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ASTRA

ASSESSMENT OF TRANSPORT STRATEGIES

Project No: ST-97-SC.1049

Annex to Deliverable D4

ASTRA Methodology - Appendices

November 2000

Project co-ordinator:

IWW, Institut für Wirtschaftspolitik und Wirtschaftsforschung, Universität Karlsruhe (GER)

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ME&P, Marcial Echenique & Partners Ltd, Cambridge (UK)

CEBR, Centre for Economics and Business Research Ltd, London (UK)

ASTRA - ASSESSMENT OF TRANSPORT STRATEGIES

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List of Abbreviations

ADT	=	Average Daily Traffic
All-TEN	=	Policy Package within which the whole TEN Projects are implemented
AM	=	Average Annual Mileage
ASP	=	ASTRA System Dynamics Model Platform
BFT	=	Balanced Fuel Tax Policy Package
Bill, B	=	Billion
BK	=	Bulk Goods Category
BU	=	Business Trip (Purpose)
CC	=	Cubic Capacity of Vehicle Engines
CCAM	=	Cubic Capacity Assignment Model
COPERT	=	Computer Programme to Calculate Emissions from Road Transport
CO_2	=	Carbon Dioxide
CSE	=	Cold Start Emissions
CTAP	=	Common Transport Action Programme
CTP	=	Common Transport Policy
DB	=	ASTRA Distance Band
DP	=	ASTRA Driving Patterns
DPC	=	Diesel Passenger Car
DPC1	=	Diesel Passenger Cars with cubic capacity less/equal than 2,0 l
DPC2	=	Diesel Passenger Cars with cubic capacity more than 2,0 l
EF	=	Emission Factor
ENV	=	Environment Sub-module
EQ	=	Emission Quantity
EST	=	Environmentally Sustainable Transport (also OECD project)

EU15	=	The 15 countries of the European Union
FPE	=	Fuel Production Emissions
FPI	=	Fair Payment for Infrastructure (EU policy)
GDP	=	Gross Domestic Product
GPC	=	Gasoline Passenger Cars
GPC1	=	Gasoline Passenger Cars with cubic capacity less than 1,4 l
GPC2	=	Gasoline Passenger Cars with cubic capacity of 1,4 to 2,0 l
GPC3	=	Gasoline Passenger Cars with cubic capacity more than 2,0 l
HB-EFAC	=	Handbook on Emission Factors of Road Transport
HDV	=	Heavy Duty Vehicle
HOT	=	Gaseous emissions from driving activity
iAM	=	ithink ASTRA model
IFT	=	Increased Fuel Tax Policy Package (also Eco Tax or Green Tax)
IPP	=	Integrated Policy Programme
ISE	=	Improved Emissions and Safety Policy Package
LDV	=	Light Duty Vehicle
LDVG	=	Light Duty Vehicle with Gasoline Engine
LDVD	=	Light Duty Vehicle with Diesel Engine
LTO	=	Landing and Take-Off Cycle
MAC	=	Macroeconomics Sub-module
MEET	=	Methodologies for Estimating Air Pollutant Emissions from Transport (EU 4th FP research project)
Mio, M	=	Million
NO_x	=	Oxides of Nitrogen
NTS	=	National Travel Surveys
NV	=	Number of Vehicles
PC	=	Passenger Car

PE	=	Private Trip (Purpose)
pkm	=	Passenger kilometers
PM	=	Particulate Matter
PM10	=	Particulate Matter with Diameter of less than 10 µm
PTR	=	Product Transformation Related Effects of Transport
Rail-TEN	=	Policy Package within which all railway TEN Projects are implemented
REM	=	Regional Economics and Land Use Sub-module
SBK	=	Semi-bulk Goods Category
SD	=	System Dynamics
SDM	=	System Dynamics Model
SP	=	Soot Particles
TAR	=	Transport Activity Related Effects of Transport
tkm	=	Ton kilometers
TO	=	Tourism Trip (Purpose)
TRA	=	Transport Sub-module
TS	=	Traffic Situation
TV	=	Traffic Volume
UF	=	Usage Factor
USD	=	Unitised Goods Category
VC	=	Vehicle Category
VDA	=	Verband der Automobilindustrie e.V. (Union of the German Auto Manufacturers)
VKT	=	Vehicle Kilometres Travelled
VOC	=	Volatile Organic Compound
VPE	=	Vehicle Production Emissions

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Remarks

The annex to deliverable 4 “ASTRA Methodology” complements the deliverable with the description of model details (e.g. exogenous data), details of scenario assumptions and other background information on the ASTRA system dynamics model platform (ASP). Furthermore as the deliverable is focussed on the description of the full Vensim version of the ASP the annex provides information on experiences and differences with the core ithink version of the ASP called iAM. However, the annex is not an independent document and therefore should always be regarded in conjunction with ASTRA deliverable 4, which is also indicated by numbering the chapters of the annex subsequently to the chapters of the deliverable.

The annex is structured into three parts:

- Annex A provides background information on the four sub-modules.
- Annex B explains details of the base scenario and the policy packages.
- Annex C describes the ASTRA ithink approach.

It should be hinted that some references in the ASTRA D4 point to chapter 9.x in the Annex. These chapters have been moved to the sections 12.x of this Annex to D4, such that chapter 12.x would now be the correct reference.

12 Annex A: Technical Description of the ASP

Annex A provides additional details (e.g. exogenous data) or background information for each of the four ASP sub-modules in the full Vensim ASTRA.

12.1 MAC Sub-module

This chapter explains further details about the MAC sub-module that is basically described within chapter 6.1 of deliverable 4.

12.1.1 Construction of the Aggregated Input-Output-Table

To model sectoral relationships and sectoral trade-offs of different policies in the MAC a sectoral disaggregation into 12 economic sectors is applied including the use of an aggregated input-output-table. As the MAC is based on the ESCOT model which is build on the German 12x12 I-O-table the existing I-O-tables for the EU countries have been transferred into this format. The most recent I-O-tables that are harmonized for all EU15 countries (except Greece) can be obtained from EUROSTAT for the year 1995. These tables are given in a 25x25 format that means they differentiate 25 economic sectors. Therefore they have to be aggregated from 25 to 12 economic sectors. As most of the 25 sectors can be assigned completely to one of the 12 aggregated sectors this task can be carried out with a small loss of information. Only the sectors 2,8 and 15 of the R25 tables have to be split into shares that are assigned to different sectors. The procedure of this assignment is shown in table 1. The convincing computing performance of the current ASTRA vensim model indicates that it should be technical feasible in the future to implement the complete R25 I-O-tables in the MAC.

