Summary Report

REDEFINE

Relationship between Demand for Freight-transport and Industrial Effects

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S1 Introduction

In most European countries there has, for several decades, been a close relationship between road freight demand and economic growth. The majority of road freight traffic forecasts have been based on the assumption that these variables will remain closely correlated for the foreseeable future. This is essentially an act of faith, as there is no guarantee that the traffic levels and economic growth will continue to follow parallel trends. Indeed in some European countries it appears that these trends have begun to diverge. Domestic and European transport statistics can only provide a crude outline of the historic developments in road freight demand for a broad set of commodity-flows, but can not attribute these developments to any underlying economic, logistical, or any other factors.

The drivers that generate the growth in road freight traffic demand have not been studied in a European context. REDEFINE has conducted research at both the macro and micro level in an attempt to satisfy this need, and shed some light on how the damaging effects of road freight traffic can be minimised through the adoption of new policy initiatives.

The objectives of REDEFINE are to:

a. Model the factors affecting the increased demand for road freight and relationship between these factors and changes in industrial and logistical structure.
b. Develop strategies to manage and improve road freight transport and logistics in order to reduce or arrest the negative externalities caused by transport.
c. Forecast the effectiveness of alternative policies, and where such policies might sit within the comprehensive transport strategy of governments.

S2 Freight transport demand (1985-1995)

The economic, trade and freight transport data of 5 economies are examined in REDEFINE: France, Germany, the Netherlands, Sweden and the United Kingdom. A demand side view was taken of the link between production and transportation. That is, the production of an item generated a demand for that item to be moved. This greatly simplified the task of matching production and transport data. Data was aggregated into 14 REDEFINE groups representing the main areas of economic activity: agricultural products; beverages and food; wood and paper; building materials; textiles and clothes; other crude minerals; chemicals and fertilisers; petrol and petroleum products; cola and coke; metals; machinery; transport equipment; other manufactured articles; and miscellaneous articles.

The framework for this analysis is illustrated in figure 2.1. which shows the relationship between the value of goods produced and road freight traffic demand as a series of key ratios. If each of these ratios remained stable, road freight traffic would be perfectly correlated with changes in the value of goods produced. In practice, each of these ratios can vary independently. By estimating changes in each of the key ratios

through time, it should be possible to establish how much of the growth of lorry traffic is a function of economic growth and how much is attributable to logistical changes.

Figure S2.1 Linking economic activity and road freight traffic

The results of the analysis on an individual country basis indicate that an increase in the average length of haul is the single most important contributor to increased road freight demand (see overview in table S2.1). In some countries, this has been accompanied by a significant rise in road's share of total traffic. Typically, this has resulted in a 50%, or so, increase in road tonne-kilometres, at least double the growth in the weight of goods produced or imported. The use of heavier vehicles has gone some way in compensating for this, leading to the average payloads being some 20% heavier. This, together with a reduction in the level of empty running (approximately 10%), has limited the increase in vehicle kilometres, and, in turn, the external costs of road freight transport impose, to about 30%. This additional demand, however, is still greater than the 20%, or so, increase that change in the weight of goods produced or imported would account for. Clearly, the relationship between economic activity and road freight transport demand is a complex one.

Table S2.1 Overview of changes in economic activity and road freight transport 1985-1995

Breakdown	France	Germany	Netherlands	Sweden	United Kingdom
Value of production and imports	+28%	+14%	+17%	+82%	-4%
Value density	*+23%*	*-2%*	*-3%*	*+51%*	*-32%*
Weight of produced and imported goods	+4%	+16%	+21%	+21%	-7%
Modal split	*+10%*	*+20%*	*0%*	*+11%*	*+1%*
Products transported by road	+14%	+33%	+21%	+34%	+1%
Handling factor	*+2%*	*-2%*	*+3%*	*-20%*	*+18%*
Road tonnes-lifted	+16%	+31%	+25%	+8%	+18%
Average length of haul	*+36%*	*+4%*	*+29%*	*+37%*	*+24%*
Tonne-kilometres	+57%	+33%	+60%	+48%	+46%
Vehicle carrying capacity	*+15%*	*N.A.*	*+24%*	*+28%*	*+9%*
Load factor	*+7%*	*N.A.*	*-3%*	*-4%*	*-4%*
Average payload	+23%	N.A.	+20%	+22%	+4%
Empty running	*-21%*	*N.A.*	*-7%*	*-7%*	*-5%*
Vehicle-kilometres	+28%	N.A.	+30%	+18%	+37%

Italic cells are ratios, others are aggregates.

S3 Drivers behind changes in key ratios 1985-1995

A breakdown of vehicle kilometre growth into 7 key ratios - value density, modal split, handling factor, average length of haul, vehicle carrying capacity, load factor and empty running - merely identifies the relative importance of the factors (in all countries, for instance, the average length of haul has led to a significant growth in vehicle km over and above the growth in production). The next purpose is to provide an *explanation* of why these ratios have changed, and by implication then go on to

consider whether the drivers of change will continue in the forecast period or have a different influence on the evolution of the 7 key ratios.

Table S3.1 lists the key logistical trends that are identified as the potential drivers behind the changes in the key ratios. The table is structured around 4 types of decision making in logistics and one concerned with product design.

