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Feasibility of an Urban Consolidation Centre in Bergen?

Transferability of best practice

Ertti Kaskelainen

Supervisor: Stein W. Wallace

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NORWEGIAN SCHOOL OF ECONOMICS

Abstract

Transportation sector is responsible for the majority part of non-quota emissions in Norway. The local government in Bergen has introduced several measures to reduce the number of polluting passenger cars on the streets. The CO_2 emittance of automobiles has been significantly reduced by incentivizing cleaner vehicles and fuels and promoting the use of public transportation. However, when it comes to vehicles used for transportation of goods the phasing-in of greener fuels lacks behind scalable technology, and due to freight transportation being a commercial matter, the organization of it is trusted in private hands. That leads to inefficient practices as a growing number of freight vehicles unutilized for their load factor are imitating each other's movements, creating congestion, and competing for already limited space with other road users. These inefficiencies contribute to local air pollution and noise emissions, while putting vulnerable road users at risk. Negative externalities of freight transportation have a measurable cost to society and call for better optimization on the movement of goods. Urban Consolidation Centre (UCC) is a potential solution to these inefficiencies and has been used as a measure for improving freight flows in many countries around Europe and the rest of the world. However, even though the environmental gains of UCCs are positive, often-times these initiatives fail to reach the break-even point economically. Replicating the success of a UCC that does have an economically sustainable business model requires analysing the enabling conditions that facilitated its effectiveness.

Contents

List of graphs

List of figures

1. Introduction

1.1 Motivation

The European Commission (EC) has updated its policy framework to meet Europe's commitments in becoming climate neutral under the Paris Agreement by 2050. The new climate target plan for 2030 seeks to reduce emissions by at least 55% compared to 1990 levels (European Commission, 2020). The European Union (EU) is Norway's most important trading partner, ultimately affecting Norway's operations. The Norwegian Government is cooperating with the EU and has committed to a 50-55% reduction in emissions by 2030. Since the inception of the European Union Emissions Trading System (EU-ETS) in 2005, Europe's emissions divide into quota and non-quota categories. In 2019 the total Norwegian emissions were nearly evenly[1] split between ETS and non-ETS emissions. The Norwegian Government has committed to the EU's planned 40% reduction in non-ETS emissions by 2030 but has a national ambition of reducing 45% from the non-quota emissions budget. The largest share (60%) of non-ETS emissions in Norway comes from the transportation sector. Thus, to facilitate such a sharp decline, the Government's goal is to reduce transportation emissions for the year 2030 by half compared to 2005 levels. (Ministry of Climate and Environment, 2021).

European transportation policy framework is aligned with the abovementioned ambitions to significantly reduce greenhouse gas emissions. European Commission's *White Paper on transport* (2011) defined a strategy for near-zero emissions in urban logistics by 2030. Planned objective in reducing transportation sector's carbon intensity requires a combination of many initiatives on all levels. Official guidelines for planning urban mobility and transportation in Europe have been laid out in *Sustainable Urban Mobility Plan* (SUMP) and *Sustainable Urban Logistics Plan* (SULP). The purpose of these documents is to share transnational knowledge, establish best-practices and guide urban planning processes. (Aifandopoulou & Xenou, 2019). Relevant guidelines presented in a Norwegian context are laid out in multiple publications in accordance with the *Sustainable Urban Logistics Plans in Norway* (NORSULP) project (Fossheim, 2020).

[1] A statistical mistake caused the number of non-quota emissions to be underreported, thus the emissions reduction needs to be even more drastic for Norway to meet its climate goals. https://www.nrk.no/norge/alvorlig-statistikkfeil-ga-for-lave-norske-utslipp-1.15458645.

1.2 Methodology

Transferability analysis is a process of evaluating the potential of an effective implementation of a measure to a target city. The prior is that the measure has already been successfully applied in an originator city. The process analyses several aspects affecting potential implementation. Following the transferability methodology can provide valuable lessons from past experiences. The mere fact that the measure has been successfully implemented before is not a sufficient argument for transferring. To reproduce the success in a different environmental, geographical, socio-economic, legal, and institutional background, principal factors of success and the conditions they were achieved under must be addressed. (European Commision, 2016).

1.3 Outline

Before arriving to the transferability of a best practice, a couple of topics need to be explored in greater detail. Firstly, a general overview of urban freight transportation is given in the beginning of Chapter II. Principally, the need for urban freight measures to tackle some of the inefficiencies in goods transportation is explained. One measure in particular – the Urban Consolidation Centre (UCC) is presented as the primary method for dealing with the negative externalities caused by urban freight movements.

Secondly, the need for such measures in the target city is evaluated in Chapter III. The latest WHO Air Quality Guidelines (WHO, 2021) are visualized in the local context, and discussed from the perspective of long- and short-term effects on the population. Then, the strengths and weaknesses of local government's strategy in dealing with the externalities of transportation is analysed. Finally, the transferability analysis is conducted to assess the conditions under which the best practice was successfully implemented in the originator city and compare it to the current corresponding conditions in the target city.

2. Literature Review

In this chapter, relevant theories concerning urban freight transportation are presented. The first part is a short introduction that explains the need to regulate freight movements. In the second part, different regulative measures that effectively deal with negative externalities are outlined. After that, a specific freight consolidation measure (UCC) is given particular focus from the perspective of its viability. Finally, a framework for transferability is presented that guides decision-making in choosing the best practice.

2.1 Urban freight movements

Urban traffic flows have concerned researchers since the 1950s when growing dependence on automotive vehicle transport started to shape our contemporary way of life. Industrialization of the automotive sector and large-scale construction of roads made motor vehicles a widespread form of transportation, resulting in a fast-paced urbanization process. However, in the designing and construction phase of those new urban areas, the focus of urban planners was on transportation of people, not goods. By the same token, the early research by academics and interest by policymakers was also mainly from the transportation of people perspective, thus neglecting freight transportation and leaving it in the hands of private stakeholders driven by market forces, consequently enabling inefficient freight movement practices to blossom. (Gonzalez-Feliu, 2018; Noortman, 1984; NMOAH, 2019).

Those inefficiencies were described by Cadotte & Robicheaux (1979) as the emergence of a large number of freight carriers, often mimicking each other's vehicle routes with partially filled trucks. The ineffectiveness of that behaviour results in needlessly high congestion of roads, heightened environmental emissions, increased energy consumption, air pollution, noise, and accidents. With constant market developments, such as the rise of e-commerce, there is a growing demand for more deliveries in urban areas, increasing expectations of more flexibility, speed, and variety from the transportation service providers. That leads to greater fragmentation of shipments transported by a multitude of vehicles that are not optimized for their load factor. (OECD, 2003). Therefore, the movement of goods is seen as one of the main propagators of negative aspects in urban transport, raising the need for authorities to develop appropriate measures to help socially optimize freight transportation movements. Effective policy instruments aim to reduce the negative externalities of freight transport while improving the efficiency of the distribution system. (Button & Pearman, 1981; Noortman, 1984).

2.2 Urban freight measures

Choosing the right measures is not a simple task of just focusing on eliminating the negative effects on society and the environment. The benefits of freight transport are indisputable, as freight transport is an essential part of stimulating the economic vitality and social functioning of an urban area (OECD, 2003). Therefore, urban logistics must be regarded as a multidimensional problem driven by constant developments in economic activities, influenced by the introduction of new technologies and changes in consumer behaviour, but at the same time optimized for environmental sustainability and liveability of cities. This multidimensionality is most apparent when considering the different stakeholders in urban logistics: city dwellers, shippers, freight forwarders, carriers, business owners, and city planners - all with diverging and often conflicting interests, operating within limited urban spaces. The conflict between commercial interests and environmental sustainability gives great importance to establishing working public-private partnerships to cultivate common objectives and solutions. (OECD, 2003; Dufour & Patier, 1999).

Allen & Browne (2011) emphasize the need for national policies coupled with local measures for successful sustainable urban development strategies. This kind of alignment is important, because a top-down strategy may safeguard that local sustainability measures do not result in target area's reduced economical attractiveness when compared to neighbouring areas. Therefore, the local policy measures are dependent on the social, economic, and environmental goals of the national authority. Button & Pearman (1981) considered a suitable policy to involve a Pareto improvement, meaning that if a change to the status quo is beneficial for at least one member in the group while not negatively affecting the others, then the policy is desirable for all stakeholders.

Extensive European and international scale research into best urban freight practices got underway in the 90s and has continued ever since. Many projects and programs (e.g., CIVITAS, BESTUFS, CITY LAB, SULP, and many more) have been established to gather expert knowledge on freight transportation, establish pilot projects and create initiatives, collect data, and evaluate the effectiveness of various measures. (Allen & Browne, 2010;

Whiteing, Browne & Allen, 2004) Some of the most frequently used policy instruments that have been successful in reducing adverse environmental effects are:

Regulatory measures:

- Access restrictions: based on vehicle size, weight, or time of day.
- Environmental zones: promotion of cleaner, less noisy, more energy-efficient vehicles.
- Off-peak deliveries: shift congestion problems to off-peak or night-time hours and promote using quieter vehicles.

Market based measures:

- Tolls, access permits, congestion charging, indirect subsidies, or national taxes on polluting engines.

Technological measures:

- Information systems: for improving efficiency of logistics operations. Intelligent transport systems (ITS), information communication systems (ICT), dynamic vehicle routing, new vehicle technologies.
- Clean fuels and vehicles: gradual shift to electric vehicle technologies, biofuels, usage of cargocycles, but also a modal shift to cleaner transportation through waterways and railways.

Land-use planning measures:

- Urban planning – integrating freight transportation into planning policies by developing adequate parking spaces and logistics zones.

Management measures:

- Consultation processes and labelling schemes: raising awareness by creating forums of discussion among stakeholders. Giving labels to freight companies that use clean vehicles.

Infrastructure measures:

- Off-street loading bays - targeting inefficiencies created by the double-parking of delivery vehicles.

- City Logistics/consolidation centres - logistics facilities from where consolidated loads make the final leg of the delivery. (Allen & Browne, 2010; Whiteing, Browne & Allen, 2004; OECD, 2003; Letnik, Marksel, Luppino, Bardi, & Božičnik, 2018; Dablanc, Patier, González-Feliu, Augereau, Leonardi, Luppino, Levifve, Simeoni & Cerdà, 2015).

Whiteing et al. (2004) stress that these measures may have considerable synergies between each other, thus could be implemented simultaneously with beneficial outcomes resulting from potential complementary effects on one another. Letnik et al. (2018) confirm these synergies in their comprehensive literature review of sustainable and energy-efficient policies and measures in European cities. In a comparison of 30 cities, the authors find that an optimal combination of measures can result in a 60-70 percent reduction in CO^2 emissions, thus significantly contributing to the EU Commission's ambitious emission reduction goals from the transportation sector. In addition to that, their analysis suggests that cities are mainly focusing on soft measures that entail low-medium costs and initial investment while achieving medium-high results. However, the most frequently proposed measures were consolidation centres, and clean fuels and vehicles, which are typically considered to be rather expensive options but effective in reducing adverse social and environmental effects in urban freight transport.

2.3 Urban consolidation centres

Different freight consolidation measures are frequently mentioned as potential solutions to improve environmental conditions and efficiency of urban freight transport processes (Noortman, 1984). The present thesis focuses on terminal consolidation, where freight consolidation happens in a planned manner at an agreed-upon transfer centre. The most frequent umbrella term in recent literature for this type of consolidation is the afore-mentioned UCC (Browne, Sweet, Woodburn & Allen, 2005). The gist of the UCC is mentioned by Button & Pearman (1981) who discuss transhipment depots that operate at the entrance point of an urban area, consolidating shipments from vehicles destined to various destinations within the city onto vehicles destined to a limited number of final destinations. Browne et al. (2005) add to this definition in their description of UCCs by describing the UCC operator's role as sorting and consolidating loads from various logistics companies and making final deliveries often by environmentally-friendly vehicles.

Using a consolidation centre can positively influence the inefficient freight transport practices discussed in previous sections. Consolidation onto smaller vehicles operating with high load factor can reduce the number of trips and total distance traveled by freight carriers, which leads to reduced environmental and noise emissions and less interactions between transport vehicles and pedestrians, thus improving liveability in urban areas. In addition, fewer vehicle movements offer economic benefits beyond freight transport operations, as the time and space saved by transportation vehicles occupying kerbside reduces traffic congestion and speeds up other economic activity (Browne, Allen & Leonardi, 2011; Quak, Kok, & de Boer, 2018).

According to Allen and Browne (2010), apart from reducing external costs, some of the main advantages of a UCC based consolidation system are:

- Improved planning of logistics operations – opportunity to introduce information systems along with the UCC to further optimize freight movements. Better use of resources.
- Additional options in supply chain management – feasible to shift from push to pull logistics. Possible to improve inventory control and product availability.
- Potential to connect with broader policy and regulatory initiatives.
- Wide range of value-added services – such as: secure storage, order preparation, pre-retailing, inventory management, reverse logistics and many more.

Whereas some of the common disadvantages of UCCs are the following:

- Potentially high set-up and operating costs – especially if the consolidation centre requires construction of new facilities in an expensive area.
- Ability to handle a wide range of goods – different handling and storage requirements make it difficult to handle a wide array of freight. For example: food and perishable goods require different storage conditions compared to stationery items.

- Additional stage in supply chain – can impose time and cost penalties depending on how well the UCC is integrated into the supply chain. Moreover, this additional stage can create security, customer service, and liability issues when another company has taken charge of handling last-mile of the freight transportation cycle.

- Diversion from regular routes – depending on the location of the UCC, some suppliers might have to deviate from their normal routes, which can mean additional costs.

- Lack of enforcement of regulations – often, the participation in the scheme is voluntary, thus making economies of scale unattainable if the conditions for participation are not economically beneficial.

2.3.1 Participation type

The success of a UCC is dependent on how big share of the target market is participating in its core business process of consolidation. Authorities can control the number of participants through legislation by making the use of the consolidation centre mandatory for everyone operating in the target business area. The near equivalent of enforcing the use of UCC are stringent access restrictions that prohibit access to the operating area for all vehicles that are not part of the UCC scheme. Consequently, these control mechanisms that compel the use of a UCC can lead to complex political and legal disputes, thus have been regarded as less desirable. The majority of the UCCs have been based on a voluntary participation type where the authorities generally encourage consolidation through monetary incentives such as subsidies or less stringent access restrictions such as time-based entry. In those cases, the imposed restrictions or incentives can drive the participants to see possible benefits in using the consolidation centre. (Allen, Browne, Woodburn & Leonardi, 2012; Zelenska & Švadlenka, 2019; Whiteing et al., 2004).

Allen et al. (2012), in their international literature review, classified UCCs into three categories based on the operation type and operating area: UCCs in the first category serve all or part of an urban area, whereas, in the second category, the definition is narrower focusing on large sites with a single landlord. The third category concerns construction projects that are most often operational for a limited time. A major difference when comparing the first category with others is in ease of governance. For example, a single landlord or a construction site developer can enforce participation in the consolidation scheme by implementing the use of the UCC as an internal part of the business process. However, in the majority case of a UCC serving all or part of an urban area, the decisions affect multiple independent actors who are often without a common goal or aligned business practices, thus making participation much more difficult to impose for the governing body.

The main reason why UCCs fail is attributable to the low level of acceptance among the private sector, which is the same even for participation schemes where regulatory power is strong (Gonzalez-Feliu, 2018). The success of mandatory participation often lies in the ability of the imposing organization to control or significantly influence the carriers and receivers involved in the scheme. However, that is more readily achievable in large sites with a single landlord such as hospitals, shopping centres, or airports. (Allen et al., 2012).

In the case of UCC serving part or all of an urban area, the local authorities can encourage or mandate participation with the help of restrictive supporting measures. An example of encouragement with less-stringent measures comes from La Rochelle, where deliveries to the historic city centre for vehicles over 3.5 tons are allowed only from 06:00-07:30 in the morning, thus driving the carriers to see economic benefits in shipping through the local UCC instead. On the contrary, very strict measures can essentially create a monopoly for the UCC vehicles in the operating area. An equivalent to that was enforced in the historic city centre of Vicenza, where access was gradually prohibited to all delivery vehicles not part of the municipal consolidation centre. (Dablanc et al., 2015)

In both municipalities, urban freight transportation was made a public service assigned to their respective consolidation centres. However, in the case of Veloce Vicenza, legal action followed, as the transport operators organized and questioned the validity of the stringent policy in court. Ultimately, the Italian State Council ruled in favour of the municipality's right to restrict the free movement of freight delivery vehicles in historical centres. The ruling was partly based on environmental arguments that derive from regulations concerning freight movements in European cities, thus creating a precedent for municipalities that might use stringent policies to protect the environment in the future. For cities with a proactive stance towards rationalizing urban freight movements, this case showcased the willingness of large express carriers (active all over Europe) to go through extensive and costly legal procedures to protect their bottom line. (Ville et al., 2013).