Table 1: Assignment of R25 sectors to R12 I-O-table

Structure of Aggregated I-O-Table (R12)			Structure of EUROSTAT I-O-Table (R25)	
Row-Nr	**Row-Name**	**% to R12**	**Row-Nr**	**Row-Name**
1	Agriculture, forestry and fishery	100	**1**	Agriculture, forestry and fishery products
2	Energy, Water, Mining Products, Crude Oil	50	**2**	Fuel and power products
3	Chemical, Mineral, Plastic, Petroleum Products	100	**4**	Non-metallic mineral products
		100	**5**	Chemical products
		100	**14**	Rubber and plastic products
		50	**2**	Fuel and power products
4	Ferrous and non-ferrous ores and metals	100	**3**	Ferrous and non-ferrous ores and metals
5	Steel products, Machinery, Transport Equipment	100	**6**	Metal products except machinery
		100	**7**	Agricultural and industrial machinery
		100	**10**	Transport equipment
		90	**8**	Office and data processing machines
6	Electrical, Optical Goods, Office and Data Processing, Toys	100	**9**	Electrical goods
		10	**8**	Optical Goods from Office and data processing machines
		75	**15**	Other manufacturing products
7	Textiles, Clothing, Paper, Wooden Goods	100	**12**	Textiles and clothing, leather and footwear
		100	**13**	Paper and printing products
		25	**15**	Wooden Goods out of Other manufacturing products
8	Food, Beverages, Tobacco	100	**11**	Food, beverages, tobacco
9	Building and Construction	100	**16**	Building and construction
10	Services for Repair, Wholesale and Retail, Transport, Communication	100	**17**	Recovery, repair services, wholesale, retail
		100	**19**	Inland transport services
		100	**20**	Maritime and air transport services
		100	**21**	Auxiliary transport services
		100	**22**	Communication services
11	Other Market Services like Lodging, Catering, Credits, Insurances	100	**18**	Lodging and catering services
		100	**23**	Services of credit and insurance institutions
		100	**24**	Other market services
12	Non-market Services	100	**25**	Non-market services

Note: The row-numbers in the left column (R12) correspond to the sector-numbers used in the following tables.

As the base year for the ASTRA project is 1985 after the aggregation to 12 sectors the sectoral data that is given for 1995 has to be transferred to the level of 1985. Also for macro region 3 the contributions of Greece have to be considered, which is done with a correction factor increasing the values for this region. This implies the hypothesis of a similar sectoral structure in Greece as within the other three countries of this region as well as the fact that the contribution of Greece is rather small compared to the regions totals.

The following tables provide the initial data for the input–output tables in 1995 Mio*EURO of domestic production.

Table 2: Initial Input-Output-Table for Macro Region 1 (A, D)

	Sector1	Sector2	Sector3	Sector4	Sector5	Sector6	Sector7	Sector8	Sector9	Sector10	Sector11	Sector12
Sector1	3,150	12	97	8	19	1,166	763	22,368	40	180	2,889	402
Sector2	1,333	7,113	12,789	3,676	2,783	1,136	2,040	1,793	1,031	7,869	5,491	2,079
Sector3	3,131	7,742	58,614	7,081	18,036	9,229	8,403	5,227	27,709	9,594	11,981	7,209
Sector4	348.33	622.5	1,780	12,542	17,901	3,280	242.49	85	3,665	1,957	515.83	170
Sector5	1,005	1,152	6,029	4,715	53,250	8,102	2,620	4,667	9,958	5,468	5,754	6,420
Sector6	225	1,045	2,119	1,059	14,790	13,601	1,692	373.33	6,911	1,972	4,040	1,537
Sector7	475	129.16	4,632	438.33	4,231	3,950	24,545	5,296	1,931	9,235	23,820	2,415
Sector8	3,491	27.5	1,243	25.83	170	64.16	267.5	21,816	33.33	895	13,191	1,965
Sector9	500	1,364	2,387	640.83	1,710	539.16	634.16	505	4,982	2,941	19,915	4,872
Sector10	3,558	3,652	16,659	15,461	27,096	10,669	9,612	12,095	12,218	30,791	20,034	10,674
Sector11	1,185	1,213	4,615	1,470	6,117	3,144	1,883	1,723	3,410	17,965	206,386	2,422
Sector12	827.49	1,114	4,105	2,133	4,823	1,131	682.5	2,640	1,764	4,276	20,725	43,889

Table 3: Initial Input-Output-Table for Macro Region 2 (F, B, NL, L)

	Sector1	Sector2	Sector3	Sector4	Sector5	Sector6	Sector7	Sector8	Sector9	Sector10	Sector11	Sector12
Sector1	9,885	20	145	4.166	20.83	915.83	682.5	31,205	31.66	147.5	1,435	977.49
Sector2	1,291	4,893	8,828	1,944	1,234	546.66	974.16	1,219	845	5,280	2,098	2,950
Sector3	4,849	5,890	33,148	3,443	8,970	5,642	3,647	3,762	14,354	7,670	3,911	6,172
Sector4	105.83	46.66	435	8,759	9,557	828.33	50.83	5.833	2,719	297.5	66.66	21.66
Sector5	1,169	487.49	3,270	733.33	33,246	4,562	1,146	1,420	7,041	4,668	2,654	6,908
Sector6	140.83	321.66	739.16	265	6,066	5,925	899.16	363.33	5,800	2,321	2,040	3,808
Sector7	169.16	114.16	2,994	105.83	1,430	1,550	18,158	2,688	1,640	4,277	12,864	3,691
Sector8	9,240	5.833	1,489	0	1.666	17.5	524.16	13,149	13.33	789.16	6,943	3,396
Sector9	398.33	895.83	1,306	192.49	455.83	215	206.66	178.33	8,107	2,276	6,669	8,595
Sector10	6,223	1,505	13,169	4,410	13,521	5,855	9,780	14,160	11,625	82,411	24,247	10,945
Sector11	658.33	192.49	1,410	535	1,730	739.16	815	756.66	2,317	7,655	51,490	29,956
Sector12	240	172.5	541.66	45	246.66	197.49	452.49	195.83	186.66	769.16	1,115	3,885

Table 4: Initial Input-Output-Table for Macro Region 3 (I, P, E, GR)

	Sector1	Sector2	Sector3	Sector4	Sector5	Sector6	Sector7	Sector8	Sector9	Sector10	Sector11	Sector12
Sector1	9,473	0.9274	633.48	5.565	32.46	365.43	1,631	29,634	16.69	48.23	3,537	434.99
Sector2	1,705	3,287	7,507	2,026	1,905	662.23	1,966	1,333	1,057	9,352	3,765	1,960
Sector3	4,529	3,531	34,906	3,953	10,279	5,311	10,573	4,393	20,686	14,338	7,767	5,210
Sector4	36.17	38.95	1,752	7,245	18,734	3,662	526.82	215.17	2,933	582.46	6.492	159.52
Sector5	855.15	544.44	2,879	992.42	27,478	3,740	1,314	1,458	6,516	9,736	1,472	4,286
Sector6	38.95	272.68	1,182	238.36	5,241	7,129	1,879	255.98	4,192	2,650	981.29	1,113
Sector7	210.54	62.14	3,744	257.84	2,301	2,798	32,121	2,195	1,303	5,997	5,091	3,174
Sector8	8,747	1.854	1,136	0	0	20.4	1,362	11,737	0	167.87	19,715	1,502
Sector9	94.6	498.99	1,129	341.31	643.68	230.01	424.79	222.6	2,251	3,788	12,593	4,506
Sector10	4,732	1,447	17,114	8,900	18,294	6,911	14,160	9,832	9,611	38,646	22,131	7,356
Sector11	626.06	467.45	2,797	542.58	3,237	1,387	2,297	1,074	2,021	8,961	83,180	1,831
Sector12	0	0	0	0	0	0	0	0	0	0	0	19.47

Table 5: Initial Input-Output-Table for Macro Region 4 (UK, IRL, DK, S, FIN)