Table S3.1 The Impact of Logistical Drivers on Key Ratios

Key Logistical Trends & Drivers 1985 to 1995	Key Ratios						
	Value density	Modal split (road share)	Hand-ling factor	Avg. length of haul	Vehicle carryin g capacity	Load factor	Empty running
1 Restructuring of logistical systems							
1.1 Spatial concentration of production; either through reduction in plant numbers, or				↑	(↑)		
increased plant specialisation ('focused production')				↑			
1.2 Spatial concentration of inventory				↑	(↑)		
1.3 Development of break-bulk / transhipment systems			↑	↓			
1.4 Centralisation of sorting operation in hub-satellite network			↑	↓			
2 Realignment of supply chains							
2.1 Vertical disintegration of production			↑	(↓)	(↓)		
2.2 Concentration of supplier sourcing				(↓)			
2.3 Wider geographical sourcing of supplies				↑			
2.4 Wider distribution of finished products				↑			
2.5 Increase in retailer's control over supply chain					(↑)	(↑)	
2.6 Concentration of international trade on hub ports		(↓)	(↑)	↑			
3 Rescheduling of product flow							
3.1 Application of JIT principle in manufacturing					↓	↓	(↑)
3.2 Adoption of Quick Response and ECR in retail distribution					↓	↓	
3.3 Growth of 'nominated day' deliveries					↓	↓	(↑)
3.4 Proliferation of booking-in / timed-delivery systems					↓	↓	(↑)
4 Changes in management of transport resources							
4.1 Improvement in road's relative cost/performance		↑					
4.2 Increased use of outside transport / distribution contractors					↑	↑	↑
4.3 Changes in vehicle size regulations		(↑)			↑		
4.4 Changes in handling systems					↑		
4.5 Increased use of Computerised Vehicle Routing and Scheduling						↑	↑
4.6 Increase in return loading						↑	↑
5 Changes in product configuration/design							
5.1 Increase in complexity, sophistication of product	↑						

↑ = positive impact ↓ = negative impact ( ) = possible impact

The approach used in the REDEFINE project is to examine in greater detail a selected number of sector-commodity combinations in different countries. The selection of the case studies was subject to three criteria: Substantial quantity, High growth rate and Logistical trends. Within each of the selected sector-commodity combinations specific supply chains have been examined. Table S3.2 shows the importance of the chosen sector-commodity group for the country concerned over the decade 1985-1995. In total the case study sectors cover over 80% of the vehicle km.

Table S3.2 The Chosen Case Studies

Sector – commodity group	Supply chains	Country	Production 1995 % share	Vehicle km 1995 % share	Production 1985-95 % change	Vehicle km 1985-95 % change
Agricultural Products	Potatoes	France	9	14	0	+43
Food & Drink	Beer Dairy Products	France	16	17	+26	+5
Wood & Paper	Newspaper Craft liner Fine paper	Sweden	5	12	+74	+13
Building Materials	Concrete products Ceramic products	Netherlands	3	9	+44	+56
Transportation equipment	Car seats Exhaust equipment Other supply parts	Germany	17	13 (a)	+27	+44 (a)
Miscellaneous	Household waste Express parcel services	United Kingdom Netherlands	n.a. n.a.	30 19	n.a. +58	+82 +163

(a) tonne km.

The forces at work that influence the key ratios over the last decade are summarised in table S3.3. There is no simple conclusion concerning these forces and their relative strength, since there are variations between products and between countries. Any forecasting exercise or policy appraisal must recognise these differences. However, in REDEFINE is examined to what extent the conclusions are valid for the other countries concerned.

Table S3.3 Logistical Trends and Drivers 1985-1995. Evidence from Case Studies

Key Logistical Trends & Drivers 1985 to 1995	Agriculture Products	Food & Drink	Wood & Paper	Building Materials	Transport Equipment	Miscell-aneous
1 Restructuring of logistical systems						
1.1 Spatial concentration of production; either through		⊕	⊕	⊕		⊕
Reduction in plant numbers, or		⊕		⊕		⊕
Increased plant specialisation ('focused production')		⊕		⊕		
1.2 Spatial concentration of inventory			⊕	⊕	⊕	
1.3 Development of breakbulk/ Transhipment systems	⊕					⊕
1.4 Centralisation of sorting operation in hub-satellite network						
2 Realignment of supply chains						
2.1 Vertical disintegration of production		⊕		⊕	⊕	⊕
2.2 Concentration of supplier sourcing			⊕		⊕	
2.3 Wider geographical sourcing of supplies		⊕				
2.4 Wider distribution of finished products	⊕		⊕			⊕
2.5 Increase in retailer's control over supply chain	⊕	⊕				
2.6 Concentration of international trade on hub ports						

Key Logistical Trends & Drivers 1985 to 1995	Agriculture Products	Food & Drink	Wood & Paper	Building Materials	Transport Equipment	Miscell-aneous
3 Rescheduling of product flow						
3.1 Application of JIT principle in manufacturing		⊕		⊕	⊕	
3.2 Adoption of Quick Response and ECR in retail distribution	⊕	⊕				
3.3 Growth of 'nominated day' deliveries						
3.4 Proliferation of booking-in/timed-delivery systems			⊕			
4 Changes in management of transport resources						
4.1 Improvement in road's relative cost/performance		⊕	⊕			⊕
4.2 Increased use of outside transport/distribution contractors		⊕	⊕			
4.3 Changes in vehicle size regulations	⊕	⊕				⊕
4.4 Changes in handling systems						
4.5 Increased use of Computerised Vehicle Routing and Scheduling	⊕	⊕	⊕			
4.6 Increase in return loading	⊕	⊕	⊕	⊕	⊕	⊕
5 Changes in product configuration/design						
5.1 Increase in complexity, sophistication of product		⊕	⊕	⊕	⊕	⊕

⊕ indicates a significant driver or force in the sector.

