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Article

Will Digitalization Change the Road Freight Transportation? - Future Scenarios with Sweden as a Case Study

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Abstract: Road freight transportation is a key function of modern societies. At the same time, road freight transportation accounts for significant emissions. To reach the UN sustainability goals, sustainable road freight transportation is key. Digitalization, including automation, digitized information, and AI provide opportunities to improve efficiency, reduce costs, and increase service levels in road freight transportation. Digitalization may also radically change the business ecosystem in the sector. In this paper, the question "How will digitalization change the road freight transportation landscape?" is addressed by developing four different future scenarios, using Sweden as a case study. For each of the four scenarios the impacts on the road freight transportation sector are investigated, and opportunities and barriers to reach a sustainable transportation system in each of the scenarios are discussed. In all scenarios an increase in vehicle kilometers travelled is predicted, and in three of the four scenarios significant increases of recycling and urban freight flows are predicted. The scenario development process highlighted how there are important uncertainties in the development of the society that will be highly important for the development of the digitized freight transportation landscape. One example is the sustainability paradigm, which was identified as a strategic uncertainty.

Key words: freight transportation; future scenarios; digitalization; intuitive logic; logistics; digitalization

1. Introduction

Road freight transportation is a key function of modern societies. At the same time, road freight transportation accounts for significant emissions and contributes to congestion. For example, in EU transportation emissions make up 23% of total CO2 emissions, whereof road transportation accounts for over 70% [1] and heavy-duty vehicles stands for 25% of CO2 emissions from road transportation in Europe [2]. In Sweden, road freight transportation is the dominating mode for domestic transportation with almost 90% of the total goods volume being carried by trucks [3]. Therefore, to reach the UN sustainability goals, a sustainable and efficient road freight transportation sector is key.

Digitalization, including e.g., automation, digitized information flows, and AI, provide many opportunities to improve efficiency, reduce costs, and increase service levels in the road freight transportation sector. Digitalization also has the potential to radically change the business ecosystem in the sector. However, the road freight transportation industry is fragmented and with a highly cost-

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minimizing oriented competition structure, a situation that might slow down the adoption rate of new technology.

Previous works have identified the potential benefits and barriers of digitalization for freight transport, see e.g. [4–8]. However, to fully understand the effects of digitalization, realize the potential, and avoid rebound effects there is call for using a holistic analysis to explore the collected impacts of digitalization on the freight transport landscape [9,10].

This paper aims to fill this gap by addressing the question "How might digitalization change the road freight transportation landscape?" by creating four future scenarios using the explorative scenario method Intuitive Logics [11,12]. The study has 2040 as target year, and uses Sweden as a case study. The scenarios are based on the input from more than 50 experts in the freight transportation domain. For each of the four scenarios the impacts of digitalization on the road freight transportation sector are investigated, including e.g., the development of emissions, vehicle kilometers travelled (VKT), ton-kilometers. Furthermore, the opportunities and barriers to reach a sustainable transportation system in each of the scenarios are investigated. The four scenarios represent plausible developments of the road freight transportation sector and provide a platform for discussions, business development, and research on how digitalization can be used to reach a sustainable road freight transportation sector.

The remainder of the paper is structured as follows: Section 2 provides an overview of previous literature on scenarios for freight transport and effects of digitalization, in Section 3 the method and the process to derive the scenarios are presented. Section 4 presents the results, including the four scenarios. The paper ends with a discussion of the results in Section 5 and a conclusion in Section 6.

2. Review of Literature

In this section, previous literature on effects of digitalization on road freight transportation, and on scenario planning for handling these uncertainties in the sector, is presented. With digitalization we mean use of digitized data, connected vehicles and automation (in particular automated driving).

2.1 Effects of digitalization on road freight transportation

Opportunities and barriers with digitalization for the freight transportation sector. Digitalization creates many changes relevant for the freight transportation sector, including e.g., circular economy [13], e-commerce and changed consumer behavior [14], new business models [5], and automation [15–17]. Cooperative Intelligent Transport Systems (C-ITS) can improve traffic flow, reduce fuel costs, increase efficiency in the transport system [18]. Digitalization does not only enable optimization of the current value chains, but also re-organization of the complete value chain [8]. With digitalization and connectivity, multimodal transportation can be optimized [19], and efficiency for haulers can be increased [20]. Most previous literature investigates potential benefits of digitalization, but Molero et al. [6] studies implementation barriers. The authors find that standardization and compatibility with existing ICT solutions are the main barriers to realize the potential of ICT solutions in the freight transport industry.

Effects of automated driving. For lower levels of automated driving, truck platooning is expected to provide several benefits [21]. Regarding driverless trucks, the first large-scale use case on public roads is expected to be long haulage on highways between logistics hubs with manual trucks performing the first and last mile [15,22]. This would result in a new organization of road freight transport towards a structure similar to current multi-modal freight transport networks [23]. Anticipated long-term impacts include trucking cost savings [24–26] which increase road transport volumes [27]. Also, increasing truck utilization is expected [28–30] which could result in smaller truck fleets. The development of automated trucks is also expected to have significant impacts on freight transport actors' business models [31] and operations [32]. Slowik et al. [33] and Paddeu et al. [34] lists potential opportunities and drawbacks of automated driving for the transport industry.

The role of the driver. Besides automation, where the driver might be removed from the vehicles, digitalization in general is expected to change the role of the driver. For example, the driver currently

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spends more than 5% of the working day on administrative tasks, and this can be reduced using digitized data and logistic related documentation [20].

Driverless vehicles are expected to not only reduce the operational costs of freight transportation by removing the driver from the vehicles but to change the cost structure of truck ownership for haulers [24–26]. Moreover, there are reports focusing on labor market issues related to automated driving in freight transportation [30,35,36].