	Sector1	Sector2	Sector3	Sector4	Sector5	Sector6	Sector7	Sector8	Sector9	Sector10	Sector11	Sector12
Sector1	5408	39	101	1	13	676	3106	25273	140	584	700	479
Sector2	411	7352	9945	845	1674	383	1445	543	870	6836	3470	2595
Sector3	2595	7714	20955	1470	8393	3095	4275	3737	12063	11859	5478	9868
Sector4	15	173	662	3244	6160	733	104	10	1134	332	163	34
Sector5	935	1153	4048	844	23108	3230	2090	2564	6408	5817	3634	6414
Sector6	115	320	616	83	3684	3354	1036	114	3525	1766	2747	3655
Sector7	460	360	2416	152	3003	2014	14744	2847	1885	7274	15830	6912
Sector8	4809	144	635	22	192	99	557	14750	157	4400	6609	3554
Sector9	796	543	1004	98	594	226	417	325	22980	3114	10546	10474
Sector10	3310	1922	11702	2776	11708	4789	7370	6164	8065	47900	30744	13031
Sector11	784	1179	4017	275	3748	1512	2203	2358	2460	10729	118574	7026
Sector12	475	165	928	70	958	362	962	740	464	2215	6626	58533

12.1.2 Elements of the Supply Side

As described in chapter 6.1 the calculation of production potential follows the following equation:

$$PO = bPO + cPO * e^{(PROD * t)} * LS(t)^{\alpha} * CS(t)^{\beta} * NR(t)^{\gamma} \qquad \text{(eq. 1)}$$

where: PO = Potential Output [Bio*EURO]

bPO = Base level variable for potential output [Bio*EURO]

cPO = Constant factor for potential output development

PROD = Productivity development

LS = Labour supply in working hours

CS = Capital Stock

NR = Natural resources

α, β, γ = production elasticities

The parameters have been estimated by the calibration and validation process, which leads to the values given in table 6:

Table 6: Parameters for the Potential Output Model

	bPO	cPO	α	β	γ
Region 1	465	0.0208	0.48	0.62	0.08
Region 2	615	0.0221	0.484	0.63	0.08
Region 3	680	0.0215	0.486	0.63	0.08
Region 4	455	0.0229	0.485	0.631	0.08

The influence of the natural resources is not differentiated for the regions and is kept rather small, such that the development of potential output is mainly driven by the production factors labour and capital. The reason is that initial approaches to include the natural resources are existing but sophisticated methodologies still have to be developed.

12.1.3 Elements of the Demand Side

The calculation of final demand is also based on the development of the 12 economic sectors explained with the input-output modelling. That means the elements of final demand consumption, investments, government expenditures and export have also to be split into these sectors. Initial values for the four elements are taken from the Eurostat R25 tables for 1995 and the German statistical yearbooks. However, they had to be transformed to reflect the situation in the year 1985 given in 1995 EUROs. The resulting initials are shown in the following tables.

Table 7: Initial values for final demand calculation in region 1 (A, D)

[Mio*EURO]	Consumption	Investment	Government	Export
Sector1	8640	314.76	0	2961
Sector2	26907	86	0	2108
Sector3	46940	1466	0	68143
Sector4	178.35	13277	0	26101
Sector5	55265	76951	0	139738
Sector6	27365	30034	0	47653
Sector7	28192	1805	0	28992
Sector8	103796	0	0	14916
Sector9	4002	153948	0	1518
Sector10	217602	17474	0	41192
Sector11	91959	0.86	0	1903
Sector12	63625	1070	276710	742.5

Table 8: Initial values for final demand calculation in region 2 (B, F, L, NL)

[Mio*EURO]	Consumption	Investment	Government	Export
Sector1	16657	345.02	0	14641
Sector2	19936	240.86	0	9690
Sector3	38375	422.22	0	68740
Sector4	160.94	62.31	0	26768
Sector5	22119	41421	0	66850
Sector6	15671	11655	0	23625
Sector7	31839	793.28	0	24308
Sector8	74623	14.88	0	33712
Sector9	6615	135250	0	1765
Sector10	161756	11207	0	66728
Sector11	77048	13.95	0	5323
Sector12	40702	508.7	263728	25370

Table 9: Initial values for final demand calculation in region 3 (E, GR, I, P)

[Mio*EURO]	Consumption	Investment	Government	Export
Sector1	18289	92.71	0	11508
Sector2	21243	0	0	5106
Sector3	43889	1270	0	54160
Sector4	0	414.48	0	16074
Sector5	16536	38280	0	105377
Sector6	18640	13642	0	34201
Sector7	57988	1258	0	61004
Sector8	83829	0	0	18066
Sector9	2340	133902	0	2.222
Sector10	232333	15116	0	60710
Sector11	130414	0	0	4107
Sector12	13331	0	357240	313.33

Table 10: Initial values for final demand calculation in region 4 (DK, FIN, IRL, S, UK)

[Mio*EURO]	Consumption	Investment	Government	Export
Sector1	8537	328.9	0	6721
Sector2	15002	16.1	0	9780
Sector3	22200	599.14	0	63861
Sector4	6.72	14.95	0	9485
Sector5	7103	29611	0	114090
Sector6	8658	8051	0	35029
Sector7	17415	579.59	0	41971
Sector8	64861	59.8	0	29750
Sector9	7416	102348	0	103
Sector10	172228	2521	0	66514
Sector11	71766	23	0	18442
Sector12	35951	69	351244	1631

12.1.4 Other Data

The development of VAT also effects the total fuel price as well as the tax revenues from general consumption. Therefore it has been modelled explicitely based on national values and on the ratios of the BIP within one macro region. The results are shown in table 11. After 1998 no further adjustments have been assumed, though one might argue that in the long run the VAT rates will be harmonised in the EU economy.

Table 11: Development of VAT in the regions

VAT	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
E1: A,D	0.14	0.14	0.14	0.14	0.145	0.145	0.145	0.145	0.145	0.155	0.155	0.155	0.164
E2: B,F,L,NL	0.18	0.18	0.18	0.18	0.186	0.186	0.186	0.186	0.186	0.201	0.201	0.201	0.201
E3: E,GR,I,P	0.155	0.155	0.155	0.155	0.161	0.161	0.161	0.161	0.161	0.179	0.179	0.179	0.185
E4: DK,FIN,IRL,S,UK	0.15	0.15	0.15	0.15	0.158	0.158	0.158	0.158	0.158	0.193	0.193	0.193	0.193

Investments of the different modes are considered in the MAC. These investments depend on the demand given as transport performance of a certain mode. The calculation is based on the investment factors per unit of transport performance given in table 12 for investment in facilities and in table 13 for investments in vehicles.

Table 12: Investment factors for facilities of the different modes per unit of transport performance

Investment factors	Bus	Air	Train	Truck	Ship
	Mio*EURO/(Bio*pkm)	Mio*EURO/(Bio*pkm)	Mio*EURO/(Bio*km)	Mio*EURO/(Bio*tkm)	Mio*EURO/(Bio*tkm)
E1: A,D	1.189	20.79	20.2	1.611	8.484
E2: B,F,L,NL	1.185	20.73	20.14	1.606	8.459
E3: E,GR,I,P	0.9935	17.37	16.87	1.345	7.087
E4: DK,FIN,IRL,S,UK	1.221	21.35	20.74	1.654	8.713

Table 13: Investment factors for vehicles of the different modes per unit of transport performance

Investment factors	Air	Train	Ship
	Mio*EURO/(Bio*pkm)	Mio*EURO/(Bio*km)	Mio*EURO/(Bio*tkm)
EU15	23	8.95	17.9

The values are taken from ESCOT and have been adjusted for the different base year. To consider the variations in the ASTRA regions the purchasing power parities have been used. For road modes the investments in vehicles have been calculated based on the new purchase according to the vehicle fleet models and an average vehicle price for the different vehicle categories (see the following tables).