S4 Forecast 1995-2005

In order to analyse the relationship between economic activity and road freight traffic in the next decade, a 3-step approach has been taken per REDEFINE-group:

1. Growth of the value of production and imports between 1995 and 2005 has been derived from country specific scenarios on future changes of production (from the ERECO-report, *Europe in 2002*).
2. Foreseen changes in key ratios has been provided by the case studies.
3. Using the forecasts on value of production and the key ratios future road transport and traffic can be calculated.

A number of options were examined in order to see to what extent it is possible to generalise the case study findings and presents forecasts of road transport activity in the year 2005 from one REDEFINE–group to another group. However, it did not result in solid evidence for similarities between REDEFINE-groups. Therefore it is concluded, that within this study case study results can not be extended to other groups for which no case studies exist.

Table S4.1 Forecast mean growth in key ratios 1995-2005

	France	*Germany (a)*	*The Netherlands*	*Sweden*	*United Kingdom*
Agricultural products:					
▲ Value-density ('currency'/kilogram)	-9%	-16%	+7%	+35%	+38%
▲ Modal split (road share in %)	+6%	+37%	+10%	+73%	-1%
▲ Handling factor	+24%	-19%	+17%	-23%	-2%
▲ Average length of haul (km)	+37%	+17%	+31%	+2%	+23%
▲ Vehicle carrying capacity (tonnes)	N.A	N.A.	+22%	-1%	+15%
▲ Load factor (%)	N.A	N.A.	-3%	+4%	0%
▲ Empty running (%)	N.A.	N.A.	-44%	-7%	-5%
Food and drinks:					
▲ Value-density ('currency'/kilogram)	+11%	+13%	+11%	+4%	+25%
▲ Modal split (road share in %)	+2%	+12%	-1%	+2%	0%
▲ Handling factor	-8%	+8%	0%	-24%	+13%
▲ Average length of haul (km)	+35%	+9%	+23%	+17%	+31%
▲ Vehicle carrying capacity (tonnes)	N.A	N.A.	+21%	+16%	+21%
▲ Load factor (%)	N.A	N.A.	+1%	-6%	-5%
▲ Empty running (%)	N.A.	N.A.	+60%	-7%	-5%
Wood and paper *(b):*					
▲ Value-density ('currency'/kilogram)				+20%	
▲ Modal split (road share in %)				+12%	
▲ Handling factor				-20%	
▲ Average length of haul (km)				+5%	
▲ Vehicle carrying capacity (tonnes)				-4%	
▲ Load factor (%)				-1%	
▲ Empty running (%)				-7%	
Building materials:					
▲ Value-density ('currency'/kilogram)	+35%	-2%	+7%	+27%	N.A.
▲ Modal split (road share in %)	+19%	+16%	-2%	+2%	+2%
▲ Handling factor	-1%	-20%	-15%	-29%	+13%
▲ Average length of haul (km)	+24%	+36%	+31%	+54%	+23%
▲ Vehicle carrying capacity (tonnes)	N.A	N.A.	+4%	+3%	+10%
▲ Load factor (%)	N.A.	N.A.	-3%	-6%	-2%
▲ Empty running (%)	N.A.	N.A.	-3%	-7%	-5%
Transport equipment					
▲ Value-density ('currency'/kilogram)	+43%	+27%	+57%	+60%	+94%
▲ Modal split (road share in %)	+7%	+22%	+5%	+29%	+1%
▲ Handling factor	-20%	+43%	+32%	-43%	+36%
▲ Average length of haul (km)	+57%	-8%	+20%	+16%	+12%
▲ Vehicle carrying capacity (tonnes)	N.A.	N.A.	+38%	+32%	+16%
▲ Load factor (%)	N.A.	N.A.	-16%	-19%	+4%
▲ Empty running (%)	N.A.	N.A.	+5%	-7%	-5%

(a) Growth rates for 1993-2005.

(b) For the wood and paper case study carried out in Sweden no European evidence was found. Therefore the case study results could not be extended to other countries.

Conclusions

In a majority of the four REDEFINE-groups, road freight activity measured in tonne-kilometres is expected to grow faster until 2005 than production in weight terms, as can be seen in the previous figures. Especially in the agricultural products and transport

equipment industry tonne-kilometres and production weight are diverging substantially. Road freight activity in vehicle-kilometres shows a similar growth path to production weight, although in most industries vehicle-kilometres are still expected to grow faster up to 2005.

On a country by country basis, one can see that in Sweden economic activity and road traffic are resolving in a desirable way. In France, the Netherlands and the United Kingdom, this is largely not so . In Sweden future trends show that less and less vehicle-kilometres are needed for the same production volume, in other words, economic activity is developing at a higher level than road traffic activity necessary for the transportation of these produced goods. In the other countries the opposite is true: road traffic is growing faster than economic activity.

S5 Externalities

In view of the expected growth of road traffic activity for some important industrial substantial external effects might result. In REDEFINE Congestion and CO_2 and NO_x Emissions have been examined.

Congestion
The process of calculating congestion is demanding in terms of data requirements. Data for France, Sweden, the Netherlands and Germany is not as comprehensive as the UK data in its coverage of the factors that contribute to congestion or the disaggregation that is required. In order to derive the congestion costs for other countries it is possible to compare some key statistics with those of the UK. The key traffic components of the congestion calculations are:
1. The overall ratio of annual traffic flow to road length (density).
2. Concentration by month, day of week and hour of day.
3. Concentration by road type and within road type.
4. The value of time of travellers.
5. The distribution of freight vehicles on different road types.