2.3.2 Participation level

Considering mandatory participation is relevant, because the number of companies participating in a consolidation scheme has direct influence on decreasing truck traffic, increasing load factors, and improving the overall efficiency of urban goods transport (Holguín-Veras & Sánchez-Díaz, 2016). Reducing congestion and improving freight travel time are considered as important attributes for local citizens and freight companies, respectively (Sanz at al., 2018). However, implementation of a consolidation centre does not guarantee less vehicle movements in urban areas if the participation level is low. Allen et al. (2012) note, that when UCC operations are scaled to serve a large part of an urban area, the reduction in total freight traffic may be limited, especially if the use of the UCC is voluntary, as the total freight activity in the urban area would be dependent on the proportion of the freight going through the UCC.

From a theoretical perspective, Veličković, Stojanović & Pantović (2021) analysed various UCC alternatives with participation based on monetary attractiveness compared to a "business as usual" situation without a UCC. The results showed that total distance travelled by freight vehicles was higher than the status quo in all proposed UCC scenarios. However, they noted that the results could be more insightful when different delivery vehicle types and utilization rates are added in the model. The latter was implemented in research by Mepparambath, Cheah & Courcoubetis, (2021) who analysed the impact of a UCC on the number of freight trips made to a retail district with two consolidation centre locations - inside and outside the retail district. Different capacity utilization scenarios (1/3, 2/3 and 3/3) and participation levels (10, 50 and 80%) were used to test the sensitivity of freight trip impact ratio. The main finding was the existence of a critical participation level that needs to be reached for a UCC based scheme to start performing less trips in the district. In the case of a UCC being inside the retail district, the freight trip impact ratio was less responsive to growing participation levels and number of deliveries made per trip, however in a scenario where the UCC is outside the retail district, the number of trips within the district were greatly reduced at growing participation levels.

Evaluation of case studies yield complementary results. Clausen, Geiger & Pöting (2016) evaluated four UCC pilots in different European countries. They found that a critical mass of participation is needed to derive full potential off capacity utilization and to reduce total distance travelled. Furthermore, authors Vaghi & Percoco (2011) by analysing measures in Italian cities, concluded that congestion decrease could happen if a large part of the total freight traffic is participating in the consolidation scheme, however major access restrictions to the operating area (which promote the use of UCC) were the pivotal factor in achieving this in the example of Veloce Logistic in Vicenza.

2.3.3 Business model

A financially sustainable business model entails profit after costs are deducted from revenues, which compels the UCC to obtain enough revenues by pricing its services to the extent that they cover the costs. However, that requires those services to offer real benefits for the companies participating in the consolidation scheme (Van Duin et al., 2016). For shippers, receivers, and carriers, benefits for participation are often zero-sum. Consequently, the additional cost of consolidation is seldom economically feasible for those stakeholders, making it very difficult to find a suitable business model that satisfies all parties. Local authorities counteract this issue by heavily subsidizing the UCC's operations. Inevitably, oftentimes when the subsidies end, so does the consolidation scheme (Kin et al., 2016).

Past experiences have shown that initial public funding for research work and pilot studies are necessary for the UCC concept to be realized. In addition, Time-limited subsidies are often used to give the scheme a competitive edge. Nevertheless, the UCC should be centered on a financially sustainable business model on a medium-long term basis without any government subsidies involved. However, if the scheme's primary motivation is reducing adverse environmental effects, hypothecated taxes from other transport-related sources such as road pricing and congestion charging could be used to cover the costs of core UCC operations (Browne et al., 2005). Achieving longevity without implementing public financing as an integral part of the business model requires clearly defining the value of the UCC, who benefits from its use, and who is willing to pay for those benefits (Clark & Hyllenius Mattisson, 2016).

As highlighted in previous parts, urban freight movements affect a multitude of stakeholders: the municipality, carriers, receivers, consumers, and city dwellers – all with a different perceived value of UCCs services. Van Duin, Van Dam, Wiegmans, & Tavasszy (2016), have developed a framework (ORKB) to analyze the added value that a UCC creates for its stakeholders. The framework can be seen as a complementary tool to the Business Model Canvas (BMC) developed by Osterwalder & Pigneur, as it provides insight beyond UCC's organizational boundaries and traditional buyer-supplier relation. The authors claim that the business models of the stakeholders are not likely to change after the introduction of a UCC. Therefore, the value is believed to be created in business interactions that correspond through a business model overlap. That gives great significance to recognizing value relationships between the stakeholders when designing viable business models (Van Duin et al., 2016).

Björklund, Abrahamsson & Johansson (2017) identified several critical factors for viable business models in UCC schemes. They stress that viability is about comprehending the business environment in the framework of a complex urban logistics system, and the ability to constantly adapt the business model. In their analysis, three factors with highest importance were recognized: high utilization of the UCC, role of advanced information systems in the design and development of the UCC, and logistics competence to access potential value streams.

2.3.4 Lessons learned

Lagorio, Pinto & Golini (2016), analyzed 83 UCCs and found that the main common factors for success were: involvement of stakeholders, two-echelon distribution scheme, involvement of a logistics provider whose core business does not entail urban goods distribution, and presence of strong access restrictions to the operating area. Moreover, they identified common characteristics in failed projects, namely: high ownership costs, and lack of participation by stakeholders. The least satisfied stakeholders were the carriers who saw consolidation centre as a top-down solution that leaves them out of decisional processes. This notion is supported by the findings of Navarro et al., (2016) who analyzed consolidation centre initiatives in Barcelona and Valencia. They found that the main challenge was to reach agreements with transport operators.

A couple of examples from UCC concepts that were established to serve a specific district in an urban area are outlined below. Both initiatives share commonalities of: retailers not receiving rationalized shipments; traffic related congestion, air pollution, noise emissions, and conflicts between pedestrians and freight vehicles. (Allen et al., 2012). The main difference between the initiatives is that Binnenstadservice is a receiver-based consolidation solution, while RegLog® was a carrier-led consolidation scheme.

Binnenstadservice 2008-

An example of a sustainable UCC business model is Binnenstadservice (BSS) from Nijmegen, Netherlands. A time-limited subsidy was granted by the local municipality for the first two years after which BSS became private. The model is receiver-based, as BSS's core customers are small retailers who pay a standard fee to receive the goods at their time of choosing by clean vehicles. The retailers change their receiving addresses to that of BSS and from then on receive shipments from their suppliers through the Binnenstadservice UCC. Apart from the standard delivery, BSS offers value-added services such as home deliveries (for large items), stock holding, delayed cross-docking, and retour logistics, among others (Van Duin et al., 2016). Financial viability has replaced environmental gains as a key driver of BSS, as they have reduced the number of partners from up to 160 to 55 due to some retailers having difficulties in meeting the payments charged for BSS's services (Björklund et al., 2017).

The value proposition of BSS to public authorities manifested in the reduction of delivery vehicles in the city centre, and improvement of road safety. Moreover, a decrease in congestion and CO_2 emittance was documented. However, there was no significant reduction in NO_2 and PM_{10} concentrations. From the receivers' perspective, the value proposition manifested in reliable and responsive service offered in a secure manner. In addition to that, BSS's value-added services provided further flexibility to the receivers and saved them time that can be invested in improving efficiency in their respective stores. (Van Duin et al., 2016).

The BSS system works because small independent retailers generally do not receive optimized deliveries. Therefore, the UCC offers them real value by bundling the products and offering additional flexibility via on-demand deliveries. Moreover, due to the deliveries being last-mile only, there is a significant reduction in the time frame the retailers receive their products (Van Duin et al., 2016). Similar retailer dynamics are evident in Italy's historic city centres where many self-supplied store owners and small truck companies make deliveries with an exceedingly low load factor. Numerous UCCs have been established to combat this inefficiency. However, compared to BSS, where participation is up to the retailers themselves, the Italian local authorities have been much more proactive in imposing the use of the consolidation centre through access restrictions. (Dablanc et al., 2015)

RegLog® 1998-2012

An example of a working UCC solution that came to a bitter end is from Regensburg, Germany. The problem statement concerned optimizing goods transportation in the historic city centre where high density of commercial activity is conducted within a relatively small area (1 km^2) on characteristic medieval streets not designed for large vehicles competing for space with pedestrians. Surveys carried out in 1996 by a local stakeholder (BMW Group) revealed the potential for streamlining freight flows and saving vehicle trips to the inner-city area. (NSEP, 2017).

The RegLog® concept was initiated by BMW Group that felt social responsibility as a car manufacturer to promote ideas and innovation on how to optimize traffic flows in cities. In cooperation with the University of Regensburg, City of Regensburg and several local carriers and receivers the bundled delivery project started in 1998. The concept was rather simple: instead of multiple carriers making independent deliveries to the centre, bundled deliveries from the RegLog® UCC left every morning with a fully loaded truck (or occasionally two) to the operating area. Apart from delivering to the city centre, the truck(s) participated in a waste disposal service and deliveries out of the centre, thus entering and leaving the city efficiently with a full load. RegLog® partners networked their shipping data through a telematic solution TeleLog which made it easy to optimize routes, even on time sensitive deliveries. (BMW Werk Regensburg, 2012)

The UCC project was initially managed by BMW that acted as a neutral moderator and a contact between the carriers and the UCC. That responsibility was later shifted to municipal logistics institutions financed by the City of Regensburg. The participation type was voluntary, thus the stakeholders needed to present a good business case to attract new participants. Generally, the more participants the bigger synergy effects to be harvested. However, many international carriers were not interested in participating. (BMW Werk Regensburg, 2012).

After the economic crisis of 2007-2009, there was a sharp decline in inner-city deliveries, while the costs of the participating companies went up. Competition against the parcel service companies became more challenging. The operations continued for 3 years with negative balances, culminating with the termination of the consolidation program in 2012 due to economical infeasibility. Extending the operations by introducing permanent subsidies was not seen as a desirable solution. Environmentally RegLog® was a success, because it saved 23 tons of CO_2 by avoiding around 70 000 truck kilometres. (Koller, 2012).

2.3.5 Micro-consolidation centres

Two conflicting trends are taking place in freight transport. On the one hand, long-distance routes are more efficient and sustainable when vehicles are scaled up in size to increase capacity. On the other hand, sustainable logistics in urban areas often require downscaling the transport modes to counteract the negative externalities generated by larger vehicles (ALICE, 2015). A logistics system that considers those conflicting trends is called the two-echelon system. The first echelon takes place at a UCC by the city borders, where freight is consolidated. The second echelon is situated at proximity to the operating area where vehicles from the UCC unload the cargo onto smaller clean vehicles/tricycles or leave it to be picked up for delivery by foot. (Van Duin & Muñuzuri, 2015). This system was demonstrated to work in a research paper by Browne, Allen and Leonardi (2011). An office supplies company trialled a change where their regular delivery scheme of seven diesel-engine vans making rounds in London city centre would be switched to electrically assisted cargo-cycles and electric vans. In the first echelon, an 18-tonne freight vehicle would start a rationalized round from the suburban depot (UCC). The vehicle would then travel to the city centre to unload the goods onto clean vehicles in a micro-consolidation centre (MCC). This operational change saved 54% CO_2 emissions per parcel. However, the total distance travelled in the operating area increased, because the lower capacities of the clean vehicles.

In a recent research paper, authors Katsela, Pålsson & Ivernå (2021) evaluated environmental impacts in a city logistics consolidation comparison of four scenarios. The article is part of a case study concerning a city logistics initiative SamCity, in Malmö, Sweden. The initiative aimed to create a financially viable business model that entails rationalized freight movements combined with value-added services. A significant contribution from the authors is quantifying the costs of externalities in different consolidation scenarios. Necessary data to establish the model's baseline scenario was recorded by observing vehicle movements in the city centre for a total of 24 hours during one week. The first scenario (Figure 1) indicates no consolidation based on the observations. In the second scenario, instead of final customers, all the freight vehicles deliver to the MCC from where consolidated rounds with an electric light lorry are made. The third scenario assumes that transport companies consolidate their freight in their own terminals before delivering to the MCC. However, in the fourth scenario, transport companies ship to the UCC, where goods are rationalized and transferred to the MCC with a heavy truck.

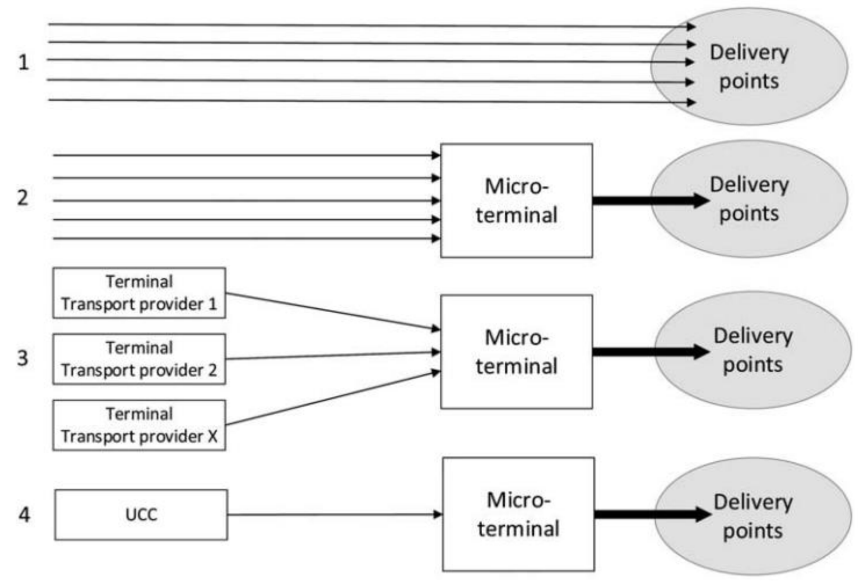


Figure 1. Freight flows in four consolidation scenarios. (Katsela, Pålsson & Infernå, © 2021)

For understanding the environmental impact of consolidation, the authors estimated the number of vehicles, vehicle kilometers, and the corresponding emissions (CO_2, NO_x & PM) for all four scenarios. Then, the emissions were monetized as per information from European Commission's handbook. The costs of externalities in the baseline scenario were calculated to comprise around 60-70% of the total transport costs in the SamCity initiative. Compared to the baseline scenario, costs of externalities in scenario 2 increased by 20% due to extra vehicle kilometers caused by deviations from regular routes. However, there are considerable reductions (30%) in the third scenario compared to the baseline, as the freight is consolidated before entering the MCC. Finally, the most successful was the fourth scenario, where cargo is sorted and consolidated in a UCC on the city's periphery before being delivered to the MCC and distributed by an electric vehicle. The reductions were 70% in that case. Quantification of externalities in monetary terms allows a better understanding of the overall costs in a business model. Consequently, it can pave the way to a positive business case and should be considered a critical factor in creating a viable business model. (Katsela, Pålsson & Ivernå, 2021)

2.4 Transferability framework

Macário & Marques (2008) have developed a logical 10-step process for transferability of sustainable urban mobility measures between cities.

1. Diagnostic of the problems.
2. Characterization of the city.
3. Analysis of the city context and implications of problems identified.
4. Searching for similar contexts.
5. Selecting examples of source urban contexts.
6. Identify measures with the potential for transferring.
7. Packaging and dimensioning the measures for transferring.
8. Ex-ante assessment of measures to transfer.
9. Identify the need for adjustment.
10. Implement measures and steer results.

Successful implementation of measures or an array of measures, applied under conditions in a comparable setting, should make a potential transfer feasible (Macário & Marques, 2008). Based on the theoretical findings from this chapter, the UCCs with sustainable business models that do not depend on direct government financing, and the ones that may be supported by authorities via favourable regulations or indirect subsidies are considered for transferability. The following chapters of the thesis are written in accordance with the steps outlined above.

3. Bergen

In this part of the thesis, the author will analyse relevant characteristics of the target area to validate the necessity for a consolidation scheme. In the first part an overall description of the city is provided, followed by an assessment of local environmental conditions. Then, local measures and government strategy is outlined. Finally, the target area description is formalized and analysed in accordance with the first three steps in the transferability framework.

3.1 City description

Bergen is a city and a municipality located on the west coast of Norway. It is the second-largest city in Norway with over 282 000 inhabitants (Statistics Norway, 2021c). Bergen has a vibrant economy with thriving offshore, maritime, media, marine, finance, shipping, and trade industries, while also being one of the most popular cruise destinations in Europe, thus giving great significance to the tourism industry. Moreover, the public sector plays a considerable role for the city through higher education, research, and many state institutions present. Overall, Bergen is a strong attraction for domestic migration and immigration alike, as the city is expected to grow even by the most modest[2] forecast (Figure 2). (Thorsnæs, 2020; Bergen Kommune, 2020b).