Table 14: Net prices for different car categories for investment calculation

[EURO/Car]	GPC1	GPC2	GPC3	DPC1	DPC2
ECE 1503	10000	15000	20000		
ECE 1504/PreEuro	10100	15200	20300	16200	19300
EURO1	10200	15400	20600	16400	19600
EURO2	10300	15600	20900	16600	19900
EURO3	10400	15800	21200	16800	20200
EURO4	10500	16000	22500	17000	20500

Table 15: Net prices for other road vehicles

[EURO/vehicle]	LDVG	LDVD	HDV	Bus
E1: A,D	19000	20000	60000	70000
E2: B,F,L,NL	17000	18000	57000	68000
E3: E,GR,I,P	16000	17000	55000	60000
E4: DK,FIN,IRL,S,UK	20000	21000	61000	70000

The model for the capital stock and the calculation of depreciation requires besides the calculation of investments also the depreciation period and usage period of investments. These values are shown in table 16.

Table 16: Depreciation and usage period of investments

	Depreciation Period		Usage Period	
[years]	Private Capital	Public Capital	Private Capital	Public Capital
E1: A,D	16.5	25	19.5	35
E2: B,F,L,NL	15.5	25	19.5	35
E3: E,GR,I,P	15	25	19.5	35
E4: DK,FIN,IRL,S,UK	14.5	25	19.5	35

12.2 REM Sub-module

12.2.1 ASTRA passenger functional zones

For the spatial representation in the passenger model in ASTRA a functional zoning system is adopted that classifies the 201 European NUTS2 zones (EU15 countries) into 6 clusters. For each cluster it is assumed that zones in the cluster have a (nearly) homogenous pattern of transport characteristics (e.g. low density regions will not dispose of a metro).

Table 18 below shows, as a reference, the classification of the principally NUTS2 zones of the EU15 used in the STREAMS Transport Model of Europe into the notional zones according to their settlement pattern. Table 17 defines the settlement types and Figure 9 in deliverable 4 illustrates the functional zoning scheme adopted in this project that corresponds with table 18.

Table 17: Table Showing Definitions of Settlement Types

Settlement Pattern ID	Settlement Type Description
1	Large Stand Alone Metropolitan Areas (LSA)
2	Metropolitan Areas plus Hinterland (MPH)
3	High Density Urbanised Areas (HDU)
4	High Density Dispersed Areas (HDD)
5	Medium Density Areas (MDR)
6	Low Density Regions (LDR)

Table 18: Classification of STREAMS zones by Settlement Pattern for the use in ASTRA

STREAMS Zone Number	NUTS Code	Zone name	Settlement pattern
Austria *Zones 1 - 9*			
1	at11	BURGENLAND	5
2	at12	NIEDEROESTERREICH	5
3	at13	WIEN	1
4	at21	KAERNTEN	5
5	at22	STEIERMARK	5
6	at31	OBEROESTERREICH	4
7	at32	SALZBURG	4
8	at33	TIROL	5
9	at34	VORARLBERG	5
Belgium & Luxembourg *Zones 10 - 20*			
10	be1	REG.BRUXELLES-CAP./BRUSSELS HFDST.GEW.	1
11	be21	ANTWERPEN	4
12	be22	LIMBURG (B)	4
13	be23	OOST-VLAANDEREN	4
14	be24	VLAAMS BRABANT	4
15	be25	WEST-VLAANDEREN	4
16	be31	BRABANT WALLON	4
17	be32	HAINAUT	4
18	be33	LIEGE	4
19	be34	LUXEMBOURG (B)	5
20	be35	NAMUR	4

Continuation on next page

Germany ***Zones 21 - 58***			
21	de11	STUTTGART	3
22	de12	KARLSRUHE	3
23	de13	FREIBURG	4
24	de14	TUEBINGEN	4
25	de21	OBERBAYERN	2
26	de22	NIEDERBAYERN	4
27	de23	OBERPFALZ	4
28	de24	OBERFRANKEN	4
29	de25	MITTELFRANKEN	4
30	de26	UNTERFRANKEN	4
31	de27	SCHWABEN	4
32	de3	BERLIN	1
33	de4	BRANDENBURG	5
34	de5	BREMEN	3
35	de6	HAMBURG	2
36	de71	DARMSTADT	3
37	de72	GIESSEN	3
38	de73	KASSEL	3
39	de8	MECKLENBURG-VORPOMMERN	5
40	de91	BRAUNSCHWEIG	3
41	de92	HANNOVER	3
42	de93	LUENEBURG	4
43	de94	WESER-EMS	4
44	dea1	DUESSELDORF	3
45	dea2	KOELN	3
46	dea3	MUENSTER	3
47	dea4	DETMOLD	3
48	dea5	ARNSBERG	3
49	deb1	KOBLENZ	3
50	deb2	TRIER	4
51	deb3	RHEINHESSEN-PFALZ	3
52	dec	SAARLAND	3
53	ded	SACHSEN	3
54	dee1	DESSAU	4
55	dee2	HALLE	3
56	dee3	MAGDEBURG	4
57	def	SCHLESWIG-HOLSTEIN	4
58	deg	THUERINGEN	4
Denmark ***Zones 59 - 60***			
59	dk11	VEST FOR STOREBAELT	3
60	dk12	HOVEDSTADTREGIONEN AND OST FOR STOREBAELT	4

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Spain ***Zones 61 - 76***			
61	Es11	GALICIA	5
62	Es12	ASTURIAS	4
63	Es13	CANTABRIA	5
64	Es21	PAIS VASCO	3
65	Es22	NAVARRA	5
66	Es23	RIOJA	5
67	Es24	ARAGON	5
68	Es3	MADRID	1
69	Es41	CASTILLA-LEON	6
70	Es42	CASTILLA-LA MANCHA	6
71	Es43	EXTREMADURA	6
72	Es51	CATALUNA	2
73	Es52	COMUNIDAD VALENCIANA	3
74	Es53	BALEARES	4
75	Es61	ANDALUCIA	5
76	Es62	MURCIA, CEUTA Y MELILLA	5
Finland ***Zones 77 - 81***			
77	fi11	UUSIMAA	2
78	fi12	ETELAE-SUOMI	5
79	fi13	ITAE-SUOMI	6
80	fi14	VAELI-SUOMI	6
81	fi15	POHJOIS-SUOMI	6
82	fi2	AHVENANMAA/AALAND	6
France ***Zones 82 - 104***			
83	Fr1	ILE DE FRANCE	1
84	Fr21	CHAMPAGNE-ARDENNE	5
85 86	Fr22 fr23	PICARDIE HAUTE-NORMANDIE	5 4
87	fr24	CENTRE	5
88	fr25	BASSE-NORMANDIE	5
89	fr26	BOURGOGNE	5
90	fr3	NORD-PAS-DE-CALAIS	4
91	fr41	LORRAINE	5
92	fr42	ALSACE	5
93	fr43	FRANCHE-COMTE	5
94	fr51	PAYS DE LA LOIRE	5
95	fr52	BRETAGNE	4
96	fr53	POITOU-CHARENTES	5
97	fr61	AQUITAINE	5
98	fr62	MIDI-PYRENEES	5
99	fr63	LIMOUSIN	6
100	fr71	RHONE-ALPES	2
101	fr72	AUVERGNE	5
102	fr81	LANGUEDOC-ROUSSILLON	5
103	fr82	PROVENCE-ALPES-COTE D'AZUR	2
104	fr83	CORSE	6

