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Freight and logistics grand challenges

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Challenges

Freight and Logistics systems face several major challenges largely arising from changing demand patterns that is making it difficult to increase efficiency as well improve sustainability and resilience.

Demand patterns

A substantial range of key challenges for freight and logistics systems stem largely from recent changes in demand patterns that is leading to lower levels of efficiency as well as difficulties for increasing sustainability. It is also becoming difficult to improve the resilience of logistics networks.

The insatiable demand for goods by consumers has led to variable and dynamic consumption patterns that have forced logistics systems to be transformed from push based to pull based networks. Increasing levels of urbanisation has led to higher levels of consumption and increased traffic congestion.

eCommerce has created the need for more distributed delivery systems due to growing demand for home deliveries. The last mile requires individual parcels and small orders of food to be delivered on demand with express deliveries becoming more common. This has substantially increased the distance travelled by delivery vehicles within urban areas.

Reverse logistics systems now face increased pressure due to product returns from eCommerce as well as the need to facilitate the circular economy. New networks are required to facilitate reuse and recycling.

Growing demand for new residences, offices, retail and industrial developments as well as infrastructure projects generate a large amount of construction activity that requires storage and transport of materials. The transient and intense nature of transport demand patterns from construction projects creates many efficiency and sustainability challenges (Thompson, et al., 2023).

Efficiency

Changing demand patterns by consumers are leading to decreasing load factors for freight vehicles that is contributing to lower levels of efficiency for logistics networks (ITF, 2018). Key challenges relate to how to increase consolidation levels in vehicles as well as the utilisation of warehouses. This is difficult since most freight and logistics networks are operated by independent carriers and shippers.

Inner urban residential and commercial development has led to depots and warehouses being relocated well away from traditional ports (logistics sprawl). Consequently, the

middle mile, transport between ports and warehouses typically involves a large amount of crisscrossing movements of freight vehicles within urban areas.

There is also much pressure from the combined effects of both massification and atomisation, where transport vehicles such as ships, trains and trucks are increasing in capacity but consumers are demanding smaller consignments largely individual parcels from eCommerce. This creates bottlenecks, due to demand surges and the need to reconsolidate loads at terminals. A high degree of coordination of the timing of transfers between transport modes to at terminals is necessary to reduce delays.

There is also a lack of innovation in freight and logistics. Manual administrative processes and handling procedures are contributing to inefficiencies and inhibiting productivity.

Resilience

The resilience of freight networks is being threatened by the increased frequency and intensity of extreme weather events as well as growing international tension from conflicts and tariffs. Global logistics networks are being disrupted with delays and uncertainty becoming real issues for trade.

Sustainability

Decarbonisation is a key challenge for freight and logistics. There is a real need to reduce vehicle emissions and consumption of fossil fuels. Total emissions from freight vehicles is the product of both the emissions produced per vehicle kilometre and the vehicle kilometres travelled. Emissions produced per vehicle kilometre largely depends on vehicle type, fuel type, engine emissions standards and operating conditions. Vehicle kilometres travelled depends on the nature of freight networks such as the location of terminals, warehouses and customers, demand for goods and vehicle load factors. Due to changing demand patterns and low levels of network efficiency, vehicle kilometres travelled by freight vehicles is growing, leading to increasing emissions. In addition to utilising alternative fuels for freight vehicles, it is necessary to implement initiatives to increase consolidation levels of freight vehicles to reduce the total distance travelled by freight vehicles.

There are a number social problems that need to be addressed when planning and operating future freight systems. These include how to minimise crashes as well as health costs associated with vehicle emissions and noise. eCommerce has put pressure on shippers and carriers to deliver goods to homes within narrow time windows. This combined with low pay rates and long shifts can increase safety risks for drivers and has led to a shortage of drivers in many countries.

Opportunities

Both City Logistics and the Physical Internet (PI) provide useful frameworks for addressing the challenges described above. City logistics promotes a holistic approach to urban freight combining multi-stakeholder engagement with multi-criteria assessment

(including triple bottom line). PI promotes open, shared and connected logistics systems (Montreuil, 2011; Crainic and Montreuil, 2016). The vision of PI is to create an integrated and seamless logistics network. Ongoing research is required for developing analytical tools for designing and evaluating emerging technologies and city logistics schemes to ensure that they can be successfully implemented.