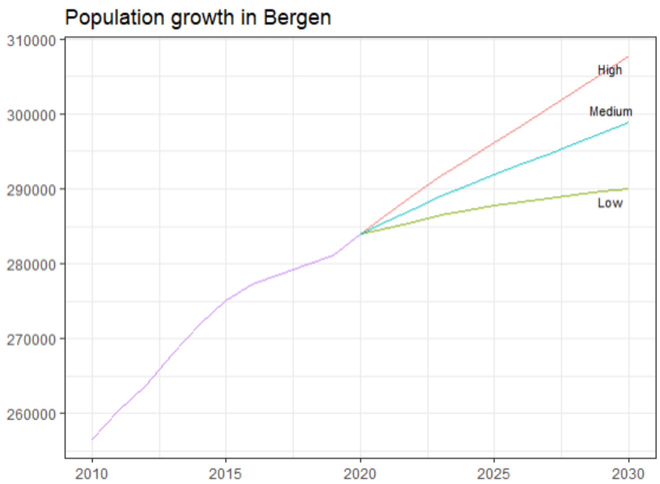


Figure 2. Population forecast for Bergen. (Data obtained from: Statistics Norway, 2021c)

[2] Low, Medium and High forecasts in Figure 1 represent LLML, MMMM, HHMH, respectively. The letters describe levels (Low, Medium & High) in the following order: fertility, life expectancy, domestic migration and immigration.

3.2 Transportation network

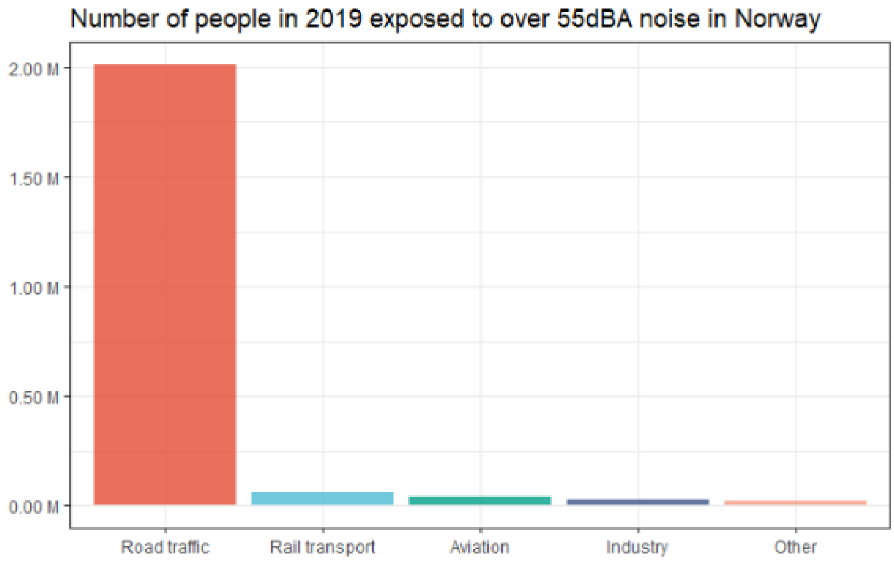
Bergen municipality is spread over a large spatial area consisting of many mountains, fjords, and bays that curtail city planning and road construction (Figure 3). The main highway (European route E39) that connects coastal cities in Southern/Western Norway passes right through Bergen and is the primary source for road-based freight coming from the north (E39), east (E16), and south (E39). Norway's second-largest port and the railway station are situated in the city centre – responsible for handling the vast majority of large-bulk freight. (Norwegian Public Roads Administration, 2017). However, as of 2017, road transport was responsible for 59% of all goods transported in the Bergen region, with 20% coming by railway and 21% by sea (Asplan Viak & NORCE, 2018).

Figure 3. Terrain map of Bergen. (Google, n.d.-a)

3.3 Environmental noise

Exposure to environmental noise is a key public health problem in Europe, impacting the health and well-being of millions. Up to one in five Europeans are exposed to harmful levels of noise pollution. Long-term exposure is estimated to cause 12 000 premature mortalities and trigger 48 000 new cases of ischemic heart disease every year. Prolonged exposure to noise pollution is associated with increased risk of psychological and physiological health effects such as severe annoyance, sleep disturbance, cognitive impairment in children, adverse cardiovascular and metabolic outcomes. (European Environment Agency, 2020). Moreover, researchers have found negative association between long-term exposure to residential road traffic noise and participation in leisure-time sports. That induces physical inactivity which is a burden on public health. (Roswall et al., 2017). The main source of environmental noise in Norway is road traffic, as around 2 million people are exposed to more than 55dBA (Graph 1). Half a million are severely bothered by noise emissions and around 200 000 suffer sleep disturbance (Bergen Kommune, 2015). Heavy vehicles produce noise disproportionately to light vehicles, as one heavy vehicle at 30 km/h can be as noisy as 15 light vehicles. At growing speeds, the differences diminish, and light vehicles dominate the noise emissions due to their high volume. However, heavy vehicles represent the peaks in produced noise which can create disturbances, especially in an urban setting and during nighttime. (Ellebjerg Larsen, 2007).

A strategic noise mapping in Bergen (2012) revealed that 38.2% of the population are exposed to a limit of over 55 decibel noise emissions at their residences, and 12.8% are exposed to a limit of more than 65 dBA. The mapping also revealed that many kindergartens and schools are exposed to high levels of noise emissions. For example, Årstads high school (next to a busy traffic junction in Danmarks plass) had a 74-decibel noise level measured at the façade that is most exposed to traffic generated noise. In total 75 kindergartens and 67 schools were exposed to more than 55 dBA of environmental noise. The Bergen city council suggested zero-emission vehicles, zero-emission zones, electrification of freight transport, reducing total car traffic, and strengthening public transport as some of the measures to tackle this problem. (Bergen Kommune, 2015)



Graph 1. Number of people exposed to more than 55 decibel noise by noise source type. (Data obtained from: Statistics Norway, 2021b)

3.4 Air quality

Bergen's most populated area lies in a relatively deep and narrow valley between mountains up to 643 meters and opens towards a bay. The primary sources of air pollution are road traffic, docking ships at the harbour, and domestic heating with firewood. Hazardous air quality occurs typically during cold winter days with low cloudiness and calm winds. Those conditions give way to an atmospheric condition called temperature inversion, where cool air is trapped below warm air, along with smog caused by pollutants. In such circumstances, local circulations can redistribute the accumulated contaminants and spread them around the central districts of Bergen. Those conditions can last for several days. Consequently, this makes meteorological variations a crucial factor in pollutant concentration levels. (Wolf & Esau, 2014; Wolf, Pettersson & Esau, 2020).

3.4.1 Nitrogen dioxide (NO_2)

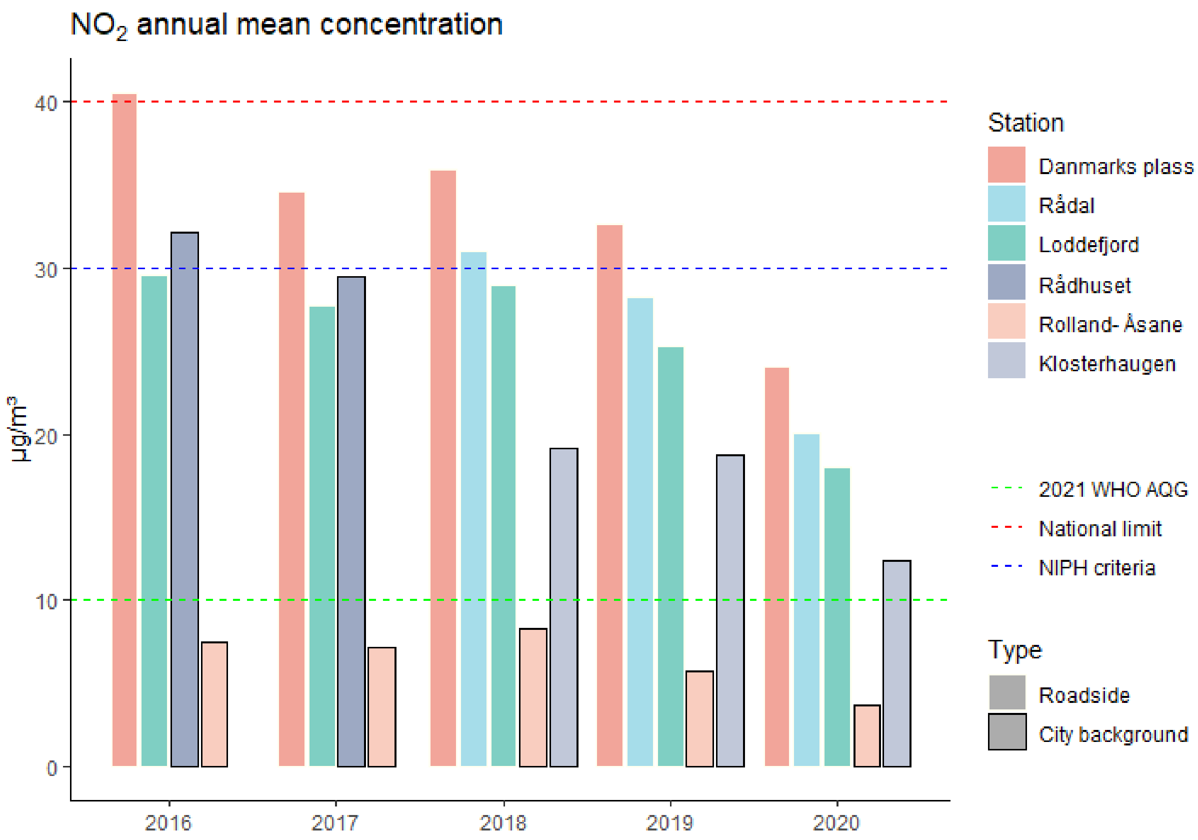
Nitrogen dioxide is a chemical compound formed at elevated temperatures, generally in a combustion process. Exposure to NO_2 can cause changes in lung function and contribute to respiratory illness. (NIPH, 2020). A study evaluating long-term risk of exposure to air pollution on developmental delay in children and teenagers was published in a peer-reviewed journal Atmosphere. Medium and High (18.17-23.90; >23.90 $\mu g/m^3$) groups of nitrogen dioxide exposure were compared to the Low (<18.17 $\mu g/m^3$) group. Adjusted odds ratio for developmental delay and NO_2 exposure were significant for both groups with 1.27 (95% CI: 1.14-1.41) for Medium and 1.40 (95% CI: 1.26-1.55) for High group. (Chen et al., 2021).

The primary source of NO_2 in Norway is road traffic. Diesel engine cars emit more than petrol, while electric vehicles do not emit at all. (NIPH, 2020). Commercial road traffic in Bergen performed by vans and heavy goods vehicles had the highest share (70%) of NO_x emittance in 2015 (Sæther, 2016). The Norwegian Institute for Air Research (NILU) shares open access data from six measuring stations in the Bergen area. These stations automatically measure round-the-clock air quality in the region. Three stations are in close vicinity of roadside, while the rest are situated in a city background setting. Danmarks plass[3] station is near a busy (E39) highway, along with Loddefjord and Rådal stations near highways 555 and 580, respectively.

[3] Danmarks plass is one of Norway's most polluted intersections. https://kommunikasjon.ntb.no/pressemelding/skal-redusere-svevestov-mengden-i-bergen?publisherId=17847490&releaseId=17903402.

The rest of the stations have a city background with Klosterhaugen and Rådhuset located in the city centre, while Rolland- Åsane station is on the periphery of Bergen. All the data used in the following figures (Graph2:Graph4) has been controlled for quality by the local municipalities and the National Reference Laboratory for Air. (NILU, n.d.)

The annual mean concentration of NO_2 for the 2015 to 2019 period is summarised in the figure below (Graph 2). The national limit[4] value for the yearly average outdoor concentration of NO_2 is set to 40 µg/m³, and the National Institute of Public Health's (NIPH) criteria is 30 µg/m³. The latter serves as reference criteria for national health and has been lowered from 40 to 30 µg/m³ in 2020 based on recent studies on long-term exposure to low concentrations of NO_2 (NIPH, 2020).



Graph 2. Annual average concentration of NO_2 in Bergen area stations. (Data from: NILU, n.d.)

World Health Organization (WHO) has derived Global Air Quality Guidelines (AQG) based on an eight-step protocol for AQG development. A systematic review (Huangfu & Atkinson,

[4] National limit values for NO_2, PM_{10} and $PM_{2,5}$ are obtained on May 16th, 2021 from Norwegian law: *Forskrift om begrensning av forurensning (forurensningsforskriften) § 7-6.Grenseverdier for tiltak*

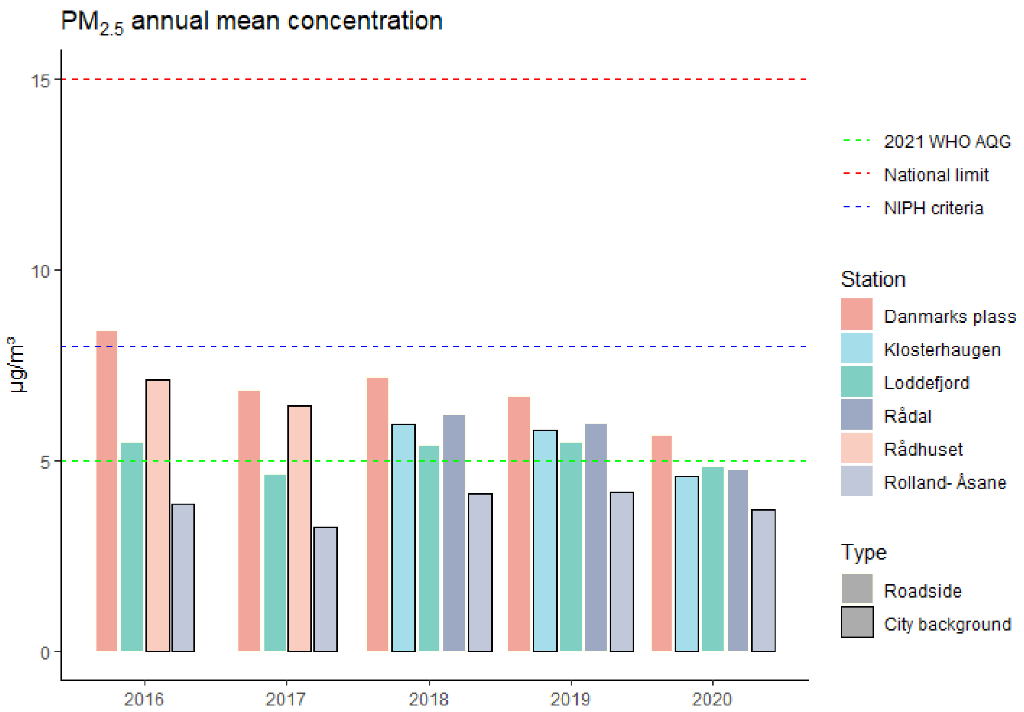
2020) on nitrogen dioxide was commissioned by WHO and published in Environment International (2021) as open access. A relative risk estimate of 1.02 was derived with a 95% confidence interval of 1.01-1.04 per 10 µg/m³ with a linearity assumption for non-accidental mortality due to long-term NO_2 exposure. As per the new evidence, WHO updated their 2005 guidelines by lowering the annual NO_2 AQG level from 40 to 10 µg/m³, along with interim targets 1 (40 µg/m³), 2 (30 µg/m³) and 3 (20 µg/m³). (WHO, 2021). Important to note that the new recommendations by WHO are not relevant to measure success in lowering pollution in Bergen for the past five years, but rather should be regarded as an important indicator about the extent of work that still needs to be done so that even the most tender citizens could breathe the air in the city without detrimental effects on their health.

Danmarks plass measuring station has once had higher annual NO_2 concentration levels than the national limit, while surpassing the new NIPH criteria for every single year from 2016 to 2019. Relatively moderate concentration levels are also observed in the roadside stations of Rådal and Loddefjord. There is considerable difference between NO_2 annual means between Klosterhaugen and Rådhuset stations even though they are within 500 meters from each other, however the former is on an elevation at a quiet neighbourhood five minutes' walk from the centrum while the latter is on the same level with many busy nearby roads in the downtown area. The concentration levels in Bergen area, with an exception of Rolland-Åsane, go well over the new AQG level, however acheiving an annual mean of 10 µg/m³ in a densely populated city area is still far away from realization. That is clear even during the 2020 COVID-19 pandemic year when traffic compared to the previous year dropped significantly (Graph).