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Greece ***Zones 105-117***			
105	gr11	ANATOLIKI MAKEDONIA, THRAKI	6
106	gr12	KENTRIKI MAKEDONIA	5
107	gr13	DYTIKI MAKEDONIA	6
108	gr14	THESSALIA	5
109	gr21	IPEIROS	6
110	gr22	IONIA NISIA	5
111	gr23	DYTIKI ELLADA	5
112	gr24	STEREA ELLADA	6
113	gr25	PELOPONNISOS	6
114	gr3	ATTIKI	1
115	gr41	VOREIO AIGAIO	6
116	gr42	NOTIO AIGAIO	6
117	gr43	KRITI	5
Ireland ***Zones 118 - 120***			
118	ie11	DUBLIN, MID-EAST	2
119	ie12	BORDER, MIDLAND AND WEST	6
120	ie13	SOUTHWEST, SOUTHEAST AND MIDWEST	5
Italy ***Zones 121 - 140***			
121	it11	PIEMONTE	2
122	it12	VALLE D'AOSTA	6
123	it13	LIGURIA	2
124	it2	LOMBARDIA	1
125	it31	TRENTINO-ALTO ADIGE	5
126	it32	VENETO	3
127	it33	FRIULI-VENEZIA GIULIA	3
128	it5	EMILIA-ROMAGNA	3
129	it51	TOSCANA	3
130	it52	UMBRIA	5
131	it53	MARCHE	4
132	it6	LAZIO	2
133	it71	ABRUZZO	4
134	it72	MOLISE	5
135	it8	CAMPANIA	2
136	it91	PUGLIA	4
137	it92	BASILICATA	5
138	it93	CALABRIA	5
139	ita	SICILIA	4
140	itb	SARDEGNA	5
Luxembourg ***Zone 141***			
141	lu	LUXEMBOURG (GRAND-DUCHE)	4

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Netherlands ***Zones 142 - 153***			
142	nl11	GRONINGEN	4
143	nl12	FRIESLAND	4
144	nl13	DRENTHE	4
145	nl21	OVERIJSSEL	4
146	nl22	GELDERLAND	4
147	nl23	FLEVOLAND	4
148	nl31	UTRECHT	4
149	nl32	NOORD-HOLLAND	3
150	nl33	ZUID-HOLLAND	3
151	nl34	ZEELAND	4
152	nl41	NOORD-BRABANT	4
153	nl42	LIMBURG (NL)	4
Portugal ***Zones 154 - 158***			
154	pt11	NORTE	3
155	pt12	CENTRO (P)	5
156	pt13	LISBOA E VALE DO TEJO	2
157	pt14	ALENTEJO	6
158	pt15	ALGARVE	5
Sweden ***Zones 159 - 166***			
159	se01	STOCKHOLM	3
160	se02	OESTRA MELLANSVERIGE	6
161	se03	SMAALAND MED OEARNA	6
162	se04	SYDSVERIGE	2
163	se05	VAESTSVERIGE	2
164	se06	NORRA MELLANSVERIGE	6
165	se07	MELLERSTA NORRLAND	6
166	se08	OEVRE NORRLAND	6

Continuation on next page

United Kingdom *Zones 167 - 201*			
167	uk11	CLEVELAND, DURHAM	3
168	uk12	CUMBRIA	5
169	uk13	NORTHUMBERLAND,TYNE AND WEAR	3
170	uk21	HUMBERSIDE	4
171	uk22	NORTH YORKSHIRE	5
172	uk23	SOUTH YORKSHIRE	3
173	uk24	WEST YORKSHIRE	3
174	uk31	DERBYSHIRE, NOTTINGHAMSHIRE	3
175	uk32	LEICS., NORTHAMPTONSHIRE	4
176	uk33	LINCOLNSHIRE	4
177	uk4	EAST ANGLIA	4
178	uk51	BEDFORDSHIRE, HERTFORDSHIRE	4
179	uk52	BERKS.,BUCKS., OXFORDSHIRE	4
180	uk53	SURREY, EAST-WEST SUSSEX	4
181	uk54	ESSEX	4
182	uk55	GREATER LONDON	1
183	uk56	HAMPSHIRE, ISLE OF WIGHT	4
184	uk57	KENT	4
185	uk61	AVON, GLOUCS., WILTSHIRE	4
186	uk62	CORNWALL, DEVON	4
187	uk63	DORSET, SOMERSET	4
188	uk71	HEREFORD-WORCS., WARWICKS.	4
189	uk72	SHROPSHIRE, STAFFORDSHIRE	4
190	uk73	WEST MIDLANDS (COUNTY)	3
191	uk81	CHESHIRE	3
192	uk82	GREATER MANCHESTER	3
193	uk83	LANCASHIRE	3
194	uk84	MERSEYSIDE	3
195	uk91	CLWYD, DYFED, GWYNEDD, POWYS	5
196	uk92	GWENT, MID-S-W GLAMORGAN	3
197	uka1	BORD.-CENTR.-FIFE-LOTH.-TAY.	3
198	uka2	DUMFR.-GALLOWAY, STRATHCLYDE	3
199	uka3	HIGHLANDS, ISLANDS	6
200	uka4	GRAMPIAN	5
201	ukb	NORTHERN IRELAND	2

12.2.2 Trends in passenger and freight transport

In Section 6.2 of ASTRA deliverable 4 and previously in ASTRA D3 some consideration was given to the discussion of trends in passenger and freight transport. This section provides some further evidence of the trends described. The work in the REM is based on these assumptions.

12.2.3 Trends in passenger transport

In D3 a number of specific interrelated trends in passenger and freight transport were identified from various statistical sources. These are summarised table 19 & table 20 below.

Table 19: Trends in passenger transport

Trend ID	Trend description
1	***The population has grown over time*** This has been a minor source of road traffic growth for example over the 20 years to 1995 the population of the EU grew by 6.5% which has been paralleled by an increase of 84% in car kilometres over the same time period (European Commission, 1997).
2	***A greater proportion of the population is now in those population age segments that have the highest trip rates, that make the longest trips and that are most likely to use cars*** In 1995 an annual average of 10,800 kms (DETR, 1997a) was travelled in the UK by those in the most mobile group i.e. those between the ages of 16 and 59. This is 130% greater than the average distance for the under 15's and 118% greater than that for over 60s. Also this most mobile group of the population is the segment which has the highest proportion of its travel taking place by car. Demographic trends over the past 20 years across the EU have seen a relative growth in the 16-64 age group compared to others. There is also evidence that the newly retired population is increasingly mobile compared to 20 years ago (SCENARIOS, C2).
3	***More people have access to cars*** In the sense that more households have cars and more individuals within the household have cars, because average household size has reduced while the average number of cars in households with two or more adults has increased rapidly. The principal reason for the increase in car ownership is the trend where the average income of individuals has increased more rapidly than the cost of car ownership. This will reduce their propensity to use other modes and encourages individuals to adopt the relatively higher travel demands of the car owning segment of the population. See figure 1 below.
4	***Cars have captured a higher share of all the trips that are made*** Since the cost-effectiveness of car travel has improved relatively more quickly than that of other modes (except air), cars have captured a greater share of all the trips that are made.
5	***People now tend to make longer trips due to the improved cost effectiveness of travel, especially by car*** This has been a significant source of growth since in the UK, for example, the average trip lengths for car drivers have increased by 12% to 13.5 kms over the 20 years to 1995 (DETR, 1997a). This growth is due to the lower car operating costs and to higher average road speeds due to the greater availability of and more intensive use of the motorways and the high quality inter-urban primary road network. Other land based modes have improved their generalised costs more slowly.
6	***People are likely to travel further due to the increased average income of individuals*** Across the EU the average length per trip increases as a function of the income of the individual. As such the relative damping effect of the monetary cost of travel becomes less important as incomes increase.
7	***People make longer trips because of the population shift away from dense urban areas*** This increase in demand results in the migration of households and jobs to areas which are less congested for cars.