Bringing together the findings of this analysis with the *Congestion Model* reveals the following table S5.1. The Projection to 2005 is based upon a growth in the Value of Time and traffic similar to that found in GB (2.4% and 1.6% respectively per year).

Table S5.1 Marginal Congestion Cost per 1,000 Vehicle kilometres of an Average Goods Vehicle

ECU per 1000 vehkm 1996 prices	Value of Time ECU/h	Marginal Cost Own Value of Time		Marginal Cost Average Value of Time	
		1996	2005	1996	2005
Great Britain	10.2	30	44	41	59
Sweden	21.0	15	22	10	14
Netherlands	13.5	30	43	31	45
Germany	11.4	34	49	41	59
France	13.3	32	46	33	48
All countries (unweighted)	13.9			31	45

The marginal congestion costs can be converted into figures for marginal congestion costs per million tonnekm by assumptions about the average payload (in this definition vehkm includes both loaded and unloaded vehkm). It can be seen that there is a strong upward trend in the marginal congestion cost of moving goods. The figures that are available suggest that this figure may vary between European countries, with Sweden providing a particularly low figure.

Table S5.2 Marginal Congestion Cost per million Tonnekilometres of an Average Goods Vehicle

kECU 1996 per M tonnekm	Average Payload (t)	Marginal Cost Own Value of Time		Marginal Cost Average Value of Time	
	1996	21996	2005	1996	2005
GB	6.5	4.6	6.4	6.3	8.7
Sweden	12.5	1.2	1.6	0.9	1.1
Netherlands	7.4	4.0	5.6	4.1	5.7
Germany	7.5	4.5	6.2	5.5	7.6
France	7.5	4.3	5.9	4.4	6.1
All countries (unweighted)				4.2	5.9

Emissions

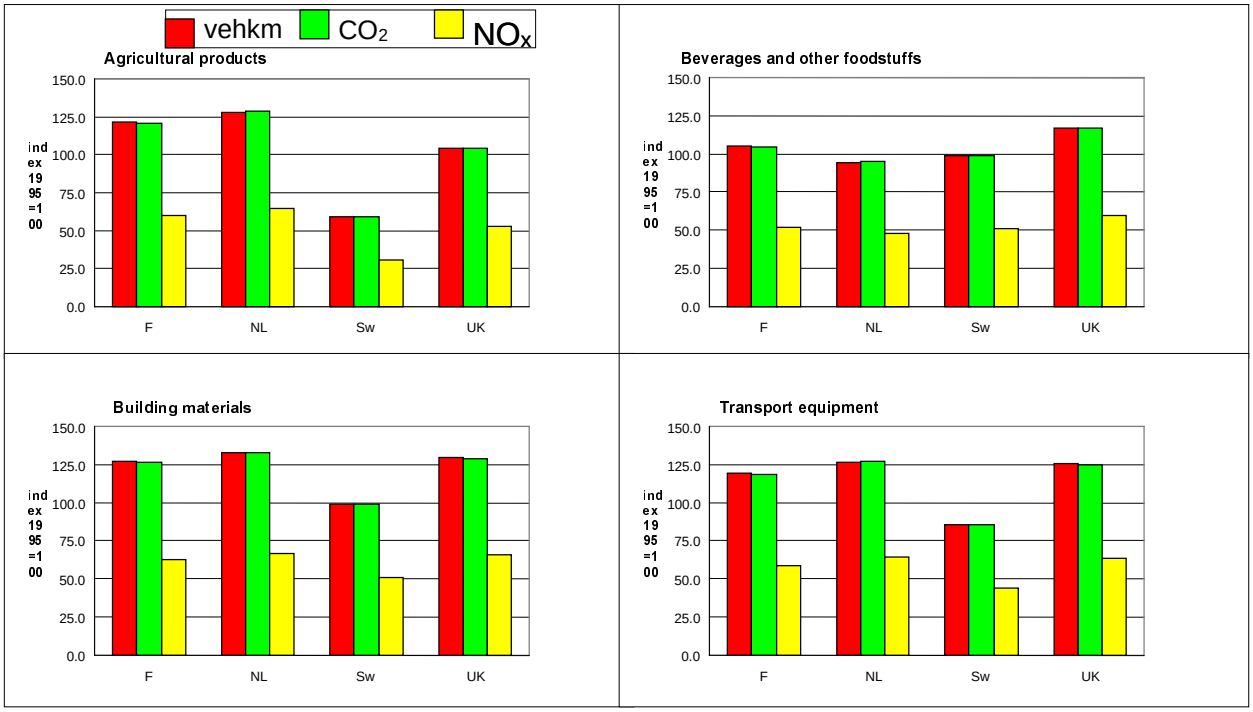
Emissions are assessed with the *FEE-model* (Fuel, Energy and Emissions). The model can be divided into two parts: one concerning fuel use and driving energy and one concerning emission calculations. Those two parts are linked through the use of fuel and energy variables in the emission equations. The model produces fuel and emission factors, expressing the use of those in grams per kilometre.

Input for the model are country specific data on:

a) Total vehicle kilometres of freight vehicles per year by vehicle type and road type.
b) Average speed of freight vehicles by type of road (within city, secondary roads, highway).
c) Load factor and load capacity of freight vehicles.
d) Median life span of freight vehicles.
e) Vintage distribution of vehicle kilometres in 1995.
f) Sulphur content of diesel (depends on legislation in a country).