New business models. Digitalization is likely to "result in radical shift in ways of business thinking" [5]. E.g., digitalization and connectivity will change the interface between the retailer and the customer [14], which have impacts on freight transport. Boon and van Wee [37] and Birtchnell et al. [38] discuss the impacts of 3D printing on transportation and logistics, and draw different scenarios for how 3D printing may unfold as a new way of manufacturing. Digitalization may be used to obtain synergies between passenger and freight transport, but there is a need for new business models to release these synergies [39].

Impacts on sustainability. World Economic Forum [40] estimates that digitalization has the potential to reduce emissions from logistics by 10-12% by 2025, primarily due to optimization of the logistic chain based on crowdsourcing and shared warehouse agreements. However, the effects sustainability effects are of course depending on how digitalization is implemented. Bieser and Hilty [4] compare methods for evaluating sustainability impacts of ICT, and Kayikci (2018) lists 23 sustainability criteria and evaluates how digitalization of freight transport can impact these criteria. In a case study of six transport companies in Turkey, Kayikci finds that focus is primarily to use digitalization to improve economic sustainability.

2.2 Scenario planning for digitized road freight transportation

Previous literature also shows that there are many uncertainties in how digitalization is expected to be materialize within the freight transport sector [10]. As a comparison, studies of the passenger transport sector show great uncertainties in the effects of digitalization on energy consumption, from -30% to +20% [41]. To fully understand the effects of digitalization on freight transport, there is a need for a holistic, system level approach [9,10,42]. In this paper we develop future scenarios, where the aim is to investigate how different trends might interplay and unfold.

Liimatainen et al. [43] developed future scenarios for the Finnish freight transport sector, focusing on CO2 emissions as a function of GDP. Muratori et al. [44] explores emission development scenarios. Winkler and Mocanu [45] investigates 3 future scenarios for road transport in Germany to investigate policies for improve sustainability of the road transport sector, and Liu et al. [9] studies the impacts of road transport on emissions, climate, and health in the US. However, these previous studies have not focused on the effects of digitalization and of how digitalization is implemented.

To summarize, there is an extensive body of literature on how use of digitalization can improve freight transport and logistics. Among those who studies effects of digitalization, most previous studies focus on the effects of one aspect of digitalization rather than the effects of a combination of solutions [7], or focus on the past or present and evaluates what has happened [5,19] rather than exploring the uncertain future.

In this study, the aim is to fill that gap, and to explore the impact of digitalization in general on the freight transport landscape, in an uncertain future. To do this we apply the holistic method scenario planning.

3. Method

3.1 The scenario development process

Scenario development can be based upon different approaches and techniques [11]. In this paper an exploratory scenario approach is used in line with the underlying assumption that the development of the digitalization of road freight transportation is inherently uncertain and that there is not one determined future. Instead, it is acknowledged that several plausible futures need to be explored in order to be prepared for future events. Explorative scenarios outline various plausible

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trajectories of development but does not intend to represent the most probable course of events (predictive scenarios) or to assess how a preferable scenario can be achieved (normative scenarios) [12,46].

In this paper the Intuitive Logics (IL) technique is used. IL is a well-established scenario technique for explorative scenarios [11,12]. The outcome of an IL study is a set of mutually exclusive scenarios. At the core of IL is an analysis of trends believed to influence the system under study. First, trends are identified and mapped according to their presumed strength of influence. Then, the level of uncertainty in how the trends may unfold is judged. Trends that are assessed as having a strong influence and a low uncertainty constitute the *certain development*. The certain development represents processes and forces shaping the study object into a different future state than the current state. The certain development alone may result in drastic changes of the system.

Among trends that are assessed to have a high influence on the system and are highly uncertain, the two most uncertain and important trends are selected to represent the *strategic uncertainties*. By crossing the strategic uncertainties, a 2x2 matrix with each quadrant representing a scenario is created [11]. A scenario is thus a representation of the future given the certain development and a certain combination of outcomes of the strategic uncertainties. The scenarios are then named, elaborated and analyzed with focus on the development of freight transportation.

The scenario development process in this study is shown in Figure 1. An important part of the process is the expert group workshops, engaging 54 experts from 33 different organizations related to the Swedish freight transport sector. The participating actors included transportation buyers, logistic service providers, road carriers, vehicle manufacturers, real estate companies, cities and regions, public bodies and authorities and researchers within transportation and logistics. Between the workshops, an analysis group consisting of the authors, one domain expert, and two future strategists analyzed and compiled the results generated during the workshops.

2040 was set as the target year in the study. However, this should not be seen as an exact year, but rather reflects a time horizon that is not only affected by incremental changes nor so far into the future that the whole society can be expected to have changed.

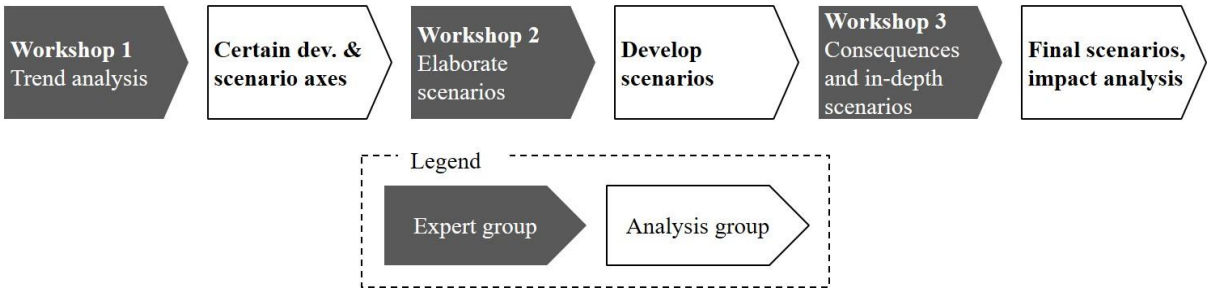

Figure 1. The scenario development process

3.2 Analysis of the transportation chain

For the analysis of the scenarios a schematic overview of transport flows is used, see Figure 2, divided into the following six flows:

1. *Raw material* transportation from extraction site(s) to product manufacturing site(s).
2. *Product* transportation from manufacturing sites to retail (e.g., physical stores or fulfilment centers for e-commerce).
3. Transportation *to consumer* from retail. This transportation may be performed by the end-consumer, e.g., by driving a private car to and from a shopping mall, or by an e-commerce distributor through home delivery or delivery to a pick-up point.
4. *Material recycling* flow, where products are transported from the consumer (or recycling centers) to material recycling plants.
5. *Product recycling* transportation where products are transported from the consumer for product refurbishment or to second-hand retailing sites.