8	***Car occupancy levels are lower*** The increase in car ownership has lessened the average number of occupants per car kilometre travelled, from 1.73 in 1975 to 1.62 in 1995 according to the UK NTS (DETR, 1997a), so that the same number of person journeys in car would now generate 7% more vehicles to make these journeys.

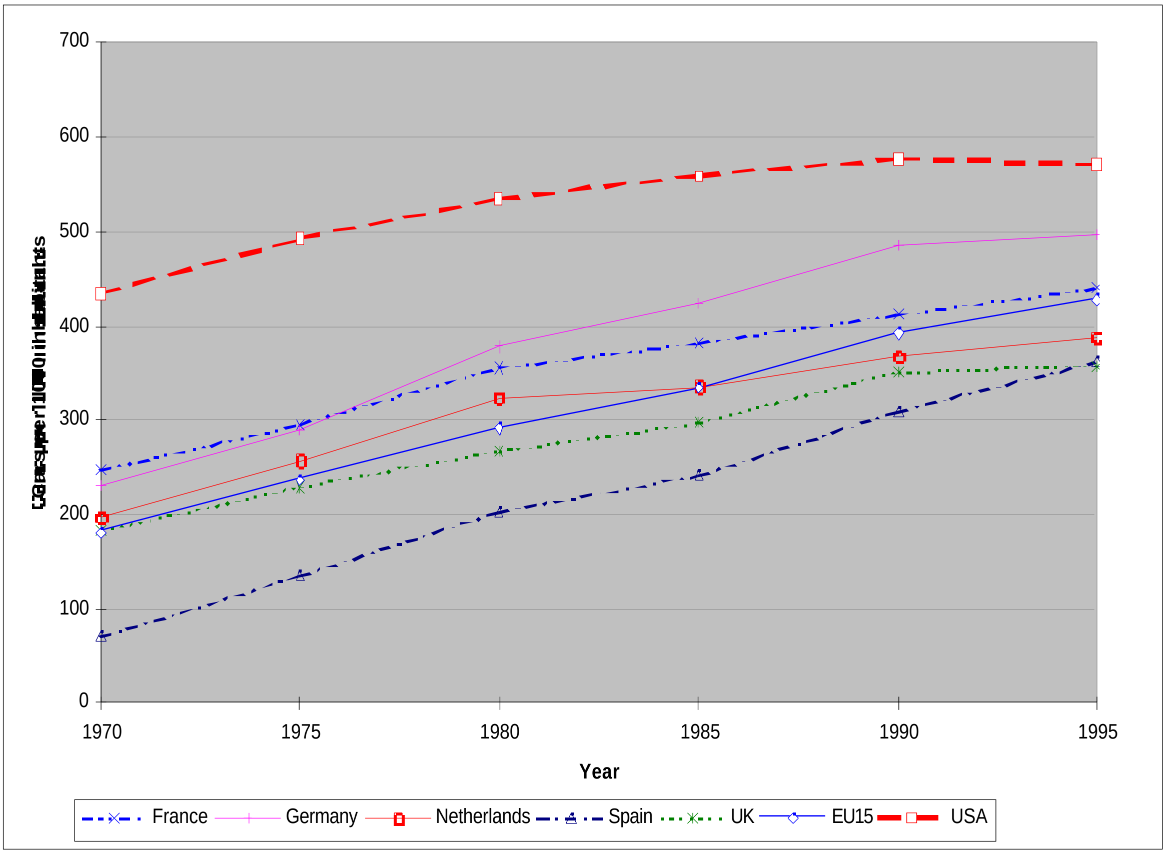

Figure 1: Cars per 1000 inhabitants selected countries and EU15 and USA[1]

12.2.4 Trends in freight transport

Two clear trends are apparent:

- The vast majority of past freight growth has arisen from increases in the length of freight journeys, rather than from increases in the number of tonnes carried. (see *figure 2*)
- The major determinant of overall freight traffic demand is the rate of economic growth, see figure 3.

Table 20: Trends in freight transport

Trend ID	Trend description
1	***General growth in value of freight goods***
2	***A greater proportion of the growth in value of freight carried has***

[1] Eurostat

	been in the high value goods The high value goods tend also to be in those sectors where freight moves over long distance because they are less cost sensitive
3	***Reductions in unit costs of transport mean freight will tend to be moved further leading to larger market access*** Although the number of tonnes moved by road has increased only sporadically e.g. by 12% over the last 22 years in the UK, the average length of haul over that same period has increased by 50%. For example in 1992 the tonnes lifted were much the same as in 1974 suggesting little growth, while the tonne kilometres have grown by 69% over the same period.
4	***Internationalisation of trade due to reduced EU barriers to trade*** Attempts to create European markets for goods by lowering trade barriers between EU member states have led to increased market penetration.
5	***Change in volume/ value ratios and density of goods (packing factors)*** The traditional heavy industries have grown in the EU at much slower rate than the modern light manufacturing industries. These modern industries produce a wide variety of low density, differentiated products e.g. electronic equipment, that need to be packaged separately rather than dispatched in bulk at high density. Consequently the average density of shipments has declined so that more vehicles have been required to transport the same number of tonnes. The trend towards lighter goods has partly offset the trend to larger vehicles. The heaviest vehicles used for long distance traffic have become larger, but the small goods vehicles have also increased in numbers. It is medium sized goods vehicles that have reduced in number.