Where data are not available in a particular country, average figures from countries, with similar freight (traffic) characteristics are used. The following figure shows the results of the analysis with the FEE-model for 1995 with projections to 2005.

Figure S5.1 Freight traffic, CO_2 and NO_x emissions in 2005 (1995=100)



The figures show that for almost all countries and REDEFINE-groups:

- Vehicle-kilometres are increasing (except for Sweden).
- CO_2 emissions are closely following the growth in vehicle-kilometres, with the impact of larger vehicles and better fuel consumption only leading to a lower rate of growth in some sectors.
- NO_x emission is projected to decrease dramatically due entirely to the introduction of more rigorous standards on new vehicles.

S6 Impact of policy measures

Finally a link has been made between possible transport policy measures and their impact on road freight transport externalities. Ultimately, policy measures are prioritised as to their relative effectiveness. In order to do so, the following steps have been taken:

A) Policy measures at the disposal of the transport policy maker are identified.
B) Five policy options (comprising a combination of policy measures) to reduce road freight transport or to reduce its externalities are identified.
C) Based on the analysis of the case studies, the scope for a reduction of road freight transport or its externalities, which individual supply chains offer in each of the

five options, is estimated. Based on the options which they address and the scope for improvement which the supply chains offer, the policy measures are brought into an order of priority.

D) Finally, key measures and general decisions to be taken by the policy maker are emphasised.

A) Types of policies affecting road freight transport

Two groups of measures have to be distinguished:

I. Measures aimed at a particular product market:
Policies impacting indirectly on transport by inducing changes in the markets of the products being transported are economic policy (liberalisation and deregulation), social and labour legislation, EU integration policy, environmental policies and RTD policies. Since it is not in the power of the transport policy maker to (directly) influence these policies, they are not considered further here, but instead, the focus is on measures which can be applied by the transport policy maker to directly influence freight transport:

II. Measures aimed at the transport market, transport systems and transport technologies:
Table S6.1 gives an overview of the policy measures which are aimed at the transport market, transport system and transport technologies.

B) Five options to reduce road freight transport or its externalities

Measures other than taxes or charges have in general a much more focused but also more limited impact on the decision making of transport users. These measures are best grouped according to the option for the reduction or improvement of road freight traffic which they are aimed at:

The basic options to reduce externalities are:
1. Reduction of transport intensity.
2. Modal shift.
3. Increased efficiency of transport.
4. Use of better vehicles and/or fuels.
5. Better use of vehicles.

Not included in this list is the option of reducing transport by cutting the level of production. In line with the REDEFINE objectives, reducing the level of economic activity is not considered among the options to reduce freight traffic related externalities.

