Report WP 3 - Criteria for sustainable freight transport

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Rationale for priority lanes

Cost of congestion

Congestion leads to several economic costs of which the increase of travel time is the most important. Others are costs due to unreliability of travel times and additional fuel costs due to higher fuel consumption under stop-and-go conditions. It is estimated that the economic losses of congestion account for 2% of total GDP in EU of which 30% caused by trucks (CE Delft et al., 2011). The problem of congestion is increasing and is projected that the related cost to society increase by 50% until 2050 (European Commission, 2011).

For logistics operations, congestion increases not only the travel time, but also leads to a reduced reliability of travel times, which in turn reduces productivity of operations within factories, warehouses and shops (McKinnon et al., 2009). The value of time and value of reliability is not unique for all traffic units, it varies significantly, depending on many different parameters. Generally, on average trucks have a higher value than cars, and bigger trucks than smaller trucks, but the average value alone is not a sufficient parameter describing the whole traffic, as the variation between the cheapest and most expensive traffic units can be very high (Figure 1).

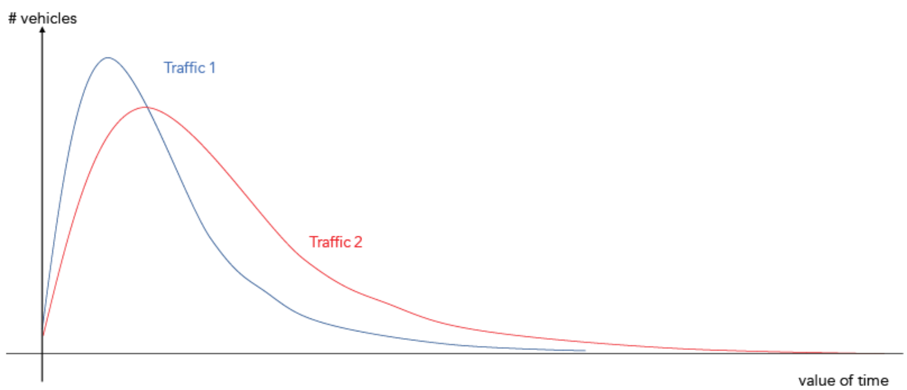

Figure 1: Example distribution of the value of time of 2 traffic situations

One strategy to reduce the economic losses of congestion is to separate normal traffic and priority traffic onto different lanes, i.e. to prioritize freight traffic which in average have a highest value of time than passenger cars. The cost benefits of these 'truck-only lanes' depend on several factors such as traffic volume, truck percentage and value of time conditions (De Palma et al., 2008; Rudra and Roorda, 2014).

Potential applications of priority lanes

Two cases of applications of priority lanes are distinguished here. The first case is to use available capacity on existing priority lanes, i.e. on bus lanes. The second case is to change one normal lane into priority lane, e.g.to convert a 3-lane motorway into a 2+1 lane motorway (2 normal lanes + 1 priority lane).

Case 1: urban motorway with bus lane (2+1 lanes)

This application includes converting an existing bus lane into a priority lane, which may also be used by prioritized freight (Figure 2).

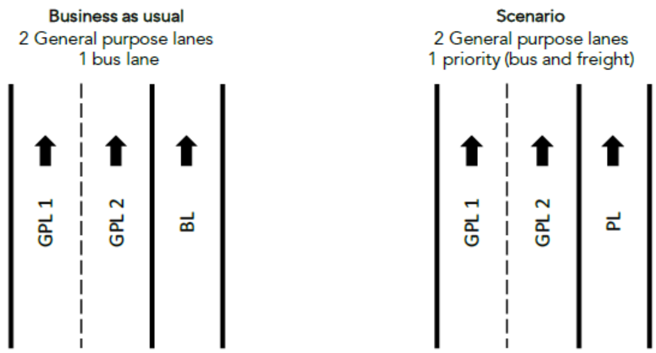

Figure 2: lane design of (a) urban motorway with bus lane, and (b) urban motorway with priority lane

The potential effect on the travel times of both normal traffic, prioritized freight and busses depends on the number of prioritized freight vehicles. Based on an assumed business as usual, where there is significant congestion on the normal lanes (very low speed) and free capacity on the bus lane (free flow speed), 2 scenarios can be distinguished (Figure 3). In the first scenario (Figure 3b), the number of prioritized freight is limited in order not to affect the bus traffic negatively. In this way, both the prioritized freight traffic and busses have a high travel speed on the priority lane. The situation on the normal lanes improves only marginally, as only a few trucks are shifted to the priority lane. The outcome can be characterized as a **Win/Win/Neutral with a limited total benefit:**

- **Win:** for prioritized freight which is significantly accelerated
- **Win:** A limited win for normal traffic
- **Neutral:** (practically) no effect on busses
- The **total benefits** are limited due to the small number of prioritized trucks.