3.4.2 Particulates

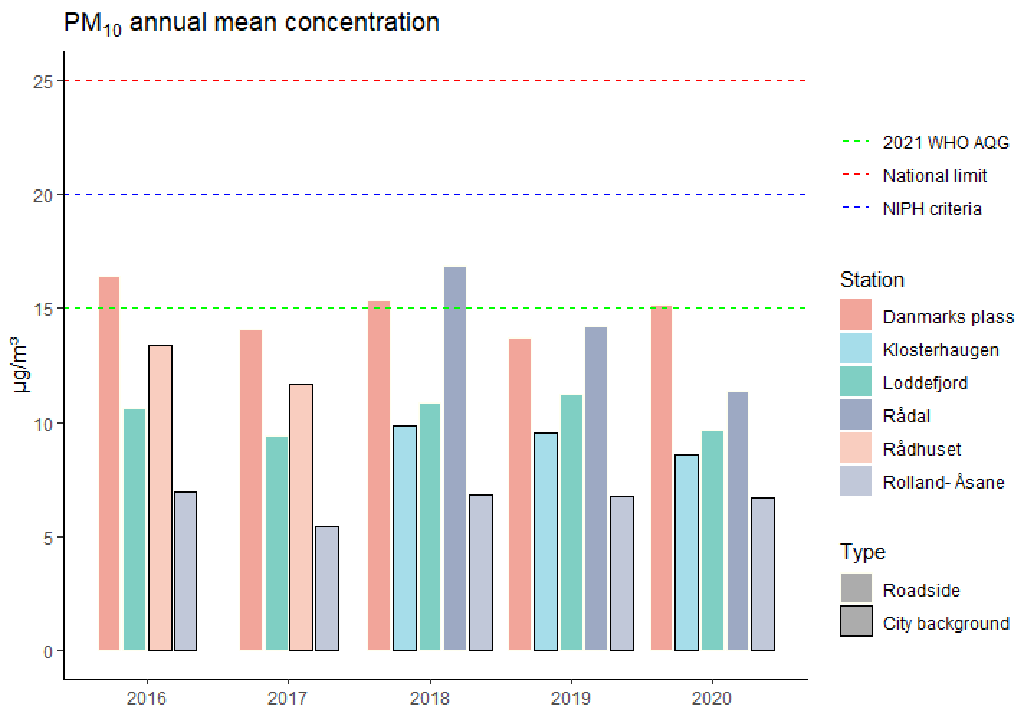
Particulates consist of microscopic airborne particles that originate from combustion engines or abrasion due to mechanical action. Exposure to particulates is one of the leading environmental causes of premature death in the world. Particulate matter varies in size and structure with the groups being labelled by their micrometric size. The main particulates that contribute to pollution in Norway are PM_{10} & $PM_{2.5}$. (NIPH, 2017). The primary sources for $PM_{2.5}$ in Bergen are wood-burning, docking ships and road traffic, and for PM_{10} unsettled road dust and tyre wear. (Wolf, Pettersson & Esau, 2020; Høiskar, Sundvor, Grythe, Johnsrud, Haug and Solli, 2017).

A systematic review was conducted for WHO by Chen & Hoek (2020) on $PM_{2.5}$ and PM_{10} exposure on cause-specific and non-accidental mortality. The combined relative risk for $PM_{2.5}$ and death from natural causes was 1.08 with a 95% CI between 1.06 and 1.09. $PM_{2.5}$ as the exposure metric had significant association with all causes of mortality evaluated, while PM_{10} did not. Use of the GRADE approach for assessing the certainty of evidence, resulted in high confidence for $PM_{2.5}$, while moderate-to low for PM_{10}. Associations with increased mortality, cardiovascular and respiratory diseases, and lung cancer were significant for both particulates. For $PM_{2.5,}$ the associations were significant even below the current annual air quality thresholds of 10 µg/m³, thus resulting in the lowering the recommended level to 5 µg/m³ as per the new air quality guidelines. (WHO, 2021). The national annual average limit in Norway for $PM_{2.5}$ is 15 µg/m³. None of the stations (Graph 3) reached that level in the 2016-2020 period. Current yearly NIPH criteria, that was adapted from 2016, is 8 for $PM_{2.5}$ (NIPH, 2017). The annual levels in almost all measuring stations have stayed well below that norm as well. However, the 2021 WHO threshold value of 5 µg/m³ is surpassed in almost every measuring station except for Rolland-Åsane, but also during the exceptional 2020 pandemic year when transportation dynamics changed due to lockdown measures.



Graph 3. Annual average of $PM_{2.5}$ in Bergen area. (Data obtained from: NILU, n.d.)

The national annual average limit for PM_{10} is 25 µg/m³, while the NIPH criteria is set at 20. None of the measuring stations reached those concentration levels (Graph 4). However, when adding the WHO AQG suggested level on the graph, the threshold is reached in roadside measuring stations on 3 out of the 5 years.



Graph 4. Annual average of PM_{10} in Bergen area. (Data obtained from: NILU, n.d.)

3.4.3 Short-term effects

A systematic review on behalf of the WHO was conducted by Orellano, Reynoso, Quaranta, Bardach & Ciapponi (2020) about the short-term exposure to particulate matter, nitrogen dioxide, and ozone on all-cause and cause-specific mortality. The study found a positive association between short-term exposure to NO_2, PM_{10} & $PM_{2.5}$ and all-cause mortality, and between exposure to particulate matter (PM_{10} & $PM_{2.5}$) and cerebrovascular, respiratory, and cardiovascular mortality. Confidence in evidence by the GRADE metric was rated "high". Compared to the long-term effects, the extent of associations for nitrogen dioxide was lower, as the risk-ratio for short-term NO_2 (24-hour average) and all-cause mortality was 1.0072 with a 95% confidence interval of 1.0059–1.0085 per 10 µg/m³ with a linearity assumption. A non-linear relationship was noted in a few studies with a possible threshold of 37.6 µg/m³. The authors note several possible reasons behind the lower magnitude, suggesting that short-term exposure might be a trigger of long-term mortality and mortality with underlying causes.

WHOs Guideline Development Group (GDG) have suggested a nitrogen dioxide short-term exposure level of 25 µg/m which relative to the new annual threshold of 10 µg/m³ represents the 99th percentile. With a NO_2 risk ratio of 1.0072 per 10 µg/m³ for all-cause mortality, a day with 25 µg/m³ compared to a day of 10 µg/m³ would result in an estimated 1.1% excess mortality. GDG note that in compliance with the recommended annual level, only on a small number of days per year the 24-hour level would be exceeded. A few days in the upper end of the distribution tail would indeed represent merely a small fraction of the total air pollution-induced health burden. (WHO, 2021). A different WHO commissioned systematic review was conducted by Zheng, Orellano, Lin, Jiang, & Guan (2021) on the effects of pollutant exposure and hospital admissions due to asthma. The authors estimated a 24-hour NO_2 risk ratio of 1.014 (95% CI: 1.009-1.019) per 10 µg/m³ which would correspond to a 2.1% excess morbidity when comparing a day with the new annual threshold of 10 µg/m³ to a day with the recommended 24-hour level of 25 µg/m³. (WHO, 2021).

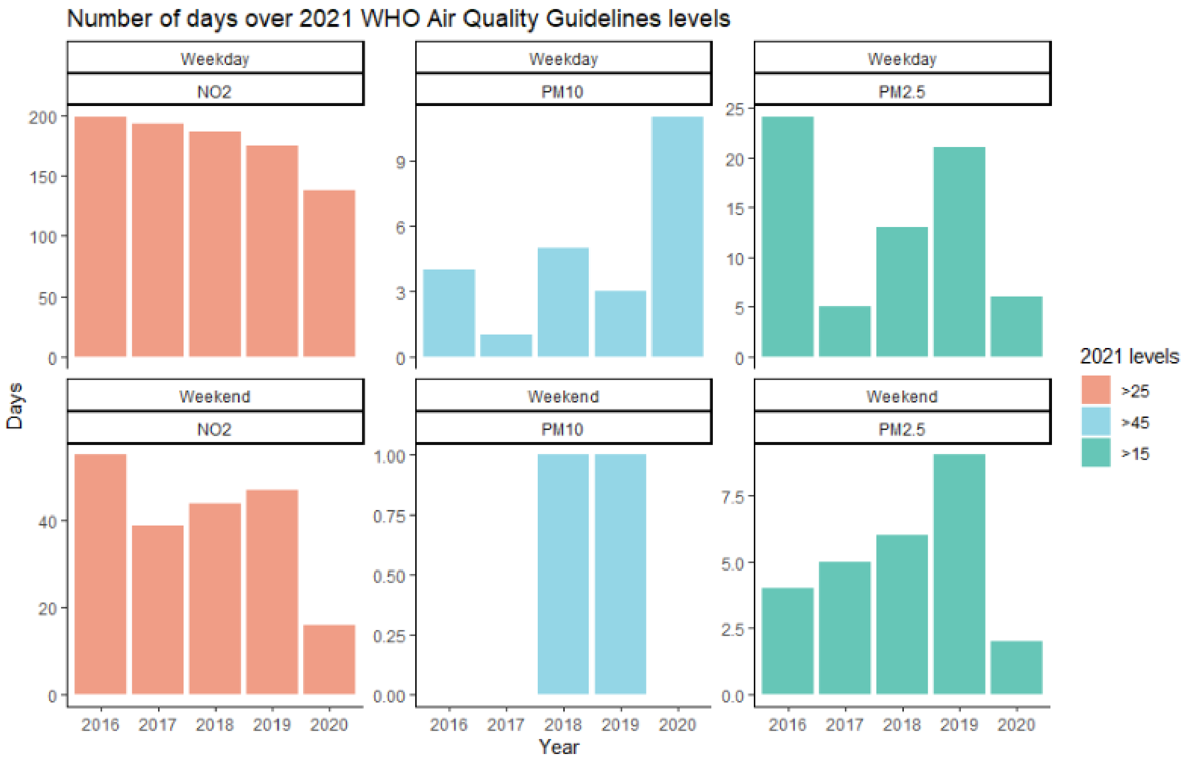
Danmarks plass

The annual concentration levels of the main pollutants are generally well below the national limits and the air quality in Bergen by those metrics is quite good, nevertheless, those are yearly aggregations used for evaluating long-term exposure effects. For short-term effects, the measuring station at Danmarks plass deserves a closer look for its central location not only from the city's perspective, but also for being the passing point for national vehicle movements through the E39 highway. Moreover, the area is surrounded by public transport stops, a school, restaurants, residences, and businesses in a busy area not just for vehicle traffic.

In the Norwegian law regarding air quality, there is no daily limit for NO2 emittance. However, there is a 1-hour limit of 200 µg/m³ which was suggested by WHO AQG in 2005. That threshold is seen as equivalent to 120 µg/m³ per day, which consequently serves as the first interim target for 2021 AQG and is directed at areas where pollution is considered high (WHO, 2021). In Danmarks plass the hourly limit of 200 µg/m³ has been surpassed only on 2 occasions during the past 4 years and the equivalent of 120 µg/m³ per 24-hours has not been surpassed. The number of days[5] in Danmarks plass which would have exceeded 2021 WHO AQG recommended values have been plotted on Graph 5. The desired levels for NO_{2}, $PM_{2.5}$,

[5] Number of missing values (days) from 2016:2020 are NO_2=23, $PM_{2.5}$=14, PM_{10}=17.

and PM_{10} are 25 µg/m³, 15 µg/m³, and 45 µg/m³, respectively. Achieving the suggested nitrogen dioxide level at Danmarks plass appears to be a demanding undertaking, as even during the shock year of 2020 the number of days over that threshold was around 150.

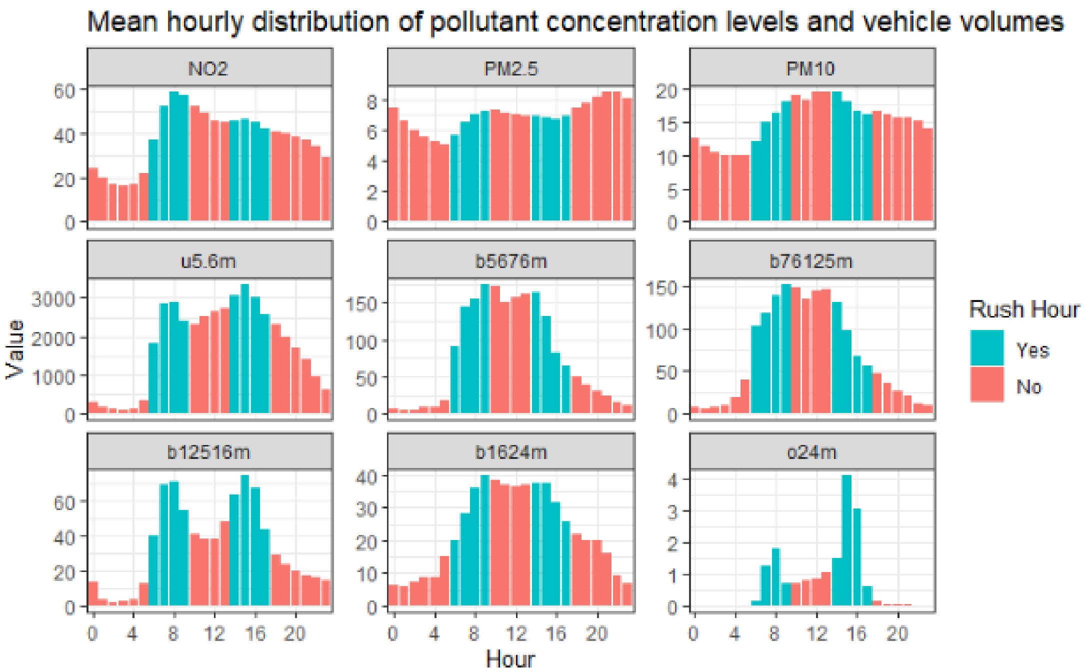


Graph 5. The number of days per year that surpass 2021 WHO AQG daily limits. (Data obtained from: NILU, n.d.)

Comparing the distribution of weekdays to weekends serves as an interesting counterfactual to recognize by how much the fleet would need to change for new WHO recommendations to be achievable on business days. Weekends compared to weekdays (from 2017: 2019) on average saw a 31% drop in light vehicle volume, in contrast to an average of 73% drop in heavy vehicle volume (NPRA 2021a). The Norwegian Public Road Administration (NPRA) collects hourly data on vehicle movements around Norway. Vehicles are distinguished by length and divided into groups of light vehicles (under 5.6 meters) and heavy vehicles[6] (over 5.6 meters). The heavy vehicles are further divided into 5 groups of 5.6-7.6 m, 7.6 - 12.5 m,

[6] The quality of vehicle length data has been under criticism in some of the measuring stations. https://lastebil.no/layout/set/newsletter/Aktuelt/Nyhetsarkiv/2020-og-eldre/2020/De-fleste-trafikktellepunkter-leverer-ubrukelige-tungbildata. In the years 2017:2019 at Danmarks plass, an average of 11 vehicles per hour were not classified, compared to an average of 162 heavy vehicles per hour. The total amount of unclassified relative to the total amount of heavy vehicles was 7%. (Norwegian Public Roads Administration, 2021).

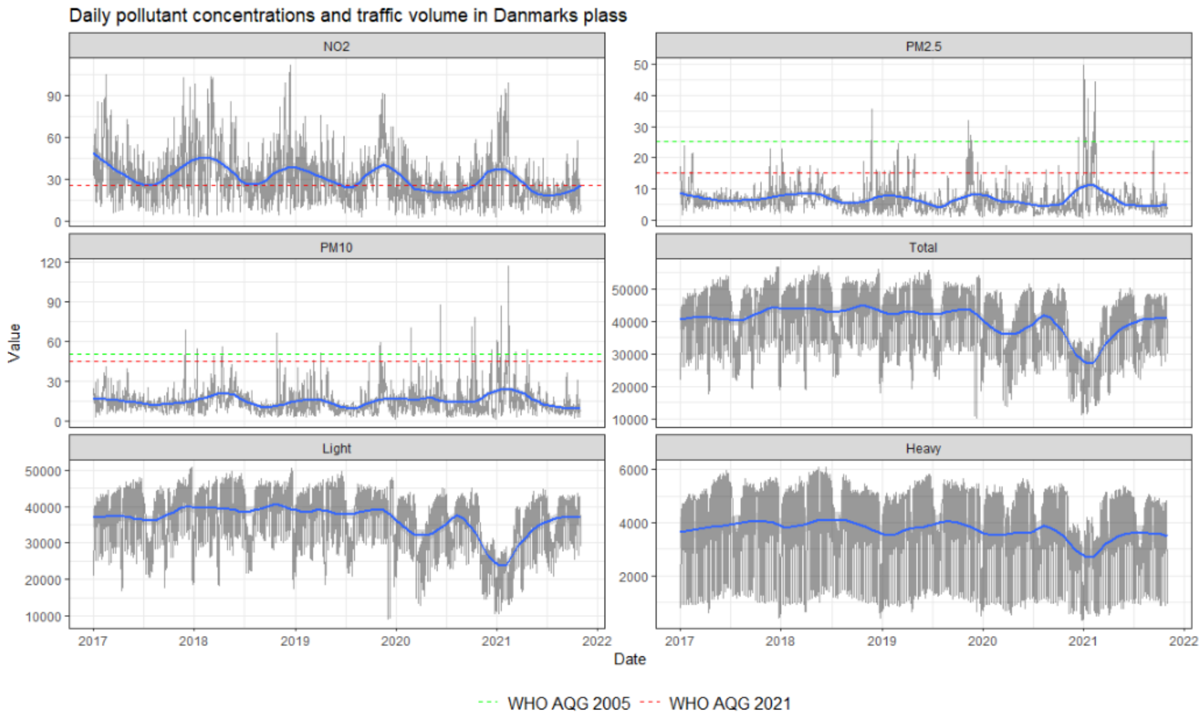
12.5-16 m, 16-24 m, and 24–27-meter vehicles. Those lengths comprise vehicles that make regular rounds around the city, but also vehicles that bypass the city. There is no known distribution of the exact type of vehicle other than the length, but the vehicles can be thought of as vans, trucks, city buses, service and maintenance vehicles, tourist buses, semi-trailers, and lorries. (NPRA, 2001; NPRA, 2021b)



Graph 6. Hourly average distribution of vehicle length volume and pollutant concentrations in Danmarks plass during the years 2017, 2018, and 2019 on weekdays. (Data obtained from: Norwegian Public Road Administration, 2021)

Hourly average distribution of NO_2, $PM_{2.5}$, and PM_{10} concentrations along with vehicle volumes are plotted above on Graph 6. The hours of 06-09 and 14-17 are marked with green color to denote rush hour. There is a clear correlation between the vehicle volumes and NO_2 levels, as the nitrogen dioxide levels rise when the business day starts in the morning and then promptly rise again with the afternoon rush. Particulate matter concentrations follow the same logic, although the sources for this type of pollution may vary. However, there is a causal reaction of NO_2 on the particular matter pollution, since the atmospheric transformations that happen after nitrogen dioxide is emitted lead to the formation of oxidants that contribute to the photochemical reactions that are a significant cause for PM_{10} and $PM_{2.5}$ (WHO, 2021).

