups.com/ae/en/newsroom/press-releases/innovation-driven/ups-to-enhance-orion-with-continuous-delivery-route-optimization.html

van Merrienboer, S., Kin, B., Quack, H., van Rijn, J., & de Vries, J. (2020, December). *Outlook renovatienouw*. Retrieved from TNO topstector logistiek: https://www.topsectorlogistiek.nl/wptop/wp-content/uploads/2021/02/Outlook-Renovatiebouw.pdf

van Rijn, J., Rondaij, A., van Merrienboer, S., Kin, B., & Quak, H. (2020, November). *Outlook bouwlogistiek*. Retrieved from TNO topsector logistiek: https://www.topsectorlogistiek.nl/wptop/wp-content/uploads/2021/02/Outlook-Bouwlogistiek.pdf

VisitStockholm. (2022, April 5). *Stockholm – leading the way in sustainability*. Retrieved from Visit Stockhoknm: https://professionals.visitstockholm.com/why-stockholm/artiklar-till-why-stockholm/sustainability/

Wolfert, H. (2022, April 1). *How can the historic quay walls of Amsterdam be(come) future-proof?* Retrieved from Amsterdam Institute of advanced metropolitan solutions: https://www.ams-institute.org/urban-challenges/resilient-cities/how-can-historic-quay-walls-amsterdam-become-future-proof/

Wuebbles, D. D. (2017). *limate Science Special Report: Fourth National Climate Assessment, Volume I.* USGCRP. Retrieved from Fourth National Climate Assessment (NCA4), Volume I: https://science2017.globalchange.gov/

WWF. (2022, January 28). *Effects of Climate change*. Retrieved from World Wild Life: https://www.worldwildlife.org/threats/effects-of-climate-change#:~:text=More%20frequent%20and%20intense%20drought,on%20people's%20livelihoods%20and%20communities.&text=As%20climate%20change%20worsens%2C%20dangerous,becoming%20more%20frequent%20or%20severe