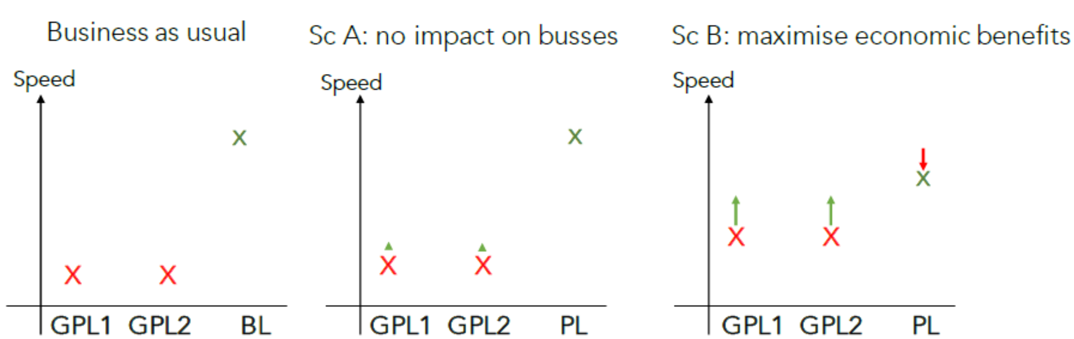

Figure 3: Potential effects on travel speeds of 2 scenarios

Larger total economic benefits can be achieved when a larger number of trucks is prioritized, and a somewhat reduced speed of buses can be accepted as traffic on the priority lane increases. This situation can therefore be characterized as **Win/Win/Lose with significant total benefits:**

- **Win** for prioritized freight which is significantly accelerated
- A substantial **win** for normal traffic
- **Lose:** Negative effect on busses

- **Significant total benefits** as both the ‘win’ for trucks and the ‘win’ for normal traffic are much higher than the ‘lose’ for busses.

Case 2: 3-lane urban motorway

This application includes converting a 3-lane motorway into a 2+1 lane motorway, i.e. one normal lane is converted into a priority lane (Figure 4).

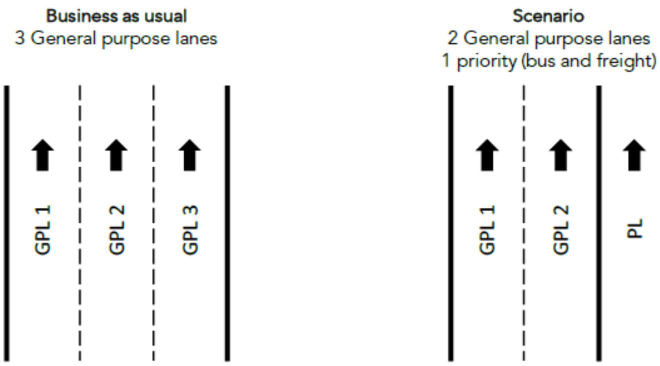

Figure 4: lane design of (a) 3-lane urban motorway, and (b) 2-lane urban motorway with priority lane

As this design involves a significant reduction of capacity for normal traffic (from 3 lanes to 2 lanes), congestion for normal traffic will probably get worse. Hence, this case leads to a **win/lose situation with total benefits** (win>lose):

- **Win:** Prioritized Freight traffic wins significantly, as travel speed on the priority lane is much higher
- **Lose:** Normal traffic loses, as capacity is reduced significantly
- **Total benefits:** The total time losses are likely to increase, but since the vehicles with the highest value of time are prioritized, the economic losses are nonetheless decreasing

The scale of the total benefits depends on the number of trucks to be prioritized. Again, 2 scenarios can be distinguished: In the first scenario, the number of prioritized trucks is limited to secure highest speed on the priority lane, e.g. 80 km/h (Figure 5b). This secures best outcome for the prioritized vehicles, but the total economic benefits are limited as only a few vehicles can benefit from this measure, which also limits the congestion relieve on the normal lanes. The second scenario (Figure 5c) accepts some speed reductions on the priority lane, e.g. 60 km/h, in order to maximize the number of prioritized trucks.