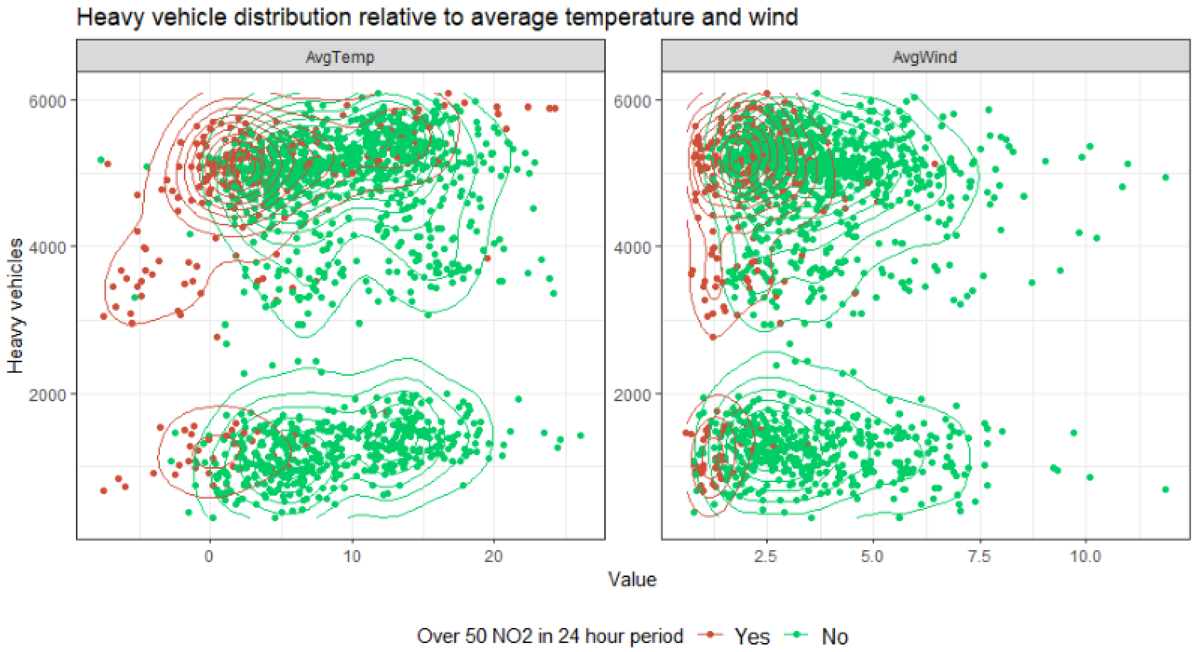
The seasonal trend of nitrogen dioxide concentration level has peaks during winters and lows during summers (Graph 7). The overall trend was decreasing before the Covid-19 shock, nevertheless, during the summer of 2020 the smoothed line goes well below the new WHO daily NO_2 limit of 25 µg/m³. Even though the vehicle volumes reach their absolute bottom during the year-end holidays and the first couple of months in 2021, the pollutant levels get a massive upward spike.



Graph 7. Daily distribution of pollutant concentration and vehicle volumes in Danmarks plass. (Data obtained from: NILU, n.d.; Norwegian Public Road Administration, 2021)

As mentioned before, at certain weather conditions the pollution concentration can reach hazardous levels in Bergen which was the case in 2021 winter as there were plenty of days with subzero temperatures, low precipitation, clear skies, and calm winds – favorable conditions for temperature inversions. Moreover, due to the Covid-19 pandemic, multiple ships were stranded at Bergen docks with engines running (Fossen, 2021), in addition to that, plenty of firewood was burnt for managing the freezing weather conditions. The combination of all those factors contributed to the high daily pollutant concentration levels.

The weather effects relative to heavy vehicle volume during 2017:2019 years are plotted below on Graph 8. Data points are separated by whether on a given day the NO_2 level was over 50 or not. That threshold was chosen, as it is the second interim target of the new WHO air quality guidelines (WHO, 2021). There are two distinct distributions of heavy vehicles. The values below 2000 likely represent weekends and holidays, whereas the values over 3000 represent business days.



Graph 8. Distribution of daily heavy vehicle volume in Danmarks plass relative to average temperature (°C) and average wind (m/s) in Florida measuring station. (Data obtained from: Klimaservicesenter. 2021; NILU, n.d.; Norwegian Public Road Administration, 2021)

As visible from the contour lines, the threshold exceedance during weekends is much more constrained by enabling weather conditions of low temperatures and calm winds. On the contrary, the days when the weekday distribution tops the threshold value have a considerably wider range and reach from rather windy conditions to warm summer days. The difference between the two distributions, holding other pollutant sources constant, gives an indication on how much the fleet must change for air quality in Danmarks plass to improve.

3.5 Local government strategy

The Bergen city council adopted a climate and energy action plan "*Green Strategy*" in 2016. The main goal of that plan is for Bergen to be fossil-free by 2030. For achieving that ambitious goal, several strategies were formed, which are summarised into two main steps. The first step reduces the scope of polluting transportation. For achieving that, transformational area and transport planning methods have been developed to centralize and densify city districts so that the need to travel outside one's neighborhood is diminished. All the necessary destinations would be within walking or cycling distance in such a setting. Strong focus is also on changing people's travel habits to promote collective transportation, along with evolving mobility culture by carpooling-esque behaviours. The second critical step, one that directly affects freight transport, is phasing-in low-emission technologies. (Bergen Kommune, 2020a).

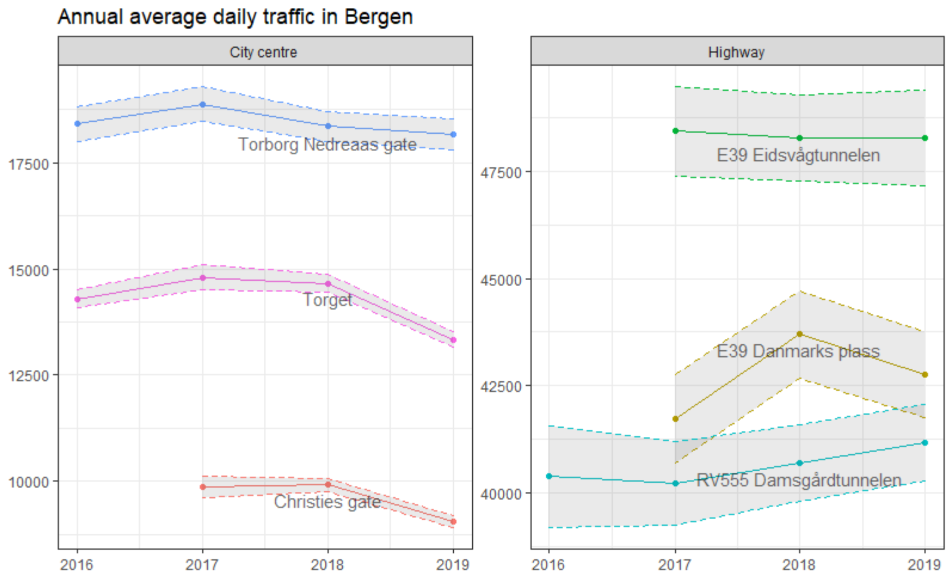
The plan further mentions long-term goals affecting freight transport, such as establishing zero-emission zones in the city centre and ultimately turning the whole centre area into a zero-emission zone by 2030. Furthermore, the final report of the plan mentions positive developments in the business community, as a large number of companies are getting united in organizations where the main objective is green change. (Bergen Kommune, 2020a). For example, the Climate Partners Vestland is a growing organization of over 60 private and public enterprises where the common goal is green business development and collaboration towards zero emissions in Vestland by 2030 (Klimapartnere, n.d.). Another organization with similar goals is Skift. Top leaders from Norwegian business and industry have aligned to contribute towards Norwegian goals within the Paris Agreement and be the driving force behind meeting those objectives. A notable initiative inside the organization is setting a goal for emission-free commercial transport within their business processes. (Skift, 2021).

3.6 Measures

The Bergen city council’s climate plan was adopted in 2016, and the first results about the effectiveness of the strategies can already be observed and speculated over. Most of the measures in the plan were concerned with limiting passenger car movements and changing commuters' behaviour to reduce traffic, improve air quality, and enhance liveability in the city. The following is a closer look at three measures by the local government that may have significant influence on freight transportation.

3.6.1 Parking policy

Bergen city council has had a strict parking policy to reduce the number of personal cars in the city centre by removing street parking in central areas and promoting communal parking lots that are properly distributed throughout the city centre. The policy effectively utilizes the street network for more efficient public and goods transport, in addition to safer walking routes and more space for cycling in the central areas of the city (Bergen Kommune, 2016). The annual average daily traffic for six counting points in Bergen is plotted below on Graph 9. Only observations with at least half a year of good data are chosen. Three points are on main highways, and the rest are in the city centre area.



Graph 9. Annual average daily traffic in Bergen municipality. (Data obtained from Norwegian Public Road Administration, 2021).

Nothing conclusive can be said about the trend on this figure, as the road network can be influenced by several confounding variables (road-works, alternative routes) not explicitly represented in the dataset. Nevertheless, the annual average traffic on highways on the chosen points indicates a growing trend, whereas in the city centre areas the trend implies reduced traffic.

3.6.2 Road pricing

As of May 2021, there are 29 toll stations spread around the greater Bergen region. In every station a fee for crossing in one direction must be paid, generally the route towards the centre is taxed. Several of those stations are situated around the access roads to the city centre, creating a toll ring around it. There is a sixty-minute rule for passing multiple stations for the fee of one. Vehicles that pass the toll stations are divided into two categories and taxed accordingly. The two main categories are over & under 3.5-ton weight groupings to separate heavy and light vehicles. The next grouping is based on whether the vehicle owner has Auto-PASS subscription or not. Following, are two special tariffs:

- **Environmentally differentiated:** prices for passing the station are based on vehicle engine type:
    - Light vehicles: petrol/rechargeable hybrid, diesel, electric or hydrogen.
    - Heavy vehicles: Euro-5/older, Euro-6/rechargeable hybrid, electric/hydrogen.
- **Time differentiated:** a rush-hour fee that is applied in 14 of the 29 stations. The prices rise during 06:30-09:00 and 14:30-16:30 during weekdays. (Ferde, 2021).

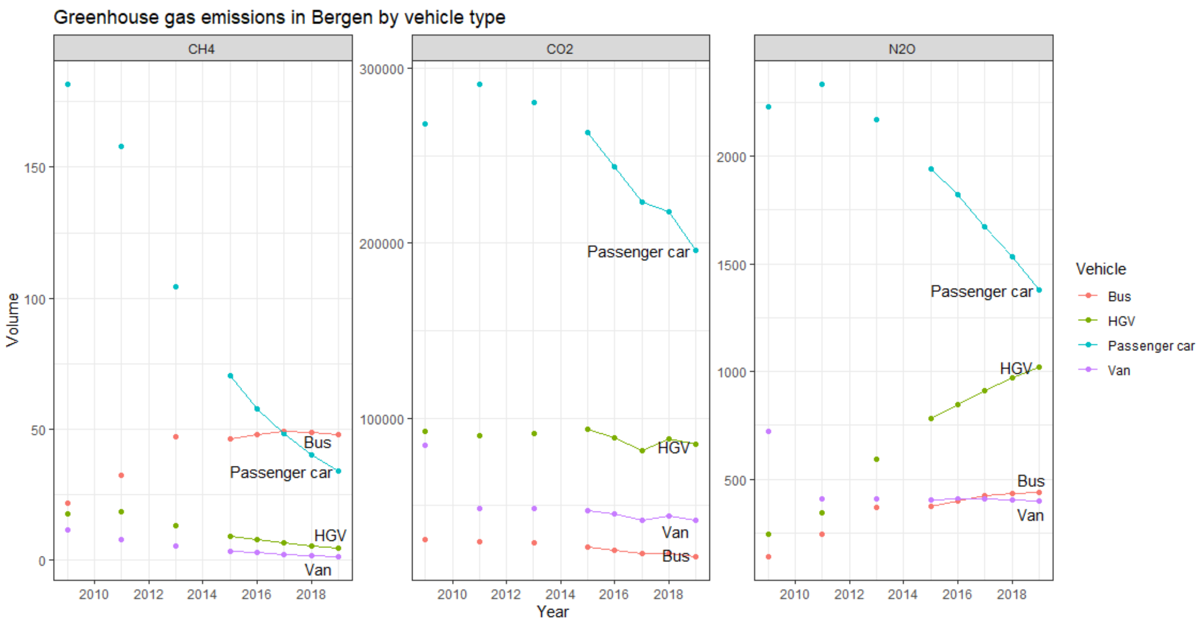
Congestion charging was introduced in 2015 and has been deemed a success. Analysis of 15 months from February 2016 to April 2017 by Presterud (2017) showed a sharp decrease in traffic volume for the rush-hour period, but an increase before and after the period, indicating that commuters changed their behaviour or used alternative modes of transport. During the rush period, travel and queue times were shortened. That has a positive effect on local air quality due to reduced emissions and airborne dust and is favorable for local working life, as time spent stuck in traffic could be spent in more productive ways. Moreover, there was an increase in the number of light-rail users and cyclists that the tariff introduction might have influenced.

Travel costs for the average car journey through the toll ring increased by 3,6%, amounting to price elasticities of -0.38 and -0.20 for light and heavy vehicles, respectively. That implies passenger car drivers being more responsive to the change in price than heavy vehicle drivers. The first year after introducing time differentiated tariffs, income from the toll ring decreased by 110 million NOK compared to previous year. That change was also influenced due to the growing share of electric vehicles passing through for free. As of 2021, there is a small fee for electric light vehicles passing the toll ring and free access for hydrogen or electric heavy vehicles.

3.6.3 Clean vehicles and fuels

The afore-mentioned environmentally differentiated toll tariffs influence new vehicle purchases, as road usage gets more expensive for vehicles with older, more polluting engines. As of 2017, the share of battery electric vehicles (BEV) in Bergen was already one of the highest in the world per capita (Valle, 2018). Moreover, the local government had significantly invested in charging infrastructure and given BEV users special rights with parking and toll exemptions, thus further promoting the use of these vehicles (Bergen Kommune, 2020a). In a recent study on electric car ownership in Norway by Fevang et al. (2021), the authors compared households with and without toll stations on their road to work. A crucial finding was that BEV commuting privileges (road toll exemption and bus lane access) were principally strong predictors of BEV ownership.