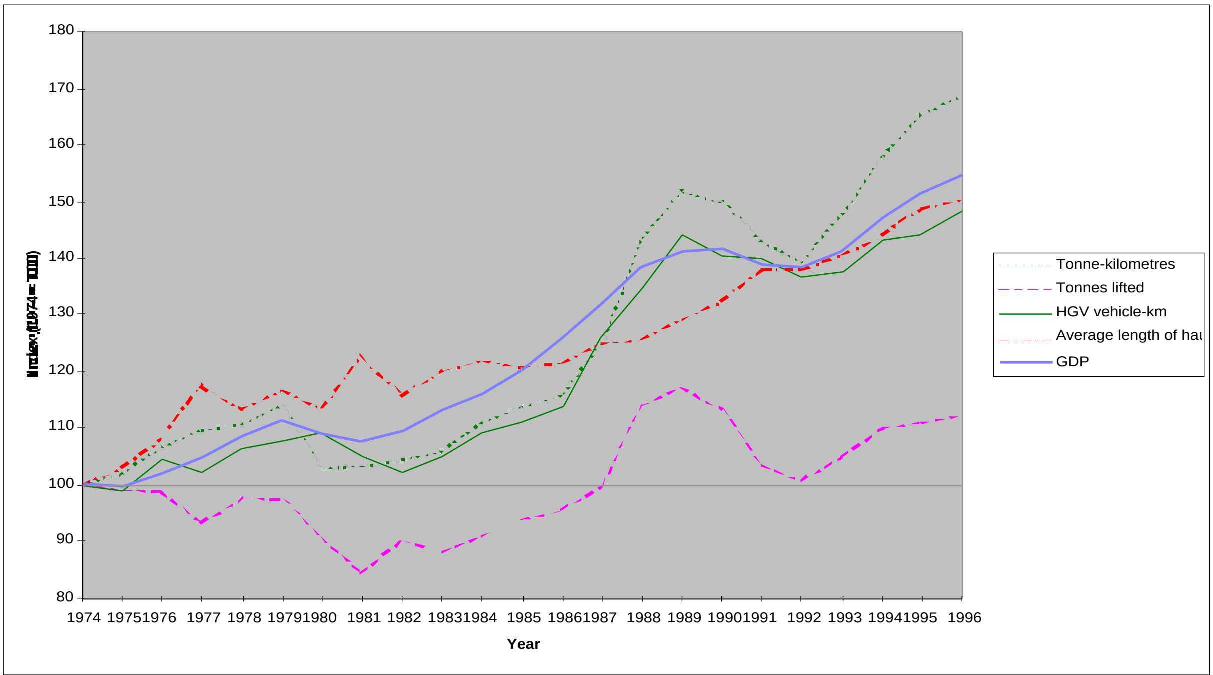

Figure 2: Annual road goods vehicle kilometres travelled, tonnes lifted, average length of haul, tonne kilometres and GDP in Great Britain[2]

[2] *National Road Traffic Forecasts (Great Britain) 1997 for goods vehicle data; UK National Accounts (The Blue Book) 1997 for GDP data*

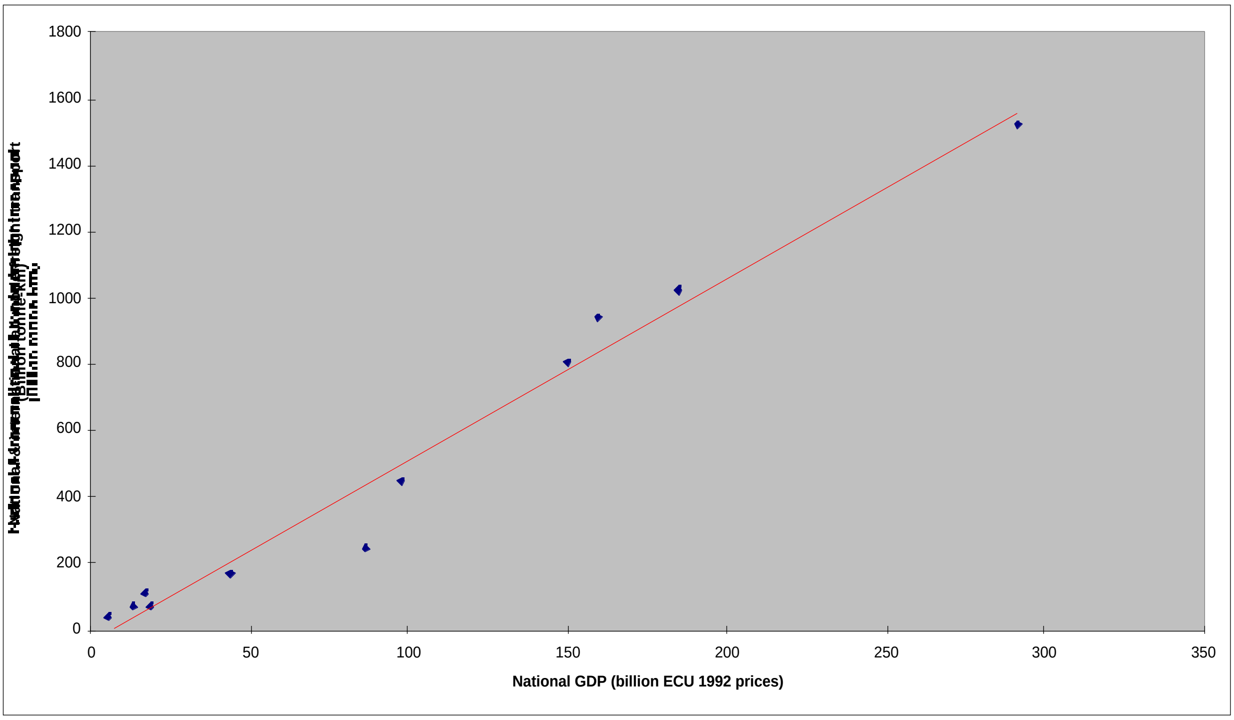

Figure 3: National and International freight transport by all modes in billion tonne-kilometres and GDP (1992) prices for EU12 Countries[3]

12.2.5 Design of REM Sub-module

12.2.5.1 Dimensions of REM Sub-module

- Demand segmentation
- Generation
- Distribution

12.2.6 Demand segmentation

12.2.6.1 Passenger model

In each functional zone in the passenger model the population is segmented into 4 groups based on

- age and
- economic position

The groups are:

- Population under 16 (P1). - All persons under 16 years.
- Population 16-64 Employed (P2). - This category includes all persons in full time and part time employment.

[3] Scenarios Deliverable D6, Annex A5

- Population 16-64 Not in Employment (P3). - This category includes all persons between 16 and 64 who are either unemployed or economically inactive.
- Population over 64 (P4). - All persons over 64 years old.

At the same time the population of each functional zone is also segmented into three car availability categories.

- No car (C0) - Persons in households with no car
- Part car (C1) - Persons in 2+ households with only one car i.e. part car
- Full car (C2) - Persons in 1 adult households with 1+ cars and persons in 2+ adult households which have 2+ cars

Together the consideration of demographic and car availability classifications enables 12 distinct travel demand segments to be identified which are included as an array in the REM sub-module. Common to both the demographic classification and car availability classification is that this data has already been collected at the NUTS2 level for the STREAMS project and so it is this data that is used to initialise the REM in the base year.

12.2.6.2 Freight model

Within each macro region the economy is segmented into a number of industrial sectors which represent production of goods and services. The market segmentation is based on relatively homogenous aggregations of the standard "NACE-CLIO" sector definitions for which suitable data is available. This approach generates the value-added flows between the modelled regions in millions of ECU for different economic sectors. The industrial sectors were listed in section 6.2 and have largely been selected on the basis of the type of freight that they generate.

12.2.7 Generation

12.2.7.1 Passenger model

In the passenger model three trip purposes are used. These categories are used in the trip generation procedure to generate trips for each population/ car availability segment for each of:

- **Commuting and Business**
- **Personal (including education and shopping)**
- **Tourism**

For each of these trip purposes and each car availability/ population segment trip rates have been determined, using STREAMS data, which are then applied to the demand segments. These then generate the total number of trips by each functional zone for each trip purpose. The trip rates used are assumed to be relatively stable over time and therefore will only grow slowly over the modelling period since, as identified in the main variant over time is the length of trips rather than the number of trips.

12.2.7.2 Freight model

In the freight model the amount of freight lifted is calculated using a set of value to volume ratios for each industrial sector. The industrial sectors generate flows according to a pattern of correspondences where each industrial sector generates no more than one flow, while the same flow may be generated by more than one economic sector.

12.2.8 Distribution

The destination zones are represented as a combination of a physical functional zone/ macro region and distance band. In the distribution model passengers and freight make use of 5 and 4 distance bands respectively, see chapter 5.4. As has previously been highlighted there is a much greater segmentation at the shorter end of the distance scale in the passenger model than in the freight model. However it was important to maintain some segmentation of distance at the lower end of the distance scale in the freight model.