Table S6.1 Policy measures classified by instruments and options

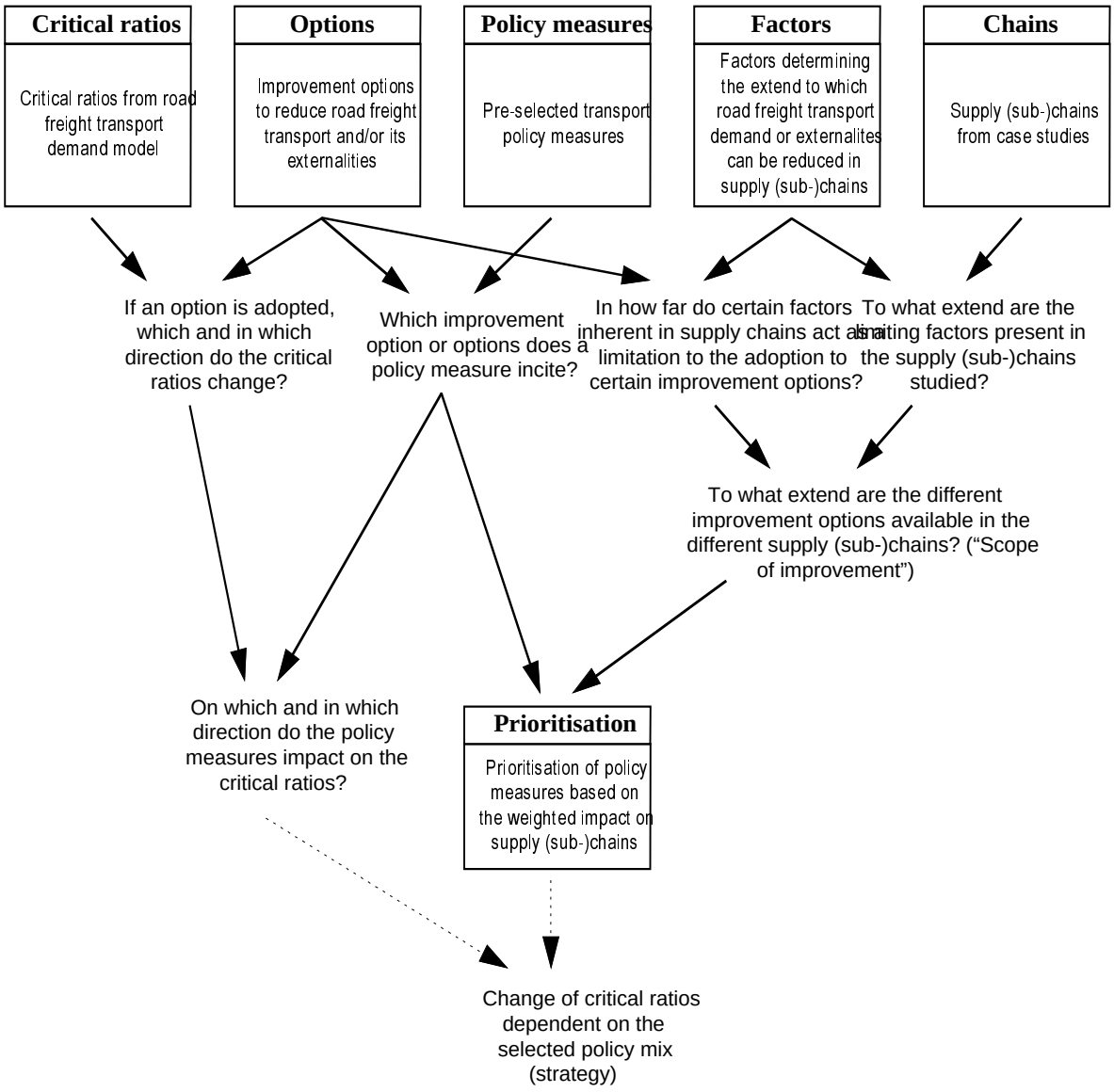
	Reduce transport intensity	Modal shift	Increased efficiency	Better vehicles/fuels	Better use of vehicles
Coercion		Ban on long distance transport by road		Differentiate spatial and/or temporal driving bans for road freight vehicles according to their externalities Tighten emission standards for new vehicles Require the use of safety devices in road freight vehicles Require the use of safety devices in road freight vehicles Introduce/tighten inspection and maintenance programmes Impose the use of emission and/or fuel use reducing devices/technologies	Introduce/extend bans for truck traffic in spatial terms Introduce/extend bans for truck traffic in temporal terms Introduce/extend congestion related bans for truck traffic Limitation of speed and/or overtaking by trucks Reduce maximum driving times Enforce driving regulations (speed, driving times) more effectively
Lift coercion		Give preferential treatment to intermodal pre- and end-hauls	Allow larger and/or heavier trucks		Introduce freight transport vehicle lanes
Coercion/ Transaction	Introduce tradable vehicle-km permits Introduce tradable emission permits	Co-ordinate land-use planning and transport planning Introduce tradable vehicle-km permits Introduce tradable emission permits	Co-ordinate land-use planning and transport planning Introduce tradable vehicle-km permits Introduce tradable emission permits	Introduce tradable emission permits	
Transaction	Introduce/increase road-pricing on a per-km, per-trip or per passage basis Introduce/increase road-pricing on a per-year basis Increase fuel tax generally Increase vehicle tax generally Introduce on-board measuring and debiting for emissions	Introduce/increase road-pricing on a per-km, per-trip or per passage basis Introduce/increase road-pricing on a per-year basis Increase fuel tax generally Increase vehicle tax generally Introduce on-board measuring and debiting for emissions Encourage the set-up of transport-intensive production and logistics activities at or their re-location to more suitable locations Give preferential treatment to intermodal pre- and end-hauls	Introduce/increase road-pricing on a per-km, per-trip or per passage basis Introduce/increase congestion pricing Increase fuel tax generally Introduce on-board measuring and debiting for emissions Encourage the set-up of transport-intensive production and logistics activities at or their re-location to more suitable locations Support the implementation of shared distribution facilities	Increase fuel tax generally Differentiate fuel tax by fuel type, according to externalities Differentiate vehicle tax according to emissions and/or fuel efficiency Introduce on-board measuring and debiting for emissions	Introduce/increase congestion pricing Increase fuel tax generally Introduce on-board measuring and debiting for emissions
Transaction/Persuasion		Invest in intermodal infrastructure			Improve/extend the road infrastructure
Persuasion	Use persuasion to reduce transport intensity Finance R&D of technologies/practices reducing transport intensity Introduce logistics "Eco-label"	Use persuasion to decrease modal share of road transport Finance R&D of technologies/practices decreasing modal share of road transport Standardisation of load units (intermodal equipment, pallets, etc.) Introduce logistics "Eco-label"	Use persuasion to bring about efficiency increases in road freight transport Finance R&D of technologies/practices increasing transport efficiency Standardisation of load units (intermodal equipment, pallets, etc.) Introduce logistics "Eco-label"	Use persuasion to realise use of better vehicles/fuels Finance R&D of technologies/practices improving vehicles/fuels Introduce logistics "Eco-label"	Use persuasion to realise better driving behaviour Finance R&D of technologies/practices improving use of vehicles Introduce logistics "Eco-label"

C) Prioritisation of policy measures

Approach to the prioritisation of policy measures

- The approach leading to the final prioritisation of policy measures according to their likely effectiveness to reduce the externalities of road freight transport is illustrated in figure S6.1.

Figure S6.1 The steps of the approach



Prioritisation of policy measures

The relative effectiveness of a policy measure can now be determined by considering the range of options it addresses and the degree to which these options are applicable in a supply chain. According to the effectiveness scores, the policy measures can be allocated to 7 groups:

Group 1: Highly effective, universal measures
Measures which are highly effective in almost all supply chains. These measures have an average relative effectiveness of at least 30 % and at least a relative effectiveness of 20 % in any supply chain. The measures are (in descending order of effectiveness):

- Introduce on-board measuring and debiting for emissions.
- Increase fuel tax generally.
- Introduce logistics "Eco-label".
- Introduce tradable emission permits.