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6. *Consumer to consumer (C2C) circulation* of products directly between consumers who sell and buy used products from each other or between consumers participating in services based on sharing economy.

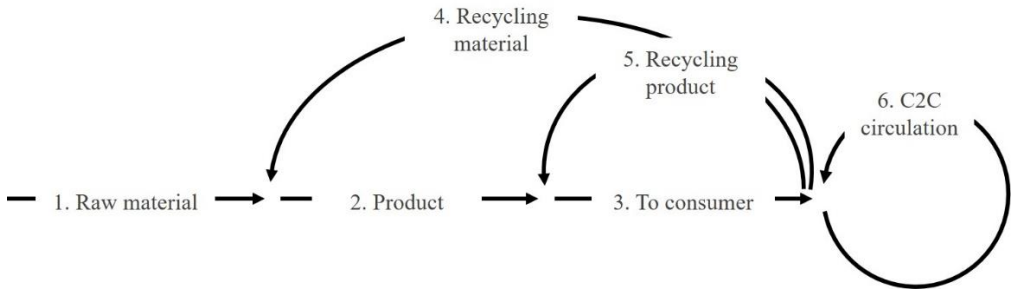

Figure 2. A schematic overview of transport flows used to analyze the scenarios.

4. Results

4.1 The certain development

The *certain development*, based on the trends that were identified by the expert group to be highly probable to materialize, is presented in Figure 3. The certain development is divided into trends external to the freight transport sector but affecting the transport sector (four areas), and trends within the freight transport sector (five areas). Brief descriptions of the nine areas are given in the following two subsections.

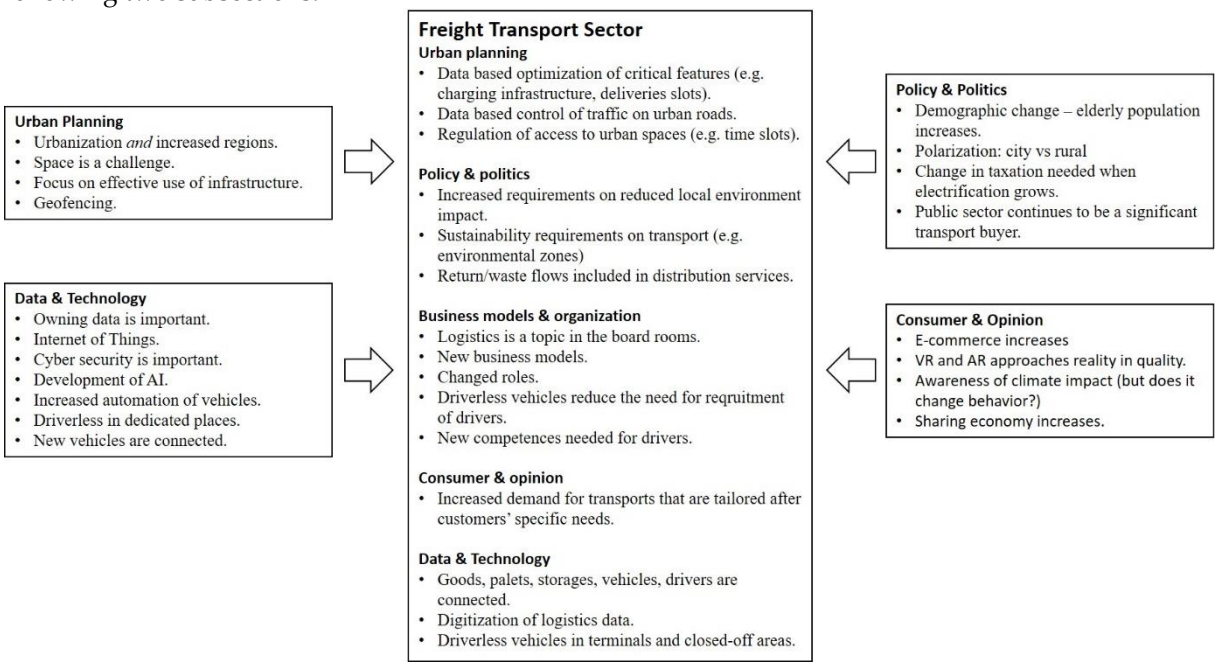

Figure 3. The certain development, including surrounding trends and trends within the freight transport sector.

4.1.1 The certain development external to the freight transport sector

Within the area of *Urban planning* the main trends identified are urbanization and at the same time an increase in region size. Urbanization is expected to lead to an increased focus on managing space limitations and efficient use of infrastructure, and functions such as geofencing[1].

[1] "Geofencing is to create a virtual geographic boundaryenabling software to trigger a response when a mobile device enters or leaves a particular area" [47]

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Within *Data & Technology* development of AI, internet of things, and automation are expected to play important roles. All new vehicles are expected to be connected, vehicles to become more and more automated, and, at least in specific areas, driverless. At the same time, the importance of data ownership and cyber security is expected to increase.