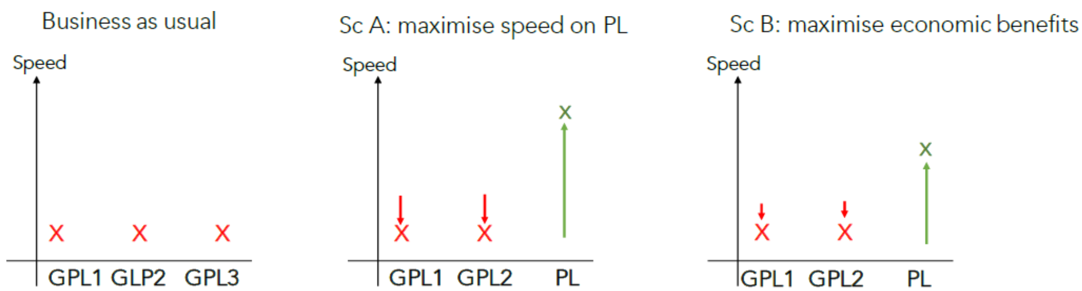

Figure 5: Potential effects on travel speeds of 2 scenarios

Determinants of sustainable freight transport[1]

In addition to the economic benefits linked to the value of time and value of travel time reliability, priority lanes can be used to support other goals of transport policy. For example, they can be used as an incentive to support sustainable transport policies such accelerating the introduction of environmentally friendly vehicles, better utilization of vehicle capacity and modal shift to rail and waterways. Freight transport generates several impacts on the environment and society, including impacts on public health and ecosystems from air pollution, climate change, noise and accidents. The scale of these impacts is generally determined by the amount of traffic (total vehicle km) and the impact per unit of traffic (i.e. of the vehicle used, e.g. CO2 per vehicle km). Consequently, a reduction of unsustainable impacts can be achieved in two ways: either by reducing traffic volumes; or by reducing the vehicles' impacts. In recent years, there have been substantial improvements on the vehicle level, e.g. efficiency improvements reducing CO2 emissions and the EURO emission limits reducing the emissions of local pollutants, reducing the impact intensity of vehicle movements. However, increasing traffic volumes have overcompensated these improvements on the vehicle level, resulting in a situation where the absolute impacts are nonetheless rising. It is therefore key to address the increasing traffic volumes if a sustainable transport sector is to be achieved. A systematic way to understand the driving forces of the continuously increasing traffic volumes, are the following equations[2]:

(1) $\textit{PM Impact} = \textit{Traffic} \times \textit{Impact intensity}$

where PM Impact is the economic impact (external costs) of PM emissions, including public health and ecosystem impacts (measured in monetary terms, e.g. SEK), traffic is the total traffic work (measured in vehicle km), and impact intensity is the average external cost per traffic unit (measured in SEK/vehicle km).

Traffic and impact intensity can be further broken down in order to identify the influencing factors:

(2) $\textit{Traffic} = \textit{Economic Activity} \times \textit{Value Density}^{-1} = \times \textit{Transport intensity} \times \textit{Traffic intensity}$

(3) $\textit{Impact intensity} = \textit{Energy intensity} \times \textit{Emission intesity} \times \textit{Emission sensitivity}$

where the factors are defined as follows:

- **Economic activity** [monetary unit]: Examples of economic activities are industrial production, services, retailing, etc. Measured in monetary terms, e.g. gross-domestic-product (GPD) of a country/region.
- **Value density** of the economy [monetary unit/ton]: the amount of goods in tons needed to generate an economic value. It converts the monetary unit of economic activity into goods produced/consumed (tons). For example, services generate less freight movements than industrial activities, a service-based economy therefore has a lower value density than an economy based on industrial manufacturing. Furthermore, bulk transports (coal, forestry, etc.) has a lower value density than manufactured goods (e.g. electronics).
- **Transport intensity** of the logistics system [ton km/ton]: the average distance a product is transported. It converts the weight of the goods produced/consumed into ton-km.