Group 2: Broad effective measures
Measures which are effective in a large number of supply chains. These measures have an average relative effectiveness of at least 15 % and a relative effectiveness of more than 20 % in at least five of the twelve supply chains considered. The measures are (in descending order of effectiveness):

- Introduce road-pricing on a per-km, per-trip or per passage basis.
- Introduce tradable vehicle-km permits.
- Introduce congestion pricing.
- Co-ordinate land-use planning and transport planning.
- Encourage the set-up of transport-intensive production and logistics activities at or their re-location to more suitable locations.
- Standardisation of load units (intermodal equipment, pallets, etc.).
- Introduce road-pricing on a per-year basis.
- Increase vehicle tax generally.

Group 3: Little effective vehicle technology and urban transport measures
Measures with a low average relative effectiveness (= 10 %) which are more effective (15 % - 20 %) in chains where the conditions favour the introduction of alternative engines and fuels which cause less pollution and/or noise. These chains are characterised by a large share of transport in urban areas, short transport distances and/or the use of relatively small vehicles. The measures are (in descending order of effectiveness):

- Differentiate fuel tax by fuel type, according to externalities.
- Differentiate vehicle tax according to emissions and/or fuel efficiency.
- Differentiate spatial and/or temporal driving bans for road freight vehicles according to their externalities.
- Tighten emission standards for new vehicles.
- Require the use of safety devices in road freight vehicles.
- Require the meeting of tighter fuel efficiency standards for new vehicles.
- Introduce/tighten inspection and maintenance programmes.
- Impose the use of emission and/or fuel use reducing devices/technologies.
- Use persuasion to realise use of better vehicles/fuels.
- Finance R&D of technologies/practices improving vehicles/fuels.

Group 4: Little effective universal measures
Measures with a low average relative effectiveness (= 10 %) across all chains. The measures are (in descending order of effectiveness):

- Introduce freight transport vehicle lanes.
- Introduce/extend bans for truck traffic in spatial terms.
- Introduce/extend bans for truck traffic in temporal terms.
- Introduce/extend congestion related bans for truck traffic.

- Limitation of speed and/or overtaking by trucks.
- Improve/extend the road infrastructure.
- Reduce maximum driving times.
- Enforce driving regulations (speed, driving times) more effectively.
- Use persuasion to realise better driving behaviour.
- Finance R&D of technologies/practices improving use of vehicles.

Group 5: Little effective modal shift measures
Measures with a very low average relative effectiveness (0 % - 5 %) which are more effective (10 % - 20 %) in chains where the conditions favour a modal shift from road to rail or inland waterways because of relatively long transport distances, a high concentration of goods flows, high volumes of consignments and/or less time critical logistics requirements. The measures are (in descending order of effectiveness):
- Give preferential treatment to intermodal pre- and end-hauls.
- Ban on long-distance traffic by road.
- Use persuasion to decrease modal share of road transport.
- Finance R&D of technologies/practices decreasing modal share of road transport.
- Invest in intermodal infrastructure.

Group 6: Very little effective transport efficiency measures
Measures with a very low average relative effectiveness (0 % - 5 %) which are more effective (10 % - 20 %) in chains which still offer a large scope for improving the efficiency of the transport operation. The measures are (in descending order of effectiveness):
- Support the implementation of shared distribution facilities.
- Use persuasion to bring about efficiency increases in road freight transport.
- Finance R&D of technologies/practices increasing transport efficiency.
- Allow larger and/or heavier trucks.

Group 7: Very little effective transport intensity measures
Measures with a very low average relative effectiveness (0 % - 5 %) which are more effective (10 % - 20 %) in chains where the conditions favour a reduction of the transport intensity, e. g. through the change of the locations of production processes in the chain. The measures are (in descending order of effectiveness):
- Use persuasion to reduce transport intensity.
- Finance R&D of technologies/practices reducing transport intensity.

D) Key measures and general decisions to be taken

Fuel-consumption-based or emission-based charge
These are measures which either impose costs per litre of fuel consumed or per amount of emissions caused. Fuel-consumption-based calculations are less costly while emission-based calculations are fairer and also make a number of other measures redundant. Which one to choose is a fundamental decision that has to be taken. Other transactional charges (vehicle tax, road pricing) are far less important as one concerns their overall effectiveness. While, in the case of fuel-consumption-based charges, a vehicle tax will still be needed to differentiate between vehicles with different emission standards, such a tax would not be required in the case of emission-based charges. An emission-based charge could easily be extended by other elements to include externalities which are related to the vehicle type and the number of kilometres driven (e. g. wear and tear of infrastructure). Note that in case

of on-board measuring devices, emission-based charges will increase in congestion situations and thus also incorporate a form of congestion pricing.

Logistics Eco label
Giving companies concerned with logistics and road freight transport a means of getting easy access to information of best available technologies and best practice concerning environmental impacts, and to reward improvement is a major challenge for policy makers. Such information does not only shorten the technology diffusion but also gives an impetus for speeding up and steering the RTD processes themselves and gives the policy maker an instrument for assessing the degree of change which it can demand from the freight transport industry without damaging European competitiveness.

Tighten emission standards
This is the measure around which all other measures aimed at reducing the externalities per vehicle-km and/or per litre of fuel burned are built. The support of RTD in the automotive industry, the implementation of standards at the time of manufacturing of vehicles, the checking of the conformance with standards during the use of the vehicle (maintenance and inspection) and incentives to replace old through new vehicles are all means to implement emission standards.