Within the *Policy & Politics* area the demographic change and that the elderly population increases are expected to be the most important trends. Urbanization, together with new types of services based on sharing that are expected to bloom in the densely populated areas, are predicted to create a polarization between cities and rural areas. A shift in taxation will be needed as fossil fuel driven vehicles are replaced by electrified vehicles. The public sector is currently a significant transport buyer, and will continue to be that. This means that the public sector will have the opportunity to put high requirements on the transporting companies.

Within the *Consumer & Opinion* area e-commerce and sharing economy are expected to continue to grow. AR and VR approaches reality in quality, which means that some physical experiences could be replaced by virtual experiences. There will be a rising awareness of the climate, but it is considered uncertain by the expert group how (and if) this will affect peoples' behavior and opinions.

4.1.2 The certain development within the freight transport sector

Urban planning trends that are expected to have a direct impact on the freight transport sector include that data will be used to optimize the utilization of critical resources and bottlenecks such as charging infrastructure and delivery slots. Data is also predicted to be used to control traffic flow on urban roads. There will be stricter regulation of access to urban spaces for vehicles, and this will be controlled using connectivity and geofencing.

Policy & Politics will put increased requirements on transport to reduce local environmental impact such as noise, particle and NOx emissions. This is expected to be implemented by using restrictions such as putting sustainability requirements on vehicles if they should pass through urban areas (called environmental zones [48]). Currently, distribution flows and return/waste flows are often performed by different organizations and with different business models. In the future new business models are expected, where these flows are integrated. This would lead to increased utilization of vehicles.

New *Business & Organization* structures will develop, with new business models and changed roles for actors. Furthermore, logistics is expected to be seen as a strategic question and become a topic in board rooms of many actors. Automation and the development of driverless vehicles will affect the business in terms of reduced costs for drivers, but also as there will be a shift in the required competences for drivers and other personnel. Recruiting drivers is currently a main challenge in haulage companies, but automation is expected to reduce this need.

Within the *Consumer & opinion* area, e-commerce and digitalization are predicted to lead to an increased demand for transport and deliveries that are both free of charge and tailored for the customers' specific needs, e.g., regarding delivery time and place.

Within the *Data & Technology* area digitization of logistics data together with the increased connectivity and IoT will generate more data of various levels including package, pallet, vehicle, and driver. This information will be used to design new services, and improve effectiveness and service level. Regarding driverless vehicles it is uncertain how fast the development and implementation will be, but it is considered certain that driverless vehicles will operate at least in terminals and closed-off areas.

4.2 The strategic uncertainties

Several uncertain trends were identified by the experts, and it was found by the analysis group that these trends could be clustered around three themes: impact of climate-related actions, data-sharing and business ecosystems, and the pace of technological development. The last of these three were selected to be included in the scenario descriptions, and the two first were selected as the two strategic uncertainties.

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In the workshops, the two clusters representing the strategic uncertainties contained trends at different levels of abstraction. The trends within each cluster where aligned by the analysis group, and the level of abstraction to be used to create the scenarios was selected. This level was selected to be a balance between the changes on the society in general and the specific impact on the freight transport sector. In Figure 4, the two themes for the strategic uncertainties are shown, and the levels selected to form the scenarios are framed.

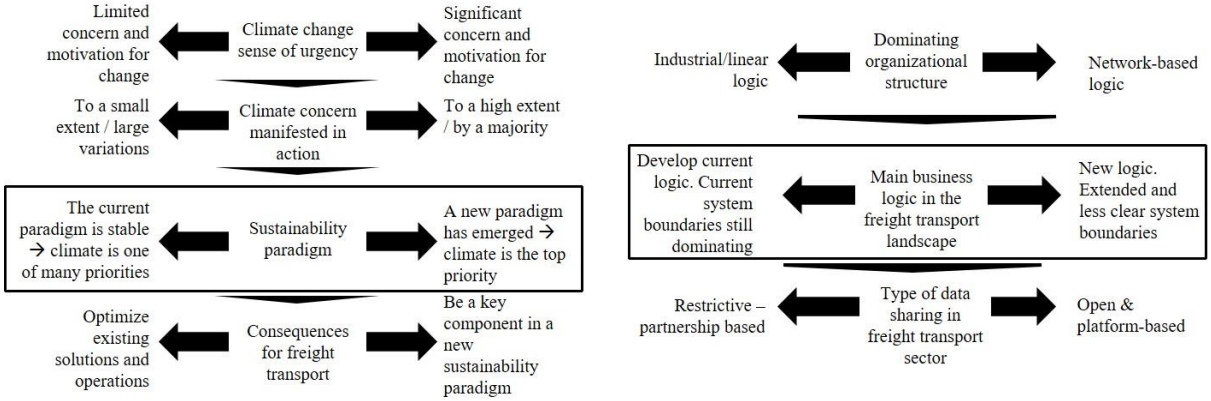

Figure 4. The strategic uncertainties used to form the scenarios.

One strategic uncertainty addresses the role and importance of climate issues in the sustainability paradigm. One outcome of this strategic uncertainty is that the current sustainability paradigm, where climate, sustainability and economic aspects along with other societal issues (education, healthcare, security, etc.) are all more or less equally important and compete for attention and resources. The other outcome is that climate issues have become the top sustainability priority and climate awareness guides individual, business and political decisions.

The other strategic uncertainty addresses the business logic in the sector. One outcome is that the current business logic is still present. Within this business logic, the willingness to share data outside the own organization and closest partner network is limited. In the other outcome, a new openness to share data has changed the business ecosystem, and enabled a new network-based business logic.

4.2 The scenarios

Combining the two strategic uncertainties gives four scenarios, see Figure 5. The four scenarios are named Social Engineering 2.0, Green Circle, Partnership Society, and Bathing in data. In all four scenarios the certain development described in Section 3.1 constitutes the background, but it is embodied in different ways depending on the outcome of the strategic uncertainties. In the remainder of this section the four scenarios are presented using fictive narrative stories, told from the perspective of 2040 and looking back.