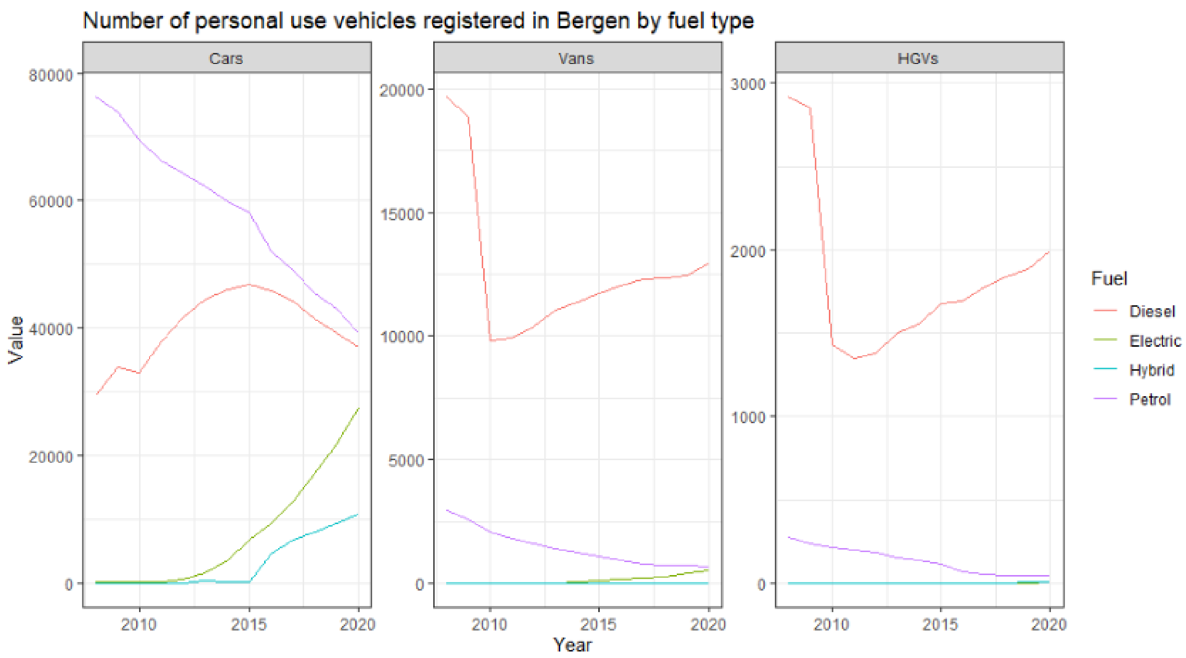
Growing share of electric vehicles in Bergen is represented in the figure below (Graph 10). The Norwegian Environment Agency collects data on methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) emission levels from road traffic by vehicle type. The dataset comprises yearly data only from 2015 onwards; consequently, to respect a continuous order, data points preceding that time are not connected with the rest. When focusing on the lined part of the figure, a sharp reduction in private vehicle emissions is evident. The local government has conceded that trend to be influenced by their measures of reducing the need for transport, parking policy, incentives and phasing-in low-emission vehicles. (Bergen Kommune, 2020a)



Graph 10. Road transport caused greenhouse gases in Bergen municipality. (Data obtained from: Norwegian Environment Agency, 2021).

Noticeable emission reductions are apparent in the passenger car segment. However, heavy goods vehicles (HGV) and vans do not follow the same trend as personal cars do. The primary reasons behind that are fewer available electric models and higher investment costs. In addition, light and heavy vans can potentially use the same charging infrastructure as passenger cars. In contrast, due to their long-distance hauls, HGVs depend on charging stations outside of fixed locations. Subsequently, competitive market conditions for electric trucks are still believed to be years away. On the contrary, investment costs for vans are gradually improving to be profitable for private purchase, mainly as a result of government programs aimed to develop that market. Furthermore, the Bergen city council's green strategy is aligned with the government's climate plan, as both documents have a goal of fossil-free light van transport by 2025 (Norwegian Environment Agency et al., 2020, Ministry of Climate and Environment, 2021; Bergen Kommune, 2020a).

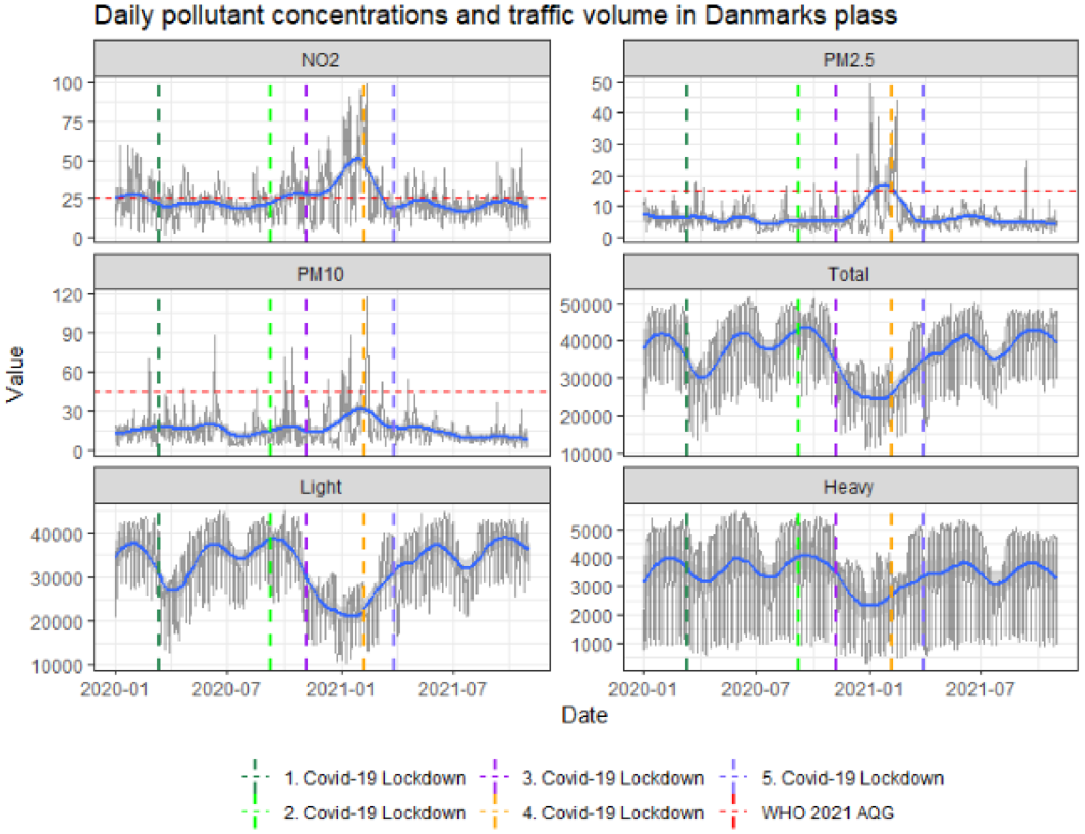
Statistics Norway publishes annual data (Graph 11) for number of registered vehicles by engine type. As of 2020, the share of electric personal cars in Bergen was 23.8% compared to 8.3% in 2016, and the share of electric vans was 3.4% compared to 1% in 2016 (Statistics Norway, 2021a). However, the electric van fleet growth in absolute numbers is miniscule compared to the growth of diesel fueled vans and HGVs for the past 5 years. Based on the current incentive schemes and market development the ambitious goals of emission-free light van transport by 2025, and green city logistics by 2030 are not attainable (Presttun, 2018).



Graph 11. Registered personal use vehicles in Bergen by fuel type. Data obtained from: Statistics Norway, 2021a.

3.6.4 Covid-19 lockdown

The interactions between Covid-19 lockdown measures relative to vehicle volumes and pollutant concentration levels are plotted on Graph 12. Five time periods are marked on the plot that denote the dates when the local government enforced interventions on people's movements during times of high infection rate. The first lockdown started on 12th March when the Bergen city council complied with national law and closed many public and private facilities to stop the spread of the virus. The second, third, fourth and fifth lockdowns are shorter in time and less severe in regulatory nature compared to the first one. (Bergen Kommune, 2021b). The end of a given lockdown was typically gradual, thus is not added as a concrete date on the graph. These strict measures altered the dynamics of vehicle movements and produced behavioural changes such as home office that reduced the number of interactions people have with each other. Moreover, since the pandemic is worldwide and international travel had at times effectively been stopped, there was less tourism related commuting in the city.



Graph 12. Daily pollutant concentrations and vehicle traffic volumes during the ongoing Covid-19 pandemic in Danmarks plass, Bergen.

When focusing on the smoothed LOESS line for light and heavy vehicles, the same underlying seasonal patterns emerge. However, the valleys for light vehicles are much steeper and deeper, meaning that that type of commuting was more sensitive to the lockdown measures, which makes sense due to government's restrictions to prevent unnecessary social interactions. Heavy vehicles that frequently operate for commercial reasons which are critical for the society to function have been less sensitive to lockdown effects. The extent by which the pollutant concentrations were affected by these measures is not that obvious from this graph, albeit there are no significant spikes immediately after the restrictions. The one exception where lockdown might not have had an immediate effect is the 4^{th} lockdown that happened during temperature inversion conditions. A stark decrease in light vehicle volume might not be so significant to nitrogen dioxide levels, because of the high share of electric vehicles in Bergen (Graph 11). Seasonal effects, especially of weather conditions unfavourable for pollutant dispersion, are still a major factor in high pollution levels which is evident at around the first two months of 2021, even at relatively low vehicle volumes.

Covid-19 lockdown effects of road traffic on air pollution has been studied from variety of cities around the world. Various methods were applied to compare the confinement period (lockdown days of March 2020) to corresponding periods from previous years. Most generally the differences between the means of the pollution levels relative to explanatory meteorological and traffic volume variables were analyzed. A significant relationship between the lockdown measure induced traffic volume decrease and lower NO_2 concentration levels was presented in numerous studies (Connerton et al., 2020; Lian et al., 2020; Baldasano, 2020; Rossi et al., 2020, Tobías et al., 2020).

Hourly NO_2 concentrations in Madrid and Barcelona dropped on average by 62% and 50%, respectively. In addition to that, the hourly peak concentration levels showed significant reductions as well, ranging from ratios of 1.2 to 1.7. Stark reduction in traffic volume compared to dispersive weather conditions was the more significant factor contributing to lower NO_2 levels. (Baldasano, 2020). In terms of particular matter pollution in Barcelona, the decrease in PM_{10} was proportionally much lower compared to the relative change in nitrogen dioxide (Tobías et al., 2020). Supporting evidence was found from Padova, Italy where NO_2 levels and vehicle volumes had a significant decline (34-40% and 69-71%, correspondingly) in both measuring stations analyzed in the study, while PM_{10} significantly decreased (10%) only in one. The reason is likely due to different sources of secondary pollutants present in one measuring station which diminishes the effect of reduced traffic relative to the other. (Rossi et al., 2020).

3.7 Conclusion

The conclusion is made following the first three steps of the transferability framework. Firstly, a few guiding objectives are presented that outline the strategic direction the target city is thriving towards. Key areas contributing to or counteracting those objectives are discussed. Secondly, target area's geographic, demographic, and transportation-related attributes are identified. Lastly, high level objectives, problems and their implications are summarized.

3.7.1 Diagnostic of the problems

The Norwegian Government is committed to a 45% reduction of non-quota emissions by 2030. Most of those emissions come from the transportation sector. The Bergen city council has outlined a regional climate plan for 2030 that seeks for the city to be fossil-free by that year. The progress towards that goal is already visible from the transportation of people perspective, as the share of light cleaner engine vehicles is steadily growing (Graph 11), moreover there have been substantial investments in green public transport through acquiring electric buses and building new light rail routes (Terjesen, 2020; Skyss, 2021). However, freight transportation vehicles, that are responsible for many negative externalities, have not made the shift to fossil-free fuels yet, at least not on a significant scale. Bergen city council has set a goal for all light goods transport to run on fossil-free vehicles from 2025 onwards (Bergen Kommune, 2020a). A goal that is supported by government subsidies. However, cleaner fuels for heavy-duty vehicle transportation are even further away, as the Norwegian government has set goals for 100% of new heavy vans, and 50% of new lorries to have zero emissions by 2030 based on the expectation of relevant technological progress and improvement in cost-efficiency (Ministry of Climate and Environment, 2021).

Controlling for the sources of greenhouse gases will have a direct influence on improving air quality and decreasing noise emissions in Bergen. As of 2020, the share of vans and heavy goods vehicles running on diesel fuel is high (Graph 11). Consequently, that is contributing to the local NO_2 and particulate matter concentration levels. The World Health Organization has published new recommendations for air quality guidelines. The long-term effects in Bergen measuring stations indicate that the air quality is quite good, however when following the newest guidelines for short-term effects, there is reason for concern. In particular, the measuring station at Danmarks plass has majority exceedances of the new thresholds, while being at a central location in the city.

Pollutant concentration correlates with morning- and afternoon rush times. Traffic queues are detrimental for both air quality and noise levels. Time- and environmentally differentiated road pricing is introduced by the local government to tackle that, however heavy vehicles operating for commercial reasons have a higher willingness to pay the tariff. Zhang & Batterman (2013) in their research about traffic congestion induced risk on near-road and on-road populations found that on high-capacity urban roads there is a higher incremental risk of adverse health effects on the population than on freeways. The authors proposed as potential explanation that rush hour conditions cause more acceleration/deceleration actions which increase emissions, and to a lesser extent that vehicle induced turbulence diminishes pollution dispersion at lower speeds.

Motor vehicle induced pollution has a strong seasonal variation with lows generally in the summer months and highs in the winter. During the right weather conditions, temperature inversion can trap the pollution, creating hazardous air quality levels. Local winds can distribute the pollution to neighbouring areas, giving importance to reducing the pollution sources in Bergen valley.

3.7.2 Characterisation of the city

Bergen is a growing city with a vibrant economy. The municipality's area is spatially large and car ownership is high, thus commuting is very common. That leads to congestion, especially during the rush-hour periods when people commute to work in the morning and home from work during the afternoon. This phenomenon is apparent when looking at the population density in Bergen compared to the business establishment density (Figure 4). Majority of the workplaces are situated in the city centre, while the population is spread out between the neighbouring boroughs. In 2010, the share of Bergen municipality's population living in the centrum (Bergenhus borough) was 16%, while the share of workplaces situated in the same area was 33% (Institute of Transport Economics, 2011).

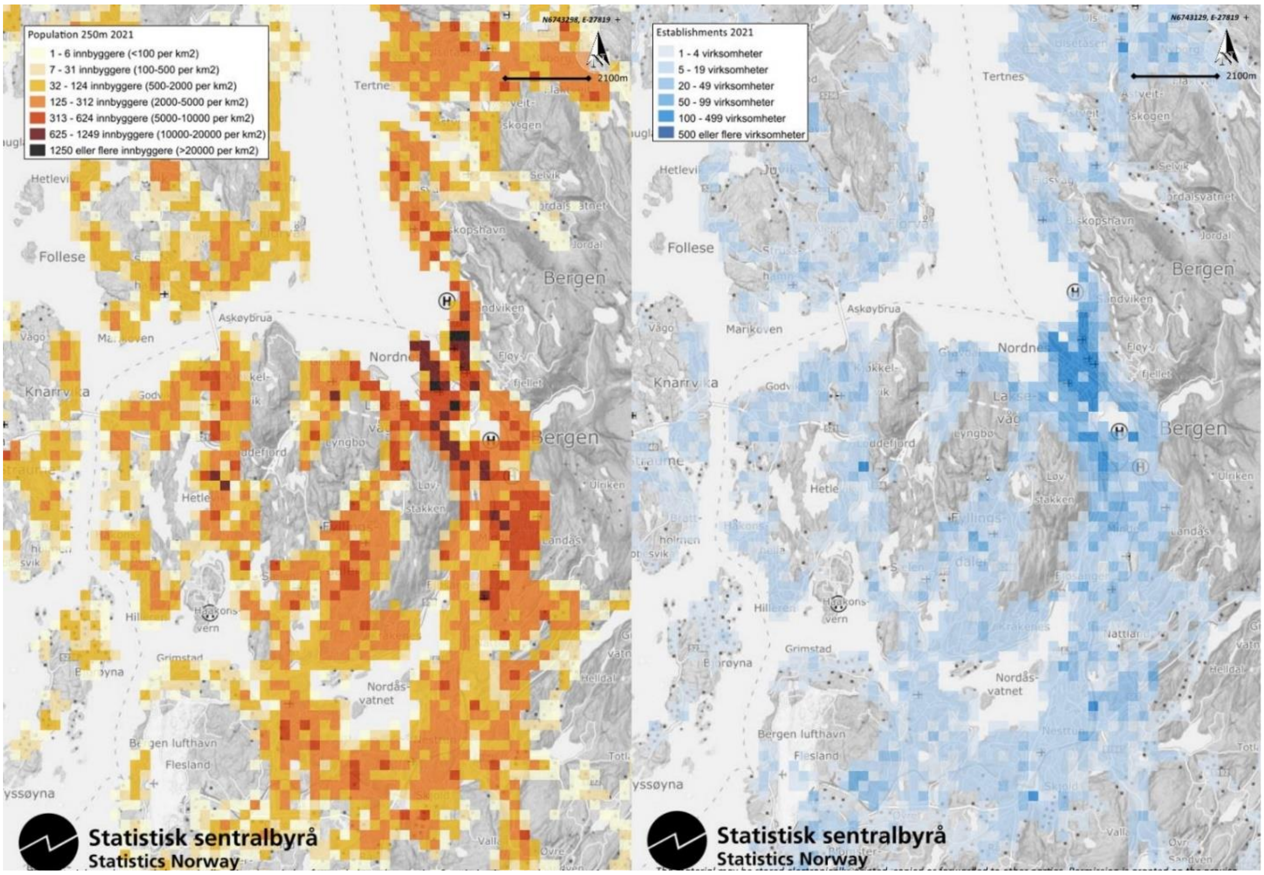


Figure 4. Population density per 250 meters and business establishment density in Bergen area. (SSB, 2021).