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[1] We use the term 'sustainable freight' instead of 'high socio-economic value', their meanings are the same.

[2] The equations show the impacts from particle emissions (PM) to visualize the transport sector's complexities and interdependencies with other sectors. The formulas can be applied in the same way for climate impacts, noise, accidents, etc.

- Longer transport distances lead to a higher transport intensity, hence outsourcing generally increases the transport intensity, local sourcing decreases the intensity.
- **Traffic intensity** of the transport system [vehicle km/ton km]: the amount of traffic (vehicle km) required to move a certain transport demand (ton km). The lower the vehicle capacity and load factor, the higher the traffic intensity. For example, 10 vans transporting 1 ton over a distance of 10 km generates 100 vehicle km. Transporting these goods with 1 large truck instead, reduces the traffic to 10 vehicle km (10 tons x 10 km x 1 vehicle). Consolidation therefore reduces the transport intensity.
- **Energy intensity** of the traffic system [energy/vehicle km]: the amount of energy needed to move the vehicles. For example, increasing the fuel efficiency of trucks reduces the energy intensity.
- **Emission intensity** of the fuel/vehicle system [emissions/energy]: the amount of emissions generated when using energy for moving a vehicle. For example, Euro 6 trucks have a lower emission intensity than Euro 1 trucks.
- **Emission sensitivity** of the urban form: [monetary unit/emission]: the economic impact the emissions generate on the urban form. For example, 1 kg of particle emissions have a high damage in high-density areas, while it does not generate a high damage in rural areas.

Combining the formulas for traffic generation (equation 2) and impact intensity (equation 3) into equation (1), the impact (external costs) from particle emissions are defined as:

$$(4)\ PM\ Impact = GDP \times \frac{Ton}{GDP} \times \frac{Ton\ km}{Ton} \times \frac{Vehicle\ km}{Ton\ km} \times \frac{Energy}{Vehicle\ km} \times \frac{PM\ Emissions}{Energy} \times \frac{Impact}{PM\ Emission}$$

Reducing the impacts from particle emissions, requires reducing one or more factors of the equation 4. Assuming that a growth of economic activities is desirable, the other factors of the formula need to be reduced. As the value density and the impact intensity cannot be directly influenced by transport policy, the focus needs to be placed the transport intensity, the traffic intensity and the impact intensity. Accordingly, the factors determining the sustainability performance of transports are:

1. Transports contributing to a low transport intensity

Factors determining the transport distances are 1) the length of the links in supply chains, and 2) the lengths of the links in transport chains.

Length of supply chain links

As transport and communication networks have improved, companies have extended their ‘logistical reach’ to find better, cheaper and more diverse sources of supply and sell their products to more distant customers, which increases the transport intensity. Local sourcing, on the other hand, reduces transport distances and hence the transport intensity. For example, by sourcing food products locally (globally), a supermarket chain can contribute to a lower (higher) transport intensity. Therefore, one possibility to reduce the transport intensity is the development of regional supply structures within which firms would source as much as possible from local suppliers.

- Local sourcing

Length of transport chain links

As a second factor, the location of logistics facilities affects the transport intensity. Goods are often routed through distribution terminals, which form the link between interregional transport and local distribution. Logistics sprawl (i.e. the trend of establishing new terminals farer away from city centers) contributes to a higher transport intensity, as they increase the distances of urban distribution activities. Therefore, another possibility to reduce the transport intensity is route freight towards centrally located terminals.

- Central locations of distribution terminals

2. Transports contributing to a low traffic intensity

The traffic intensity is defined as the amount of traffic (vehicle km) required to move a certain transport demand (ton km). Factors determining the traffic intensity are 1) the average payload (ton) on the vehicle trips, and 2) efficiency of vehicle routing.

Payload on vehicle trips

The average payload (ton) on the vehicle trips is determined by the vehicle carrying capacity, the vehicle utilization on laden trips and the level of empty running.

- High vehicle capacity
- High vehicle utilization
- Low empty running

Vehicle routing

The routing of vehicles between collection and delivery points influences the transport distances. Increasing the efficiency of vehicle routing helping to find shorter routes can therefore decrease the transport intensity

- Efficient vehicle routing

3. Transports contributing to a low impact intensity

The impact intensity is defined as the externalities generated per unit of traffic (vehicle km). Factors determining the impact intensity are 1) the vehicle’s engine and fuel, and 2) the vehicle design.