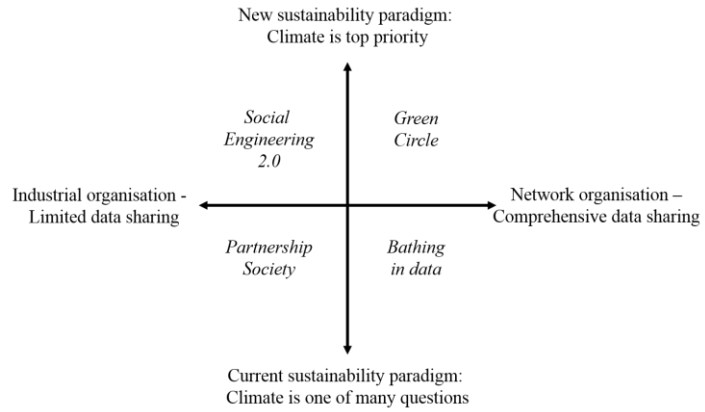

Figure 5. The four scenarios obtained by crossing the two strategic uncertainties.

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4.2.1 Social engineering 2.0

Negative impacts of climate change during the 2020s created support for transformative policies. Since then, taxes on petrol and diesel has multiplied, making vehicles powered by fossil fuel so expensive that they are almost not used anymore. Today, in 2040, there are also extensive taxes on extraction of non-degradable raw materials. Furthermore, a national digital nudging-system has been introduced to incentivize a more sustainable consumption. EU-level regulations forcing all manufacturing companies to track and recycle all materials used has been implemented.

Consumers perceived the development with mixed feelings. There was a strong awareness about the impacts of climate change but the willingness to decrease consumption was limited. This led to that the producing companies addressed the climate issue by shifting bio-material based production, and national and global demand for Swedish bio-based materials have skyrocketed. Also, the re-use of products and material recycling have grown drastically since 2020s. Subscription and deposit models have made it easier to comply consumption with the recycling regulations that are present. Today, to be on top of logistic for a company means keeping track of your products after they sold as well as keeping track of the components ordered for production.

Developments within AI and IoT have materialized by an abundance of sensors and data, and provided new decision support systems. Most people are aware of the business value in personal data. However, previous scandals in which personal data was shared with third parties for commercial and political purposes has created a skepticism to data sharing. For public bodies it has been necessary to introduce data sharing regulations forcing companies to report emission data.

In 2025 the parliament settled on a long-term transport agreement to promote climate aware transport. Legislation on minimum fill rates was one of the interventions. It was first received with criticism but over time it has improved collaboration and efficiency by the use of connected goods. Another important policy was the decision to invest in electric roads for important freight corridors and the European highways. The surging demand for biomaterial has increased the amount of road freight transport of timber and wood products.

The increase of recycling and reuse of products has generated a new type of local transport flows. In the cities, a steady stream of used products is transported to new users, second-hand retail or recycling facilities. However, material recycling typically requires large-scale plants for economic reasons and therefore there are increased outflows from cities. The growing urban freight traffic, the skepticism towards data sharing and fill rate regulations make delivery times for e-commerce packages around the same as in 2019. To counter the increased urban traffic, logistics is centered in "community hubs" serving as both package pick-up- and drop-off points for waste and products for recycling.

The bonus-malus policy incentivizing electric vehicles together with the governmental investments in electric infrastructure has catalyzed the shift to an electrified vehicle fleet. The new urban freight flows have led to a more diverse and flexible freight vehicle fleet. Automated vehicles are frequently used in the industrial flows of bio-material to keep transport costs low.

The strong data integrity focus has led to silo-structures, where large actors from different sectors has created alliances. Data is shared only within these alliances. Transport actors are attractive partners due to their abilities to gather data about goods and freight movements and conditions along the roads and within cities.

4.2.2 Green Circle

Stopping the climate changes is not only one of many goals, it is the highest goal. Back in the early 2020s powerful computer-based simulations and visualizations was able to clearly deliver the message showing the consequences of the climate changes. The sense of urgency empowered government, companies and people in general to take tough decisions to fulfill UNs global goals to stop climate change. Just as EU went from a place where smoking indoors was taken for granted to something that is almost unthinkable during the 10s, cities and streets without vehicles has been something people has become accustomed and appreciative of. It is easy to buy sustainable through taxes, subsidies and a governmentally supported labelling of sustainable products. The economic

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structure is now based on circular principles, and a radical reduction of material-based consumption has changed the way we produce, consume and value our possessions. Selling something that you no longer use, mending something that is no longer working or recycle things you don't need any more is easy while throwing things away is expensive.

The circular economy has led to that the main form of transportation today is a peer-to-peer where local re-use and re-selling are producing big flows of goods where people live. Previous long-distance goods transports that was almost invisible to consumers has shifted to short distance logistics occurring in everyone's backyard. These more visible transports have made many citizens upset, and has forced the haulage and logistics companies to come up with smarter and better ways of doing things. Data sharing has been the key success factor to enable effective transports and use of the shared public space in the cities. This was recognized by the government, who already in the early 2020s not only provided a platform for data sharing, but also implemented laws that forced the actors to share their data on the platform to be transparent on their environmental impact. The openness in data has provided opportunities to create new services and also provided tools for anyone to verify that the services are sustainable.

Compared to early 2020s there has been a big change in focus in politics, with less attention to employment, equal rights, and welfare on behalf of the environment. This change has not gone by without protest and it has been a turbulent time were some citizens feel that they have sacrificed more than others and big protests has been a part of the political landscape.

A big flora of actors is present, and the scene is dramatically different from how it looked in the beginning of the 2020s. New actors as well as actors from other business are entering the logistic sector where established actors are struggling to make money in the new data intense era. Flexible and innovative small actors have changed how transportation is performed in both urban and rural areas.