Commercial traffic is expected to increase, as there is a growing trend of parcel deliveries in Norway. During the pandemic year of 2020 over 99 million parcels were delivered which is a 30% increase compared to the previous year. However, the trend has been growing even before the shock year of 2020, as Norway's largest (79% market share) carrier Posten experienced 54.9% growth in parcel volume from 2011 to 2019. The volume of parcels delivered globally is expected to double within 5 years relative to current volume in 2021. (Pitney Bowes, 2021; Posten Norge, 2019)

Goods transport vehicles enter the central areas of the city largely through the main highway (E39) or national road 555. In terms of weight, considerable amount of freight enters Bergen both through E39 from north and south side relative to Bergen centrum (Asplan Viak & NORCE, 2018). That complicates the decision-making regarding a possible consolidation centre's location, because when cross-docking would happen in either side from the centrum, then the long-haul traffic from the opposite direction would still need to pass through the central areas of the city. In addition to vehicles destined to Bergen, many by-pass vehicles must go through the central areas to reach their destinations, thus contributing to the congestion and local air pollution, especially when bigger vehicles get stuck in traffic jams. The volume of through traffic might not be trivial, as noted in the Goods Survey for Vestland (Asplan Viak & NORCE, 2018), the share of through traffic leaving and entering Bergen area by the E39 Halhjem-Sandvikvåg ferry quay was 33% and 25%, respectively.

3.7.3 Analysis of the city context and implications of problems identified

Bergen has relative problems with traffic congestion, air and noise pollution conducive to increased public health risk. These problems have been addressed by local government's measures and policies that reduce transportation movements in the city. However, an important aspect of transportation - the transportation of goods is largely unaffected by those measures, either due to the participating companies having higher willingness to pay a congestion fare, or by policymakers considering freight transportation as a future problem due to the lack of scalable low-emission technology for heavy-duty vehicles.

Optimizing freight vehicle movements in the city has the potential to reduce congestion, reduce air and noise pollution, and improve the quality of life for the local population. Less fossil-fuel powered vehicles on the streets will contribute towards the local high-level objectives of Bergen becoming a fossil-free city by 2030, and the long-term goal of becoming a 1.5-degree city by 2050 (Bergen Kommune, 2020a). Some of the carriers and logistics operators active in Bergen do concur with those objectives and refer to the goals of the Paris Agreement as guiding principles for their sustainability efforts. The largest carrier Posten aims to be a frontrunner and only use sustainable energy sources in their transportation vehicles and buildings by 2025 (Posten Norge, 2021). Two companies with strong focus on last-mile deliveries that witnessed enormous growth during the pandemic year are Helthjem and Post Nord (Krager, 2021). The former aims to reduce CO_2 emissions by 50% come 2025 (Helthjem, 2021), however the latter does not yet mention any concrete, accountable climate goals for the future in the sustainability section of their website (PostNord, 2021).

International transportation enterprise DHL intends to electrify 60% of last-mile deliveries and increase the proportion of sustainable fuels by more than 30% in line-haul (Deutsche Post AG, 2021). Line-haul intensive logistics operator DB Schenker anticipates having 100% climate neutral land-transport by 2027 (DB Schenker, 2021). However, the line-haul trucking industry overall is a very fragmented one, as almost half of the transport firms consist of sole proprietors, while companies with over 50 employees represent around 40% of the turnover. The share of trucks used for own transport is 27%, although they represent just 18% of the total milage, moreover these are generally older trucks with lower horsepower, thus more susceptible for electrification. However, companies with larger fleet would have more flexibility to consolidate loads and to control for some of the technical limitations of electrification such as loss of payload due to battery weight, range and trailer use limitations, and lack of engine power. (Institute of Transport Economics, 2019).

Air pollution induced deaths and disabilities hold a measurable economic cost to society. Road transportation is claimed to be the main cause of pollution-associated deaths in Europe and USA in respect to the totality of deaths. Total health and non-health related costs of air pollution in EU28 was 66.7 billion euros in 2016. The proportion of diesel vehicles responsible for these costs is estimated at 83%. One of the metrics for deriving such costs is ambient particular matter pollution (APMP), that represents fine particulate matter particle ($PM_{2.5}$) caused outdoor air pollution. Norway's mid-point estimate for premature deaths from APMP in 2015 was 269 out of a million, while the cost of mortalities was approximated at 7 699 million USD_{2015} which was relative to 2.4% of Norway's GDP. Governments' interventions on limiting the sources of air pollution by strict policies and measures can therefore result in considerable cost savings. (CE Delft, 2018; Roy & Braathen, 2017).

4. Transferability analysis

The current chapter of the thesis focuses on the implementation of an urban consolidation centre as the main measure against problems identified in the previous chapter. Examples of consolidation centres that have managed to become financially sustainable in the long run are unfortunately only a few. That heavily narrows the pool of best practices (Dablanc et al., 2015), at least in the economic dimension. The following analysis, with some limitations, will follow the remaining transferability framework steps proposed by Macário & Marques (2008). Firstly, an example of a successful urban distribution centre is presented, and its enabling context and effectiveness is analysed. Secondly, the compatibility of that best practice in the target city is assessed. Finally, barriers responsive to change and success factors are identified in the target city.

4.1.1 Demonstration

The negative externalities of freight transportation in theory and practice are mitigated using a consolidation centre. However, environmental gains without an economically sustainable business model does not fare well for the longevity of the project unless subsidies are involved. From the literature review, an important aspect concerning the success of a consolidation centre was the ability to operate at scale. With the additional stage that a UCC creates in the supply chain, the extra handling cost at the consolidation facility is generally what turns carriers away from participating. With low participation rate the costs are even higher.

The local government has the authority to effectively enforce participation by instating favourable regulations in support of the UCC operator. However, such regulations should be made consentaneously by involving the stakeholders that experience a significant change in their daily operations. Coming back to the experience from Vicenza, Italy where freight vans were banned from the historic city centre by law, the carriers that were not involved in this decision experienced a loss in service quality when using the UCC. Even though the Italian State Council ruled in favor of the local authorities to limit movements in the centre, the carriers colluded to shun the UCC operator and side-step regulations by completing last-mile deliveries on cargo-bikes and trolleys, successfully hindering the UCC operator’s prospect of scaling in the operating area (Negrin, 2011).

Cityporto Padua

A successful implementation of an urban consolidation centre that has managed to scale comes from Padua, Italy. Cityporto has been active since April, 2004 and was founded in collaboration between the City of Padua, Commercial Chamber of Padua, A.P.S Holding S.p.A., and a selection of freight transport operators - that in contrast to Veloce Vicenza, stress the importance of early stakeholder involvement. The consolidation centre is operated by a neutral party Interporto di Padova that is in the logistics business, but not a direct competitor to urban freight operators (Ferpress, 2018). Padua shares the same urban transport problems as many other cities, notably traffic congestion, air and noise pollution, and conflicts between freight vehicles and pedestrians in historical city centre. (Dablanc et al., 2015).

One of the key factors to the success of Cityporto has been gradual implementation of activities (Interporto Padova S.p.a., 2021). In 1997, a survey was conducted to identify the movements of goods in the municipality. Thereafter, a regional law that fosters developing urban logistics projects was established. In 2001, the local municipality of Padua identified its mobility policy and defined a Zone with Limited Traffic (LTZ). The plan to implement a UCC came through an agreement between the municipality and local trade associations to promote environmentally friendlier goods transport. After meetings between the UCC operator and the stakeholders the signatures for the consolidation project were signed and the project started just weeks after. The UCC was initially financed by gradually decreasing public grants, however since 2007 they have not received any public funding. (Dablanc et al., 2015). Since April 2015, daily delivery of perishable goods started to five supermarkets in the operating area. (Interporto Padova S.p.a., 2021).

Another significant success factor is the geographical location of Cityporto. Apart from being close to the historical city centre, it is conveniently in the same area as the intermodal platform Interporto Padova that integrates rail and road transport. The Interporto terminal is connected to the rail network (national and international) through an electrified line, which in turn is connected to major national and international ports. A considerable share of goods can thus be transported to the city by rail instead of the more polluting long-haul vehicles. (Interporto Padova S.p.a., 2021; Ferpress, 2018). The size of the Interporto property is 1.1 million m^2, from where the intermodal freight terminal covers 300 000 m^2 and handles around 275 000 TEU yearly, while having capacity for over 750 000 TEU per year. In addition to that, there is capacity for 270 000 m^2 of warehouse space on the premises. (Interporto Padova S.p.a., 2021). Moreover, the industrial area surrounding Interporto's property is populated by cargo terminals of many national and international transport operators, essentially forming a logistics cluster.

The participation type for using Interporto's consolidation service is voluntary, however the local municipality is strongly supporting the UCC operator by several favourable regulations. Owing to public ownership of Cityporto's vehicles (Vaghi & Percoco, 2011) last-mile delivery vehicles used for the service are allowed to use preferential lanes, have unlimited access to the electronically monitored limited traffic zone, and are exempt from time-limited parking regulations. Light vehicles under 3.5t can enter the LTZ for loading/unloading purposes only at certain times per day. Heavy vehicles over 3.5t must request authorization. The concept of freight consolidation is supported by a Veneto Region law 36/99 that regulates the rationalization of goods distribution with the purpose of reducing air pollution in urban areas. (Interporto Padova S.p.a., 2021)

The business model of Cityporto is again rather simple. Freight transport operators and carriers who make deliveries to the LTZ or the neighboring urban areas deliver to a logistics platform in Interporto Padova instead for an agreed upon tariff per delivery (VPF, 2017). Consolidated rounds from thereon leave for the last-mile twice per day with maximized loading capacity using environmentally-friendly vehicles. Only authorized vehicles can enter the restricted traffic area depending on time of day and weight of vehicle. Illicitly entering vehicle owner is subject to a fine of 80 euros. (Interporto Padova S.p.a., 2021)

Cityporto's environmental indicators. From 2005 to 2019 over 1 million deliveries have been performed and 5 million km vehicle trips saved. That equals to a reduction of 140 thousand liters of diesel, 1891 tons of CO_2 and 442 kg of PM_{10} due to greener last-mile deliveries in the operating area. Thanks to the consolidation effort, about 100 diesel transportation vans are removed from the city centre every day. (Interporto Padova S.p.a., 2021)

4.1.2 Transferability

The operational viability of the best practice in its environment will not be a sufficient condition for transferability. Even though it is proved to be effective in its setting, the enabling conditions that facilitated this effectiveness need to be compared to the existing conditions in the target city. This is especially true when considering the potentially risky urban consolidation centre which does not only require political will and community acceptance, but also needs to be cost-effective to have a chance at being sustainable in the long run. Replication of a successful business model might require some underlying conditions to be met regarding physical, organizational, and functional domains (Macário & Marques, 2008). One of the strongest factors contributing to the success in Padua is that the local multimodal logistics operator Interporto Padova has essentially integrated the freight consolidation centre into their business processes. That boosts the UCC's competitiveness due to already available logistics operations expertise and infrastructure combined with plenty of capacity for scaling.

An equivalent intermodal freight terminal in Bergen is in the city centre at Nygårdstangen. However, contrary to Interporto Padova, this terminal is administrated by a governmental agency Bane NOR SF that share the terminal operator duties with multiple other companies (Bane NOR, n.d.). The terminal handles around 130 000 TEU annually but is already operating at nearly maximum capacity. The Norwegian Railway Directorate has commissioned Bane NOR to rebuild the terminal by 2024 to improve the operations, increase capacity, and strengthen rail transportation over road. (Bane NOR, 2019). However, for accommodating the construction work, Bane NOR have ordered two major logistics operators to move away from the premises, forcing PostNord and Schenker to search for new locations for their freight terminals. A move criticized by the former as it will cause additional truck trips between Nygårdstangen and the new terminal, given they are going to continue using rail for long-haul in the future. (Ludt, 2020). PostNord will move their terminal 20 km south on E39 to Os, while Shencker has started building near Bergen's airport. (Ludt, 2021).

Even though participation in the consolidation scheme in Padua is voluntary it is combined with several supporting measures that are fostered by regional law. A legal framework for freight rationalization is key for being able to regulate access to the LTZ and consequently promote the usage of the consolidation centre. The Bergen City Council has implemented a regulation in 2012 based on the Road Traffic Act § 7[7] for banning automobile movements during acute air pollution. However, many exemptions apply including for vehicles used for business purposes (Bergen Kommune, 2021a). In addition to that, road pricing is used for vehicles entering the city central areas, however the behaviour of vehicle owners operating for business purposes is less likely to be affected by the tariff. The Norwegian Government has committed to using regulation for supplementing general taxation on emissions, particularly

[7] Norwegian law: *Lov om vegtrafikk (vegtrafikkloven): § 7.Særlige forbud mot trafikk.*

in cases where complying with softer measures such as road pricing is still profitable when paying the fee (Ministry of Climate and Environment, 2021). This commitment gives confidence to the local government in Bergen for future plans regarding the implementation of a zero-emission zone in the city centre (NRK, 2021).

Stakeholder acceptance is a crucial element in a successful consolidation centre scheme. Carriers, due to being in natural competition against each other, are generally not prone to participate in such a collaborative endeavour (Holguín-Veras & Sánchez-Díaz, 2016). As of 2021, there are over 50 freight operators cooperating with Cityporto, which includes most of the freight operators active in Padua (Interporto Padova S.p.a., 2021; Vaghi & Percoco, 2011). Cityporto's cost-effectiveness might have been enhanced by its strategic location and the fact that freight traffic regulations were already set in the operating area, thus making participation more desirable for freight operators. However, Interporto Padova stress that it is the UCC operator's neutrality in respect to transport operators that facilitates multi-carrier cooperation (PadovaOggi, 2018). Cityporto's customers know that there is no priority for some companies over others in cross-docking or last-mile processes (Vaghi & Percoco, 2011).

The number of transport operators participating in Cityporto seems large and would indicate a very fragmented market. Nonetheless, the Italian parcel delivery market can be characterized as competitive, but relatively consolidated due to local companies BRT and Poste Italiane sharing 40% of the total parcel volume, while six major international carriers are sharing 50% of the volume, whereas the others account for the remaining 10% (Pitney Bowes, 2021). However, the others are a very fragmented group, as among them are many small truck companies and own-account operators who generally do not perform rationalized trips. That might explain the willingness of Italian authorities to implement restrictive policies for freight traffic regulation. (Dablanc et al., 2015). In contrast, the parcel market in Norway is dominated by the state-owned company Posten with 79% share both in total volume and revenue (Pitney Bowes, 2021). Regardless of Posten's strong position there is increased competition in the growing market, which in turn has lowered the prices and strengthened the position of other players, especially in the B2B segment (Strømmen, 2019).

4.1.3 Assessment

The main objective for the implementation of Cityporto in Padua was tackling adverse environmental and social effects caused by freight transportation. Since the project is supported by public institutions and connected to local legislation, several targets need to be met regarding the environmental performance of Cityporto. During a 15-month period from 2004-2005 the environmental gains based on financial weights on PM_{10}, noise emissions, and accident reductions were estimated to be around 174 thousand euros per year (Vaghi and Pastanella 2006, as cited in Gonzalez-Feliu & Morana, 2011). The monetization of these gains justifies the early investment by the local authorities and validates project implementation. Gonzalez-Feliu & Morana (2011) further analyzed the performance of Cityporto in the April 2004 - September 2009 period and estimated the environmental gains compared to a 2003 period of no consolidation to be nearly 30%. The authors note that these are local gains based on consolidation efforts within the operating area in the city centre, as the global gains to the whole urban area are much smaller.

Figure 5 shows a road traffic map of Padua during a Monday morning. The color of the road illustrates typical traffic flow from quick (green) to slow (dark red). Some of the smaller roads are omitted due to the scale of the map. The overall structure of the road network relative to the location of Interporto Padova indicates that the consolidation centre is in a great geographic location in terms of accessibility via major highways and vicinity to the city's central areas.

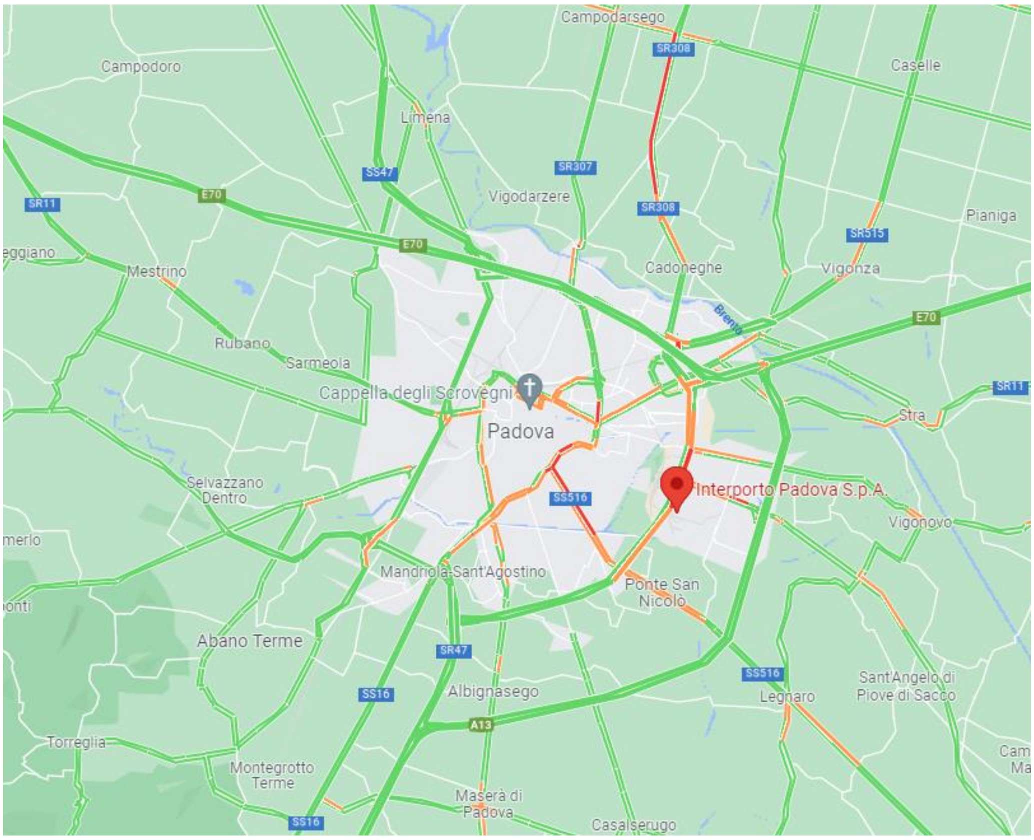


Figure 5. Padua map with typical Monday morning (9 am) traffic. Google, n.d.-b.