Engine and fuel

The quantity of greenhouse gases emissions causing climate change and other noxious gases causing local air pollution are determined by the carbon content of the fuel and nature of the engine converting the fuel energy into movement (a full life-cycle-emissions including fuel and vehicle production should be considered). Noise emissions are also determined by the nature of the engine.

- Low energy consumption
- Low greenhouse gas emissions
- Low emissions of local air pollutants
- Low noise emissions

Vehicle design

One factor contributing to the number and severity of accidents is the vehicle design. Compared to passenger cars, trucks have poor visibility and blind spots leading to accidents with cyclists and pedestrians. A vehicle with significantly better surrounding visibility can therefore decrease the accidents intensity of trucks.

- High surrounding visibility

4. Transports contributing to social sustainability

Not all social impacts of transport are related to traffic activities and emissions having negative impact on the general public. Transport companies are economic corporations which are part of the society, hence they have social responsibility. Significant social impacts are related to how transport companies comply with laws and regulations as well as the forms of employment for their staff.

- Socially responsible transport companies

Summary

This section summarizes the determinants for sustainable freight transport identified above:

1. Low transport intensity
    a. Local sourcing (shipper/receiver)
    b. Central locations of distribution terminals (transport provider)
2. Low traffic intensity
    a. High vehicle capacity (transport provider)
    b. High vehicle utilization (transport provider)
    c. Low empty running (transport provider)
    d. Efficient vehicle routing (Transport provider, haulier)
3. Low impact intensity
    a. Low energy consumption (vehicle manufacturer)
    b. Low greenhouse gas emissions (vehicle manufacturer)
    c. Low emissions of local air pollutants (vehicle manufacturer)
    d. Low noise emissions (vehicle manufacturer)
    e. High surrounding visibility (vehicle manufacturer)
4. High social responsibility
    a. Socially responsible transport companies (transport provider)

Some issues to consider

The determinants are generic, i.e. they aim to be valid for all types of transport, including different modes, differing goods, different transport tasks (e.g. line haul, distribution, etc.). The determinants do not take into account any potential problems with identifying transports matching these determinants (e.g. lack of data), or implementation problems (legal barriers). These theoretical determinants can be used to derive criteria which can be applied in practice, i.e. taking into account the context data availability and the regulatory framework. Potential criteria for sustainable freight transport based on these determinants are discussed in the next section.

Criteria for sustainable freight transport

Reducing the unsustainable impacts from the transport sector requires reducing one or more of the factors above. As the value density cannot be directly influenced by transport policy, the focus needs to be placed on the transport intensity, the traffic intensity, the energy intensity, the emission and impact intensity, as well as emission and impact sensitivity. Accordingly, criteria for sustainable freight transport can be derived from these factors.

The resulting criteria is listed below:

KEY RATIO	DETERMINANT	SHIPPER/RECEIVER	TRANSPORT	VEHICLE
TRANSPORT INTENSITY	Length of supply chain links	Local sourcing		
	Location of logistics facilities		Centrally located terminal	
TRAFFIC INTENSITY	Payload on vehicle trips	Large shipment sizes	Transports to rail/sea terminals	
		Lead time flexibility	Transports to microterminals	
		Packaging enabling consolidation	Open network	
	Vehicle routing		Efficient routing (shortest)	
ENERGY INTENSITY	Driveline			Energy efficient drivelines
	Operations		Eco driving	
			Efficient routing (congestion)	
EMISSION INTENSITY	Driveline/fuel			Low-emission driveline/fuel
				Renewable fuels
IMPACT INTENSITY	Vehicle design			Surrounding visibility
				Low-noise equipment
	Driveline			Low-noise driveline/fuel combinations
	Operations		Low-noise operations	
EMISSION/ IMPACT SENSITIVITY	Location of logistics facilities		Terminal in low-density areas	
	Timing of transports	Flexible delivery time windows		
IMPACT SENSITIVITY	Location of logistics facilities		Terminal in low density areas	
SOCIAL SUSTAINABILITY	Social responsibility		Comply with laws	
			Sharing data	

References

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