4.2.3 Partnership Society

Back in the 2010's start-ups in various fields tried to challenge the big companies by providing new services. However, intensive flow of news in media highlighted issues with data security, and that data was abused to track people made people reluctant to data sharing. As a consequence, the new services based on data did not take off. The large, already established enterprises that could continue to build on their existing strong customer relations turned out to be the winners. These large companies realized the potential in utilizing customer data. They managed to change their business, and engaged in strategic partnerships and alliances to increase their access to data and create new services. Today, in 2040, all producing companies (e.g., vehicles, furniture, …) also have significant businesses providing services based on insights from using AI on the data collected by their products. Beside these large companies, there is a number of large platform-based companies (including Airbnb and "LogisticsCloud") providing links between suppliers and consumers.

Since several years there are significant and visible signs of a planet in ecological and social stress, but during the economic crisis 2022 the "Paris Agreement" was forgotten and EU decided to prioritize actions to reach a stable economy. The years before 2020 there were signs of decreasing global trade, but that has shifted and today the global and regional trade is larger than ever. It is obvious that the situation with the climate is untenable, and the number of climate migrants is expected to be all time high in 2040. This has led to new immigration challenges in many countries. To be politically viable, it is important that suggestions are beneficial for the economy, society, and well-fare. Environment alone is not a sufficient argument. The complex political landscape has led to that short-sighted decisions made by political parties with the main focus to win next election instead of political agreements with a long-term focus. All this has made climate actions very slow, but one example is the shift to electric vehicles powered by solar energy, that turned out to be a very lucrative business.

Everyday life has not changed significantly since the late 2010's, but the new data-based services has made life much smoother. People and businesses are highly aware of the risks of sharing data, but most consumers and companies are willing to take the risk to share their data if the service they

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get in return is sufficiently good. Services include e.g., clothes tailored after the measurements provided by the smart mirror in the bedroom or proactive food deliveries based on the current content in the smart fridge. There is a strong focus on how data is treated and shared to 3rd parties, and the GDPR legislation has been updated and is now even stricter than its first version that came in 2018.

There is a number of parallel platforms, owned by the main actors in the industry, providing effective logistics and deliveries. It is the largest actors during 2010's that has developed their own systems by adding data and AI. Flows are more effective than ever before, and both fill rate and route planning has reached new levels. To survive in the business, partnerships are fundamental. Both for larger companies, who can exchange data within the collaboration, and for smaller companies that need to be allied with the main actors to get access to the platforms and the services provided on them.

Increased population and increased transport demand have contributed to an economic growth in the transport sector. Data based solutions have made transport efficiency better than ever before, and service levels have increased significantly. GHG emissions per ton-km have decreased, but due to the increase in transported goods volumes GHG and emissions are still on the same level as back in 2020.

4.2.4 Bathing in data

Economic inefficiencies of public organizations triggered an extensive public and political debate in Sweden during the 2020s. Inspired by the good examples of how Dutch and Estonian municipalities reduced their operation costs and created new and improved digital organizations and services, the government declared the concept of "*network as a basis*" for all public organizations and actions in 2026. This declaration empowered the Agency for Digital Government to carry out a reorganization of public authorities, and increased publication of data between the authorities and for commercial actors creating proactive services in education/schools, healthcare, and crime prevention. The utility of data sharing has also manifested itself in several transport related services, for example, geofencing has allowed the spread of deliveries and traffic over all hours of the day and AI-powered predictive approaches for infrastructure maintenance have significantly reduced the number of unplanned service outages. Next to economic growth and efficiency, sustainability has also benefited from the network organization and the comprehensive data sharing. Initiatives like "Sharing for Earth", that was started in 2025, has triggered companies and organizations to share their data to reach environmental and social sustainability goals.

Inspired by the new efficient and convenient solutions and services citizens as well as organizations and municipalities are more open to share their data. To enable novel and genuinely effective and user-friendly solutions by utilizing various kinds of data, several companies in Sweden and globally have joined the "The digital deal" agreement that specifies how data collected from / about people, buildings, vehicles, utilities and organizations should be shared and used. The few companies that did not submit to the data sharing paradigm and did not dare to open their data and a consequence have lost their competitive edge.

The amount of goods transported is at an all-time high. E-commerce has dramatically grown. People expect deliveries to be delivered just-in-time that are fitted to their personal schedules and conveniences. The last-mile delivery challenge has been resolved by a number of innovations such as autonomous electric distributions vehicles, delivery robots, integrated pick-up-delivery boxes powered by digital locks, and modular multi-purpose vehicles that can pick up recycling after package deliveries. In addition to enabling efficient consolidation of local distribution, data sharing and digitalization became the key to a number of AI-powered predictive solutions that combine user and consumer insight with information about transport flows and vehicle demand. For example, through predictive shipping and autonomous electric vehicles the concept of rolling warehouse becomes reality.

There are groups of citizens that are fed up with fast paced and largely convenience- and efficiency-driven society. Despite data sharing and sustainability initiatives, we did not manage to

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keep the climate temperature increases below the 2 degrees Celsius goal. This has led to a global political dissatisfaction in the geopolitical landscape that has drastically changed due to elimination of fossil-fuel based economy.

In addition to the established transport actors that capitalized on the opportunities that are provided by the network organization and comprehensive data sharing paradigm, digitalization also created new market entrants and partnerships. IT and social network giants not only became important via the customer insights that they deliver, but have created pay-as-you-go building blocks of cloud-based logistics that service providers can build on. New global transport actors appear that without having their own vehicle fleet, drivers, warehouses or terminals can create niche services with little investments. The opportunistic creation of such niche services is enabled by digital micro contracts that enable the simple and secure procurement of small and special transport assignments.