For contrast, a map of Bergen on an analogous scale is displayed on Figure 6. The roads are colored again by the intensity of a typical Monday morning rush. Four locations that create a sizable amount of freight traffic are pinned on the map as an illustration. Not all the freight coming from these locations is conducive to consolidation, particularly dry and wet bulk from the port and railway, however just like through traffic on the E39, these flows could be seen as a constant when thinking about the placement of a potential consolidation centre.

- Green pin represents the intermodal terminal for rail and trucks at Nygårdstangen.
- Yellow pin indicates the logistics terminal of Norway's largest carrier Posten;
- Purple pin denotes the Port of Bergen.
- Dark-red pin is for the Bergen Airport.

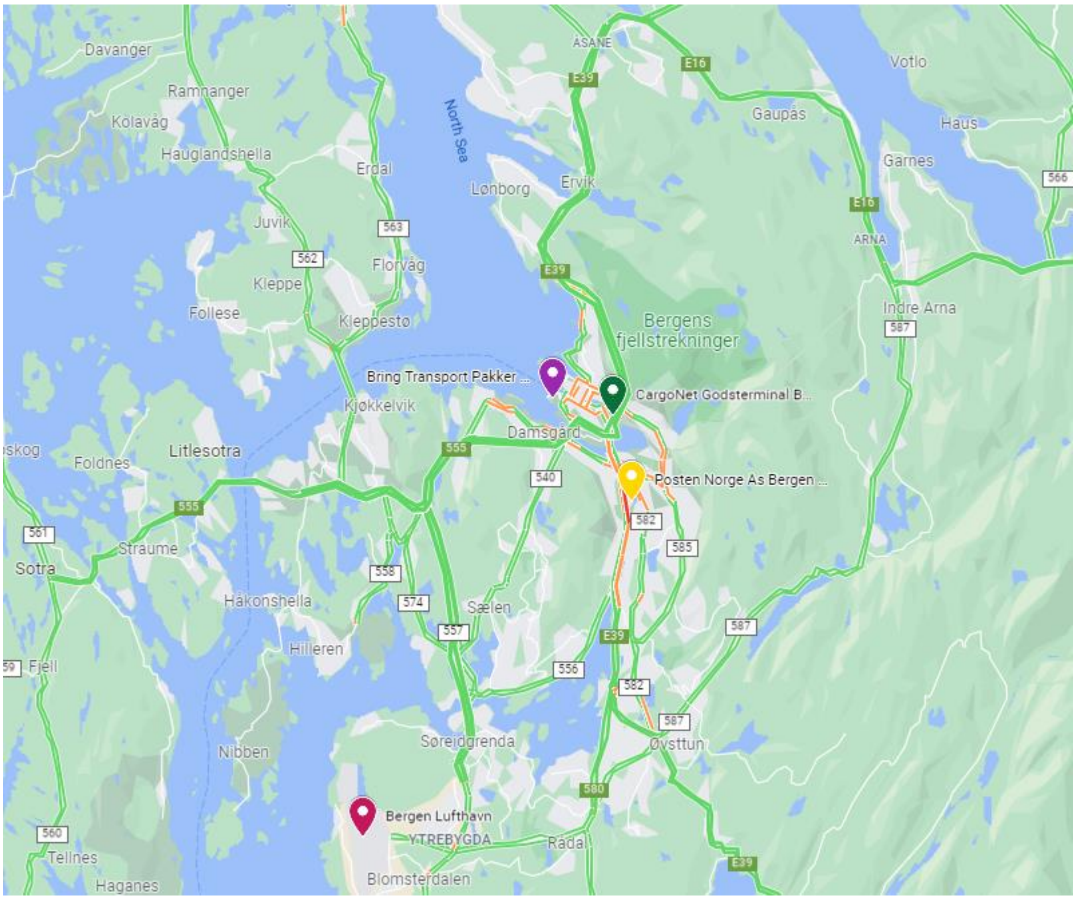


Figure 6. Bergen map with typical Monday morning (9 am) traffic. Google, n.d.-c.

The biggest challenge for Bergen to adopt a similar consolidation measure is physical geography, which due to the topography and waterways surrounding the city's central areas has created urban sprawl and has limited the planning and design of the road network in the municipality. When following the example from Padua, an intermodal terminal operator would be a suitable neutral party for handling the UCC operations, however even if Bergen's equivalent of that would have the additional capacity for necessary cross-docking and storage, sending long-haul vehicles to the city centre for consolidation does not improve the negative externalities outlined in the third chapter. Ideally, long-haul freight destined to Bergen should be consolidated on the periphery of the city, however due to large amounts of goods flowing to Bergen from north and south via E39 (assuming that commodities suitable for consolidation come in similar proportions from both directions), having the consolidation centre on either end would mean that the freight coming from the opposite end would have to pass through the city centre and potentially make a costly deviation from regular routes (Herzog, 2010).

Taking that barrier into account, establishing two UCCs could be considered. For example, one covering the north side of E39, say near to Åsane, while the other covers the southern side, suppose near the Bergen Flesland Airport. Economically this would be an expensive solution, as the set-up costs of a single UCC are already high. A project like this would certainly require a large amount of initial investment through local government grants or hypothecated taxes. Nevertheless, as presented by Katsela et al. (2021) and seen in the case of Cityporto, monetizing the negative externalities could well justify time-limited subsidies.

The possibility of establishing more than one UCC has been examined in several feasibility studies, however it does not seem to have been implemented in practice so far. Janjevic et al. (2016) assessed different UCC scenarios compared to a business-as-usual for the city of Brussels. The authors compared one UCC to two and four UCCs on different conditions such as road pricing, night-time deliveries, and vehicle engine type. Evaluation metrics were cost of transport, congestion, emissions, noise pollution, and profitability. The reductions in congestion and emissions were noticeable as the number of consolidation centres increased. However, the conditions which were applied to different scenarios were very case specific, thus might not be generalizable. Leonardi et al. (2015) by analyzing different UCC scenarios for the city of Luxembourg came up with a collaborative idea considering currently existing logistics terminals in the city. The authors proposed that any freight operator in the city can become an UCC, on the condition that clean vehicles with high load factor are used for deliveries to the restricted area in the city centre. However, implementing that would require very strict access restrictions for diesel vehicles to the operating area. Moreover, as of December 2021, no public info could be found about this system being operational.

An important aspect affecting the functionality of a UCC is the area it serves. In the case of Padua, the operating area was in the city centre. It is fair to say that much of Cityporto's success can be attributed to policy synergy between the consolidation centre measure and the restricted low traffic zone. In Bergen such zone does not currently exist, however there is a toll ring that surrounds the city centre and is used as a policy tool for mainly environmental reasons. The inner toll ring is surrounded by roads leading to Bergenhus borough, which is in the heart of the city, while the outer toll ring (Figure 7) has been implemented during acute air pollution to restrict passenger vehicle movements. The area of the outer toll ring comprises the last few kilometers of E39 passing through the critical traffic junction in Danmarks plass. Given the air quality problems discussed in previous chapter specific to that location, the outer toll ring could very well be a suitable operating area served by consolidation centre(s) in Bergen.

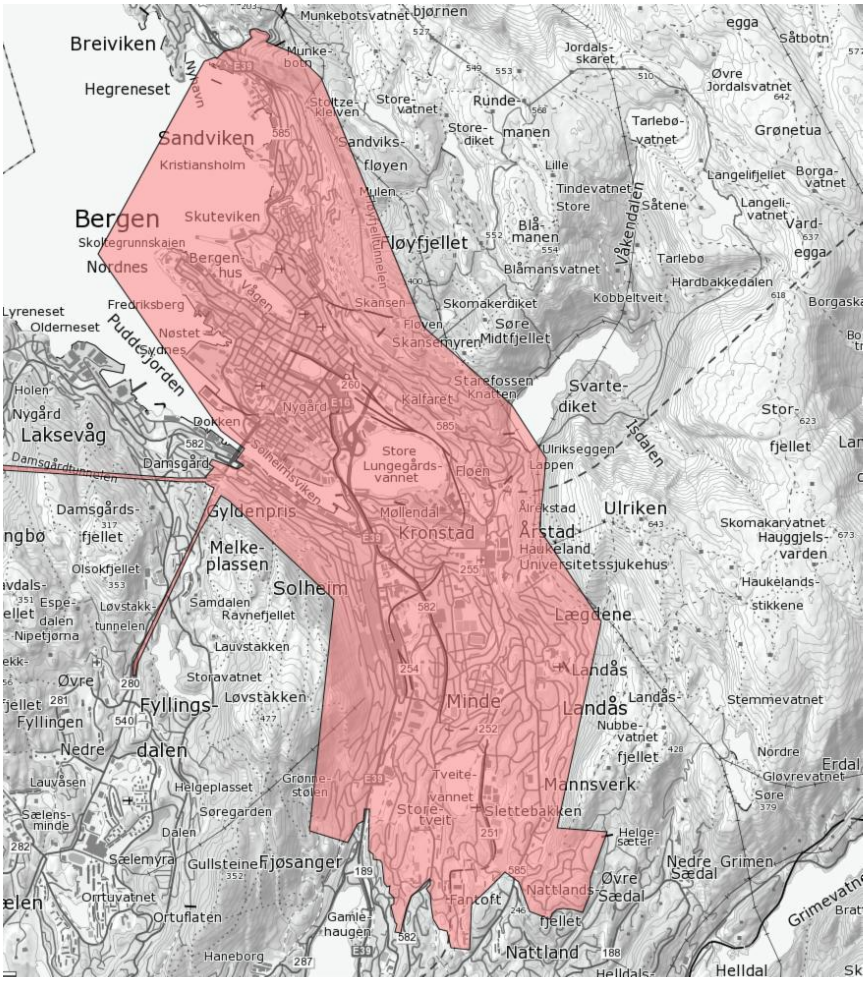


Figure 7. Bergen toll ring during acute air pollution. (Bergen Kommune, 2021a).

5. Discussion

Urban consolidation centre has proven to be a successful measure in mitigating negative externalities induced by freight traffic (Dablanc et al., 2015). Air quality data from Bergen suggests that such a measure would be beneficial for the local population, particularly for those who are disproportionally affected by traffic flows. However, often-times UCC projects do not even advance the initial research or feasibility stages (Allen et al., 2012). When UCCs do become operational, common reasons for failure are high ownership costs, loss of public funding, and low stakeholder participance (Lagorio et al., 2016). A best practice that operates on an economically sustainable business model is Cityporto from Padua, Italy. Despite the known operational factors facilitating its success, the transferability of that practice may require Bergen to share some underlying conditions that enable its cost-effectiveness. On the one hand, the presence of a toll ring and local government's zero-emission zone ambitions facilitate the adoption of a restricted delivery area. On the other hand, establishing a single UCC in Bergen might not reduce the negative externalities due to peculiarities concerning the design of the current road network.

The fact that one UCC on the periphery of the city would require freight from the opposite end to pass the city centre is not inconsequential, as that could mean extra distance driven for the more polluting long-haul vehicles. An immediate response to this problem would be establishing more than one UCC. However, a new problem emerges in the case of two UCCs on opposite sides on the periphery of Bergen. Independent customers could have freight coming from both north and south of E39, which means that vehicles parting from their respective UCCs could be mimicking each other's behavior when delivering to the same customers. For counteracting that inefficiency, establishing a micro-consolidation in the city centre with cross-docking capability would be plausible. Case study by Katsela et al. (2021) displays that a two-echelon solution (Figure 1) where freight is first consolidated in suburban consolidation centres and then delivered to a micro-consolidation centre for the last mile would have significant environmental gains. However, due to an additional handling-stage in the supply chain the costs of deliveries would also be higher (Janjevic et al., 2016).

The distinctiveness about Bergen (Figure 6), contrary to Padua is that many of the biggest logistics terminals are right in the heart of the city. When adding the through traffic that passes the city centre via E39, then the constant number of trucks that are not conducive to consolidation can be assumed to be relatively high. Notwithstanding, there may still be potential to improve the local environmental indicators by establishing a UCC that serves the city centre. The distribution of vehicle movements and pollutant concentrations (Graph 6) in Danmarks plass shows correlation between the pollutant levels and rush hour which makes it crucial to avoid heavy-duty traffic during those hours. One of the advantages of an UCC, and especially the two-echelon solution, is that freight can be moved to the second handling stage during off-hours, either by night-time or early morning delivery. The downside of this may be noise disturbances during night, however that gives importance to choosing the right type of vehicle and an appropriate location for the micro-consolidation centre so that it would be easily accessible by road, but not too close to a residential area.

One of the primary aspects leading to a successful implementation of a UCC is stakeholder participation in its operations, particularly that of freight operators. The authorities in Padua have heavily influenced this by creating a limited traffic zone with time limited access for light vehicles and authorization requirement for all heavy vehicles. Delivery of goods to that area is a publicly driven and subsidized service offered by Cityporto, thus UCC vehicles are exempt from any access restrictions (Interporto Padova S.p.a., 2021). However, electric vehicles and vehicles powered by LP gas or methane are also exempt from access restrictions. When considering similar methods for influencing stakeholder participation in Bergen, but at the same time considering that the electrification of commercial fleet will happen at some point in the future as well, then how effective would a regulation restricting polluting transport vehicles to the city be as a tool for increasing participation in the UCC? One could see the effectiveness of that diminishing over time. Although it would align with the broader goals of adopting clean vehicles and fuels it would not benefit the UCC in the long run.

Gathering freight operators to see benefits of participating in the UCC project is not a simple matter. Experience from Vicenza shows that these stakeholders are vital to the economic sustainability of the consolidation centre. Experience from Regensburg proved that competing against the carriers is not sustainable for the UCC operator. However, maybe it is the receivers who have more power influencing the upstream of the supply chain? The idea of such consolidation was presented in the example of Binnenstadservice. However, contrary to local small retailers using the BSS service, big businesses and governmental institutions in Bergen who collaborate in organizations (Klimapartnere, Skift) with a common goal of green change could be leading the consolidation efforts instead. Though, large business entities with big supply chains using market leading carriers generally receive more consolidated freight (Presttun, 2018).

5.1 Limitations

Not all the steps proposed by Macário & Marques (2008) in the transferability framework could be duly followed. The primary reason is a very narrow definition on a successful implementation of a measure. A secondary reason is convenience, as there might be other economically sustainable UCCs, however the example from Padua is very well documented, and from a macro perspective it is in a comparable context due to being in Europe. Therefore, rather than following the remaining steps from 4 to 10, the transferability analysis was done more broadly in accordance with three stages instead.

Giving a lot of attention to the relatively bad air quality at the measuring station in Danmarks plass could be perceived as biased. Bergen is spatially large, and many people live on the lower slopes of the surrounding hills, far from major roads. However, Danmarks plass is the only roadside measuring station in the central areas of Bergen valley. The second measuring station that is in the centre of Bergen is in city-background at Klosterhaugen. Which one of them would be more representative of pollution exposure to the average habitant is hard to tell, however it might be important to also take short-term exposure into account, as there is certainly more movement of people in the vicinity of major roads.

5.2 Suggestions for future research

Recently published WHO air quality guidelines (WHO, 2021) indicate that the economic costs of air pollution might be higher than previously accounted for. The implications can be significant for environmental legislation and for guiding future policy. In particular, the counterfactual that the Covid-19 pandemic unveiled on air quality improvement due to decreased traffic movements in Bergen could be used for impact assessment of a potential urban freight measure.

Location planning for the potential UCC(s) in Bergen could be further investigated. It should be optimized to meet the needs of the stakeholders involved. Some methods for doing that exist in the literature. For example, accessibility analysis for UCC location planning (Gonzalez-Feliu et al., 2014), and scenario planning for multiple UCCs (Janjevic et al., 2016). The former requires generating freight transport demand, and shipper-customer route estimations, while the latter is more challenging since costs and profitability are involved in a field that usually lacks good costs data.

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