City logistics

A range of City Logistics solutions, including parcel lockers, Autonomous Delivery Vehicles (ADV), crowdshipping, consolidation and transfer hubs as well as High Performance Freight Vehicles (HPVs) have good potential for addressing sustainability and efficiency challenges.

Parcel lockers provide convenient and flexible receipt points for receivers that reduce delivery costs and distances travelled by carriers (Mohri et al., 2024). Models need to be developed for determining the optimal number of sites as well as their location and whether they are located within buildings or in public spaces. Parcel lockers can also be used for exchanging goods between carriers to create benefits for shippers, carriers, receivers and the community (Guo, et al., 2021).

Autonomous vehicles such as delivery robots and drones have good potential for reducing emissions. New approaches are required for designing networks that integrate multiple modes, considering battery charging as well as capacity constraints.

Crowdshipping provides opportunities for reducing carrier operating costs as well as emissions from vans in residential areas. There is a need to develop behavioural models to understand the willingness of the public to participate in such schemes and accept tasks. Both optimisation and behaviour choice models are required for designing networks incorporating options such as parcel lockers and public transport (Mohri et al., 2025).

Consolidation centres and transfer hubs provide good prospects for improving network efficiency of distribution networks in urban areas. There is the need to determine the optimal number and location of consolidation centres to satisfy customer service requirements. Open hubs provide an opportunity to transfer goods between different types of vehicles such as eBikes to achieve more efficient last mile deliveries. High Productivity Freight Vehicles (HPFVs) including multi-combination trucks can reduce shipper costs, improve productivity for carriers and reduce congestion for road managers (Thompson, et al., 2020).

Physical Internet

The PI Roadmap (ALICE-ETP, 2020) identifies milestones for achieving the PI vision and provides clear directions for researchers in what key elements are necessary for the realisation of the PI.

Synchromodality involves the dynamic matching of supply and demand to minimise the effects of disruption (Sakti et al., 2023). There is good potential to reduce logistics costs and increase reliability by designing flexible contracts and developing improved risk analysis and management procedures as well as platforms for matching supply and demand.

Sharing warehouses can reduce storage and transport costs. Procedures for dynamically optimising the location of storage facilities and pricing of transport services will also be necessary for PI concepts to be implemented.

Digital platforms provide a means for shippers, carriers and receivers to interact and negotiate prices and service levels. AI can assist in automating the exchange of goods to improve the efficiency and profitability for stakeholders (Guo et al., 2021).

Digital Twins (DTs) provide a framework for integrating a range of technologies such as the Internet of Things (IoT), agent based modelling and artificial intelligence (AI). Descriptive, predictive and prescriptive analytics can be developed to improve the management of dynamic logistics systems (Taniguchi et al., 2024).

AI has great potential for automating prediction and classification systems as well as negotiation between stakeholders in freight systems.

Digitalisation of logistics systems through sensor networks allows Geographic Information Systems (GIS) and real-time visualization and management of freight networks to be undertaken.

Developments in autonomous and connected vehicles will lead to improved levels of safety and productivity. IoT has good potential for improving fatigue and stress management systems.

Other solutions

There is a range of energy options that can eliminate or reduce tailpipe emissions from freight vehicles. Research is required to assess their viability and practicality for carriers. Electric Road Systems (ERS) and electric vehicle charging infrastructure provide good potential for reduce vehicle emissions. This will require improved methods for demand forecasting, user acceptance and risk management to plan and manage the infrastructure necessary for their successful implementation.

Flexible business models and technologies offer potential for promoting intermodal freight networks to ensure that they are open and shared. Logistics parks where transport depots and warehouses are co-located with intermodal terminals provide good opportunities to increase consolidation levels and reduce transport distances.

Dedicated freight infrastructure such as Hyperloop (US), Autoflow road (Japan) and Cargo Sous Terrain (Switzerland) have potential for improving efficiency and sustainability. However, procedures for integrating these automated high capacity links at logistics nodes will be necessary.

Integrated land use and freight demand models need to be developed for planning new freight areas as well as protecting

storage and transfer facilities in inner and middle metropolitan areas to reduce distances travelled by freight vehicles.

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