Enforcement of existing driving regulations and measures to realise better driving behaviour
Driving regulations are relatively easy and fast to implement if desired by local policy makers and should as such not be a concern of EU policy makers. The EU should however support an EU-wide control and enforcement of driving regulations and labour regulations. In addition, the EU could take over an active role in promoting certain training standards of drivers with respect to improving the driver behaviour (more fuel efficient, less dangerous driving).

Larger trucks
The admission of larger trucks to European roads is one of the few general means that could increase the efficiency of road freight transport. It is an option that should carefully be considered.

Investment in intermodal infrastructure
Intermodal transport will only have a chance of sustained success if its quality is improved considerably and its costs are lowered in comparison to the costs of road-only transport. Investments are a pull measure and as such outside the scope of policy making concerned with road freight transport only. All push measures at the disposal of the road freight transport policy maker, however, will be reduced in effectiveness if the necessary improvements in intermodal infrastructure and services do not take place.

S7 Recommendations

REDEFINE's focus on supply chains has helped to identify key drivers of road freight traffic growth. Furthermore, considering this growth REDEFINE shows how regulators might try to moderate road freight demand at different levels in the supply chain.

By extending the understanding of the underlying logistics trends it should be possible to build better models of transport demand, which, in turn, should improve the quality of freight traffic forecasting. This would also allow a more detailed examination of the implications of changes in logistical structure, and the extent to which EU policy innovations might influence that structure.

However, the following areas are considered as still not well understood. Further research would not only increase the value of REDEFINE's output, but would also be worthwhile pursuing as separate projects.

- Test the wider validity of the supply chain case studies in REDEFINE by means of a large survey. The views of firms that were included in the case studies could form the basis of a more extensive survey of a larger sample of firms. This would enable us to assess the likely impact of freight transport policy measures on a broader spectrum of firms and establish a firmer basis for generalisation.
- The connection between the production output classification (SIC) and the goods in transit classification (NST/R) is based on a supply side model. Production, in terms of goods produced, was linked to movement of those goods from the factory to the consumer. Imported goods were added to the analysis. It would be possible to construct a model in which the production and imports of goods would be linked to the associated movement of raw materials. This would require the use of input-output tables, or even better make-use tables, to establish more complex relationships between production and transport classification that better reflect the nature of industrial and logistical processes.
- Even more ambitious would be an attempt to build a spatial dimension and cost (of logistics and production) element into the model. This would permit more detailed analysis of a range of freight transport issues and a more detailed assessment of the effects of policy measures.
- Examine the constraints on vehicle utilisation. All official data on vehicle utilisation are weight-based. It takes no account of the limits on the cubic volume that can be carried or of time constraints on the delivery operation. Evidence from the UK indicates that volume is more important as weight when considering the utilisation of a vehicle carrying frozen food. In addition, transport capacity is not used evenly throughout the day. If some transport activity could be shifted from peak periods to off-peak periods then a significant increase in vehicle utilisation might be achieved, with consequent reductions in traffic congestion and emissions. The relative importance of volume (m^3) utilisation, deck area (m^2) utilisation, weight utilisation (tonnes) and time utilisation could be established through a survey of operators.
- Establish if goods are becoming less dense (kg/m^2) as is often suggested. If this is the case, the impact on road freight movements could be assessed. Dependent on the relative importance of weight and volume constraints in an industry, any changes in the packaging of goods, or the materials from which the goods or packaging are manufactured, could have a significant effect on freight vehicle kilometres. In addition, the effects of dematerialization of goods could be considered (for example, the substitution of material goods, such as CD's, videos and letters, by electronic media).

- Consider how NST/R 99 ("miscellaneous articles") could be split into sub-classes. This NST/R class currently accounts for approximately 25% of all road freight activity. It includes things as mixed loads, unknown loads, waste (estimated at about 30% of miscellaneous), parcels, mail, household removals, etc. This masks the importance of some activities in terms of road freight, and makes it difficult to understand logistical trends in this category.
- Many non-transport policies may have an effect on the transport intensity of an economy. The key ratios distinguished in REDEFINE ought to be adopted to provide a framework for transport policy advisers to show how non-transport policies may impact upon transport intensity. Furthermore, the relationship between policy measures, companies' supply and demand side pressures is fundamental to the organisation of industrial supply chains, which, through driving the key ratios, determine the transport intensity of an economy.
- Sustainable development, in which economic growth is balanced with its environmental impacts, has been a core concept in most policy development in the last decade. Also in transport, sustainability has been given an important place, both world-wide and in the EU. Energy consumption and CO_2 emission leading to the well-known greenhouse effect are one of the key issues in this respect. Recently, the importance of CO_2 reduction has been further emphasised in the Kyoto Climate Treaty in which the EU agreed to reduce its CO_2 emission by 8% in 2020 in comparison with the 1990 level. The transport industry, as one of the main sources of CO_2 emissions, is expected to play an important role in reaching this objective. Since freight transport is only part of the logistical decision making process, transport policy measures are often not effective. Since transport is only part of the logistical decision making process, policy measures on reducing CO_2 in freight transport by mobility changes are often not effective. Therefore policy measures should take a broader view than only on transport, i.e. a view on logistics. Research should identify to what extend logistical operations can contribute to the desired CO_2 reduction in the EU. Furthermore, this research must determine for which part of the CO_2 emissions the transport sector is responsible. Finally, it is possible to identify which policy measures are effective for reducing CO_2 emissions of logistical operations.

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