4.3 Transportation flows in the scenarios

In this section, the main characteristics of the transport flows in the different scenarios are presented. The flows are visualized in Figure 6 and an overview is given in Table 1, and. These results are based on estimations by the expert group members, combined with the analysis group's analysis of the discussions during the export group workshops, and changes in volumes are in comparison with current levels.

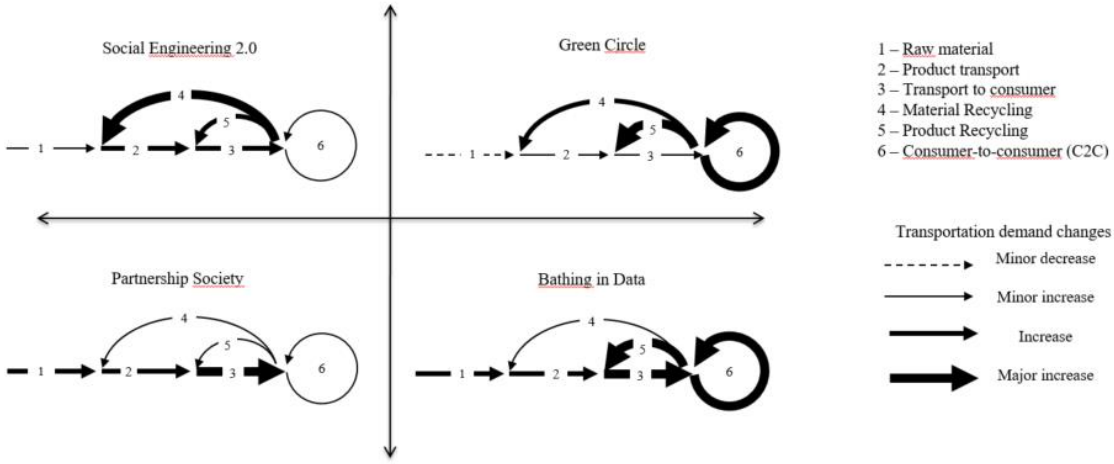

Figure 6. Expected transportation demand changes in the four scenarios.

4.3.1 Transportation flows in Social Engineering 2.0

Consumption is growing, but policies have shifted consumption towards products that are less energy and material intense to produce, and towards products made of biomaterial and recycled material. Two factors explaining the consumption growth are the growing population and the fact that people experience less bad consciousness when consuming products of biomaterial and thus consume more. Because of the growing global demand for biomaterial, there is an increase in export transports of forest-based biomaterial from Sweden.

Data sharing and collaboration within alliances of companies have made transport more efficient and increased consolidation levels and fill rates. These effects are primarily affecting the industrial flows of raw material and products (flows 1 and 2 in Figure 6), where the demand is repeatable and that only involves a limited number of actors. The recycling flows are much more difficult to optimize with the limited data sharing across actors in Social Engineering 2.0.

Altogether, in the Social Engineering 2.0 society, there is an increased transport demand in all transport flows, but primarily in flows 2, 3, 4, and 5, see Figure 6.

4.3.2 Transportation flows in Green Circle

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Changed consumer behavior, with increased demand for reused and recycled products, have significantly increased the demand for recycling transports (flows 4 and 5) and peer-2-peer transport (flow 6), but also for transport of products and to consumers (flows 2 and 3). However, as a consequence of the broad data sharing in combination with strong sustainability regulations, the fill rates and the efficiency of transport have improved. This is significant in flows 2 and 3, that are relatively regular and where goods can be efficiently packed. The transport flows 4, 5, and 6 are much more difficult to improve, both as they are less regular and as the goods transported typically is bulky.

4.3.3 Transportation flows in Partnership Society

Population growth and increased e-commerce increases transport demand, and to attract customers the companies have to deliver products and solution that are convenient and tailored to the customers' needs. To be successful strategic partnerships within which data is shared are crucial.

There is an increase in transport demand primarily in the flows 1, 2, and 3. For transports of raw materials and products (flows 1 and 2) data can be shared within the strategic partnerships to improve efficiency. This is more challenging in distribution (flow 3), as the competitors operate in parallel instead of sharing data and space. In particular, there is an increased competition towards short delivery times that makes efficiency improvements even more difficult.

As there is limited interest in recycled products and no forcing legislation, these flows are limited. Also, the limited data sharing holds back the potential of sharing services, leading to that also the peer-to-peer flow is limited.

4.3.4 Transport flows in Bathing in Data

In this scenario, focus is primarily on using data to improve services and products for customers and consumers. This means short delivery times and extensive sharing services. Customers demand has increased since the services are so convenient. This has led to an increased transport demand in the flows 1, 2, 3, 5 and 6. Improving efficiency is the second priority. The result is effective transports for material and products (flows 1 and 2). For the flows to and from the consumer (3, 5, and 6) the customer experience with flexibility and short delivery times is limiting the efficiency in the flows.

Table 1. The effects of different parts of the transport chain in the four scenarios. The change in transport in vehicle-kilometers is marked with + and – signs, spanning from major demand increase (+++) to major demand decrease (---) compared to current levels.

Part of flow	Social Engineering 2.0	Green Circle	Partnership Society	Bathing in Data
1 Raw material	+ Increase in forest and other bio-based material for manufacturing Increasing export flows of bio-materials Shift to rail and sea offset CO2 emission increase from volume growth	-- Increased re-use and recycling leads to decreases in raw material transportation.	++ Population growth and increased consumption increases demand Intermodal transport pushed by government Automation and driverless vehicles in industrial flows.	++ Transport demand increases, but data enables improved efficiency and fill rates Intermodality has increased due to data sharing
2 Product	++	+	++	++

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	Fewer products produced from new raw-materials More products made of recycled material are transported.	Fewer products produced from new raw-materials Products made are made out of recycled material. Data sharing enables high fill rates and effective transport.	Population growth and increased consumption increases demand Limited data sharing limits efficiency improvements	Increased demand due to e-commerce and population growth. Data sharing enables effective transport.
3 To consumer	++ Increase in consumption enabled by sustainable production and recycled materials	+ Increased distribution of recycled products Improved efficiency and fill rates due to data sharing	+++ Population growth and increased consumption increases demand. Limited data sharing limits efficiency improvements	+++ Increased demand due increased e-commerce and increased sharing economy Short delivery times and tailored deliveries increases transport demand
4 Recycled Material	+++ High taxes on raw material generate material recycling	++ Green policies foster increased recycling of material.	+ A limited increase, primarily driven by scarcity of raw materials.	+ A limited increase, primarily driven by scarcity of raw materials.
5 Recycled Products	+ Limited product recycling	+++ Increased sharing and product recycling driven by sustainability policies and enabled by data sharing.	+ A limited increase, primarily driven by larger companies offering recycling of their own products.	+++ Many new services based on circular principles provided by companies. Short delivery times and tailored

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				deliveries increases transport demand
6 Consumer to consumer (C2C)	+ Policies make peer-to-peer sharing services attractive, but growth potential is held back by limited data sharing	+++ New and growing flow between customers when goods are resold and/or reused. New platforms and connections enable new possibilities for sharing, changing and selling.	+ Growth potential is held back by limited data sharing, and by lack of customer demand.	+++ Many new services for peer-to-peer sharing enabled by data sharing Short delivery times and tailored deliveries increases transport demand
Typical e-commerce delivery times (to consume)	Several days	Hours - Days	Hours - Days	Minutes - hours

5. Discussion

As discussed in the introduction, the development of the road freight transportation sector is one key to meet the sustainability goals. Therefore, in this section we discuss the developments in the scenarios from a climate perspective.

5.1 Vehicle kilometers travelled

The expected development of vehicle kilometers is relevant to study as it is related both to energy consumption (and thereby greenhouse gas emissions, in particular if vehicles are using fossil fuels) and to congestion. The experts expect that digitalization may lead to increased consumption in general as it enables new and tailored services and products that are more attractive. At the same time, they expect digitalization to enable services based on sharing economy and circular economy. These developments lead to increased vehicle kilometers travelled (VKT). Digitalization is also expected to contribute to reductions of VKT. It provides opportunities for setting and following up new regulations such as kilometer-based taxes, and fill rates can be increased through data sharing and by connecting goods (Internet of Things). Digitalization may also improve route planning and optimization, as well as optimized packaging of the goods into the vehicles. As shown in Figure 6, the outcome of these counteracting aspects depends on the scenario.

In the two scenarios on the left-hand side of the scenario matrix, in which a traditional business logic is dominating, the flows 1-3 are central for the development. These flows are stable, predictable, and between relatively few actors or "from one supplier to many delivery points", and thereby relatively simple to optimize.

In the scenarios on the right-hand side, where a network-based business logic is dominating, the flows 4-6 are central for the development. These flows are typically "many to many" that makes them

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more challenging to optimize than the flows 1-3. In addition, the goods have often bulkier as it is not effectively packed, compare e.g., transporting furniture from a factory efficiently packed to optimize transport and then to be mounted at the arrival to the customer with used furniture that is already mounted when transported between two users. On the other hand, the flows 4-6 are often local or regional and thus shorter than the flows 1-3, so a shift from flows 1-3 to flows 4-6 might lead to a decrease in total VKT. To fully understand the impacts of digitalization on the total VKT, more detailed analysis and simulations are needed.

5.2 Climate priority

As suggested in the scenarios, increased climate priority can unfold in two different directions. In the *Social Engineering 2.0* scenario climate priority leads to an increased use of bio based raw material, e.g., from forestry. In turn, this leads to an induced transportation demand in particular in the flows 1-3. Furthermore, it may also induce export flows if the raw material is exported to other countries.

In the *Green circle* scenario, the increased climate priority leads to increased attention to reuse and recycle products, based on sharing and circular principles, and focus shifts towards the flows 4-6. As discussed above, this requires new optimization schemes and new challenges with transport related to the bulkier goods. Another challenge with the shift towards flows 4-6 is that they typically appear in the areas where people live. Thus, transport will become more visible to citizens. A solution might be to use off-peak deliveries where transports are performed during night time [49].

7. Conclusions

In this paper, four explorative scenarios describing how digitalization may affect the freight transportation landscape have been developed using the Intuitive Logics method. During the process two main uncertainties were identified: Whether a new sustainability paradigm with climate as the top priority will be present or not, and whether traditional (hierarchical) business logic or network-based business logic will be dominant. By combining the different outcomes of the two strategic uncertainties, the four scenarios are formed.

The four scenarios should not be seen as the most probable futures, but rather as plausible futures with "extreme" characteristics that provides a platform for discussion and development. The development of the transport sector is envisioned to be very different in the different scenarios. Three main take-aways are:

Increased recycling flows - In three of the four scenarios there will be an increased focus on recycling flows. In two of the scenarios, significant increases of recycle flows and flows from peer to peer are predicted. This leads to new challenges in optimization of flows, and that freight transportation are increased in urban areas.

Increase of VKT – In all scenarios an over-all increase in VKT is predicted, also in scenarios where climate has a high priority. Handling of this increase is important to reach climate goals, including developments of fossil free fuels, efficiency improvements, and policies that target the climate goals.

External events and uncertainties – The scenario development process highlighted that uncertainties in the development of the society that are not directly related to neither freight transport nor digitalization are highly important for the development of the digitized freight transport landscape. This is highlighted by the strategic uncertainty related to if the current sustainability paradigm will transform towards an increased climate focus. The societal development will have a strong influence on what problems the digitalization of the freight transport sector should solve and what digital solutions are feasible.

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