It is within the trip distribution part of the demand model that the total demand generated for each zone by trip purpose (in the case of the passenger model) or freight category (in the freight model) is distributed across the respective distance bands. This distribution pattern, in part, is affected by the transport times/costs that are fed into the demand model from the transport model through an interface in the SDM. If the generalised cost of travel increases for one or more modes between time periods then the average overall trip length will reduce; and vice versa. The output from the trip distribution procedure in the form of O-D demand matrices is then fed into the transport sub-module. This calculation takes place in each time period with a new set of transport costs/ times from the TRA sub-module and a new set of trip generation data.

After the distribution of freight the industrial sectors are aggregated up to a set of freight categories. The definition of the freight categories is primarily based on the need to create relatively homogenous segments for the modal split and allow the model to pick up the trends in the demand for freight highlighted earlier (see section 6.2.3.5). At the same time it was necessary to minimise the number of categories. Three freight categories are used, listed below, to generate the transport flows

- **Solid and liquid bulk**
- **Semi-bulk**
- **Unitised freight**

12.2.9 Features of REM Sub-module

There are several elements of the REM sub-module that it is thought interesting to describe in further detail;

- Car ownership model
- Multi-nomial distribution function

- Spatial co-efficients
- Intermediate inputs and outputs

12.2.9.1 Car ownership model

The approach adopted in ASTRA is to model car ownership in such a way all the feedbacks between the different sub-modules are incorporated as far as possible. This involves separating the responsibility with the ENV sub-module in order to model explicitly the relationship between car ownership and income in terms of the growth in the vehicle stock and the REM modelling the demographic distribution of the vehicle stock in each functional zone.

12.2.9.1.1 Methodology

The general structure of the model can be specified as:

$$P_{ia}^{ct} = P_{ia}^{ct-1} B_{ia}^{ct} \qquad \textbf{(eq. 2)}$$

where the variables are defined as follows:

P_{ia}^{ct} denotes the population in the segment a in the functional zone i which has the car ownership category c in the time period t. The total population P_{ia}^{+t}, undifferentiated by car ownership category, will already have been estimated within the demographic section of the REM model.

B_{ia}^{ct} is a function that translates the growth in population and in car ownership into a form specific to each detailed population segment. The main subject of this note is the method by which this term can be calculated.

Various aspects arise in the specification of a suitable form for the function within the equation (2).

1. It needs to take account of the relative changes through time in the proportions of the population in the various segments, since these changes in themselves will modify the overall car ownership rate, averaged over the population as a whole.
2. It needs to match to the exogenously specified vehicle fleet within the zone without upsetting the iterative solution structure for the model as a whole. The vehicle fleet constraint is represented by

$$V_i^t = \underset{c',a'}{} \left(P_{ia'}^{ct} \, N_{ia'}^{ct} \right) \qquad \textbf{(eq. 3)}$$

where

N_{ia}^{ct} denotes the average number of cars per person who is in the car ownership category c and population age group a in the functional zone i in the time period t

V_i^t denotes the size of the vehicle fleet in the functional zone i in the time period t. This value is an input from the ENV module.

3. It needs to take account of the relative changes through time in the average number of cars per person in each person type segment *a*. In general these changes in the value of the variable N_{ia}^{ct} would be expected to be small. For children and those in non car owning households the value would remain at zero. For adults in full car owning households the value would tend to approach or perhaps eventually move above 1. In part car owning households the value for adults would tend to 0.5 as a saturation level, being driven mainly by reductions in the average household size.

The basic relationship (eq. 2) that should be satisfied by the allocation of the population to car ownership categories can be expanded as

$$\Delta V_i^t = V_i^t - V_i^{t-1} = \sum_{ca} \left(P_{ia}^{ct} N_{ia}^{ct} - P_{ia}^{ct-1} N_{ia}^{ct-1} \right) \qquad \textbf{(eq. 4)}$$

12.2.9.1.2 The updating procedure

This involves the following steps. Firstly, scale the population by age group in line with the demographic change in the period in order to take account of its implications for the size of the fleet.

$$\ddot{P}_{ia}^{ct} = P_{ia}^{ct-1} \left(P_{ia}^{+t} / P_{ia}^{+t-1} \right) \qquad \textbf{(eq. 5)}$$

The next step is to implement the switching between car ownership categories in a form that will match the required growth in the car fleet. The approach is based on people switching from their current car ownership category to the neighbouring category. The equations for the case where the car fleet is increasing can be written as follows for the three car ownership categories

$$P_{ia}^{0t} = \ddot{P}_{ia}^{0t} \left[1 - \alpha_{ia}^{0} f\left(\Delta V_i^t \right) \right] \qquad \textbf{For } \boldsymbol{c=0}\textbf{, no car households (eq. 6)}$$

$$P_{ia}^{1t} = \ddot{P}_{ia}^{1t} \left[1 - \alpha_{ia}^{1} f\left(\Delta V_i^t \right) \right] + \ddot{P}_{ia}^{0t} \left[\alpha_{ia}^{0} f\left(\Delta V_i^t \right) \right] \qquad \textbf{For } \boldsymbol{c=1}\textbf{, part car households (eq. 7)}$$

$$P_{ia}^{2t} = \ddot{P}_{ia}^{2t} + \ddot{P}_{ia}^{1t} \left[\alpha_{ia}^{1} f\left(\Delta V_i^t \right) \right] \qquad \textbf{or } \boldsymbol{c=2}\textbf{, full car households (eq. 8)}$$

Here the parameters α_{ia}^{c} are positive valued and denote the relative propensity of change in car ownership for the non and part car owning households.

The method by which the form of the function *f()* is determined is now derived. Substituting the equations (6) to (8) into the restriction (4) gives the expression:

$$\Delta V_i^t = -\sum_{ca} \left[P_{ia}^{ct-1} N_{ia}^{ct-1} \right] + \sum_{a} \left[P_{ia}^{+t} / P_{ia}^{+t-1} \right] P_{ia}^{0t-1} \left(N_{ia}^{0t} + \left[\alpha_{ia}^{0} f\left(\Delta V_i^t \right) \right] \left[N_{ia}^{1t} - N_{ia}^{0t} \right] \right) + P_{ia}^{1t-1} \left(N_{ia}^{1t} + \left[\alpha_{ia}^{1} f\left(\Delta V_i^t \right) \right] \left[N_{ia}^{2t} - N_{ia}^{1t} \right] \right) + P_{ia}^{2t-1} N_{ia}^{2t} \, ? \qquad \textbf{(eq. 9)}$$

This can be rewritten in a form that separates out the function of car growth giving

$$\Delta V_i^t = \sum_{ca} \left\{ \left[P_{ia}^{+t} / P_{ia}^{+t-1} \right] \left[P_{ia}^{ct-1} N_{ia}^{ct} \right] - \left[P_{ia}^{ct-1} N_{ia}^{ct-1} \right] \right\} + f\left(\Delta V_i^t\right) \sum_a \left[P_{ia}^{+t} / P_{ia}^{+t-1} \right] \left[P_{ia}^{0t-1} \alpha_{ia}^{0} \left(N_{ia}^{1t} - N_{ia}^{0t} \right) + P_{ia}^{1t-1} \alpha_{ia}^{1} \left(N_{ia}^{2t} - N_{ia}^{1t} \right) \right] \qquad \textbf{(eq. 10)}$$

Which when rearranged gives a suitable form for the updating function as

$$f\left(\Delta V_i^t\right) = \frac{\Delta V_i^t - \sum_{ca} \left\{ \left[P_{ia}^{+t} / P_{ia}^{+t-1} \right] \left[P_{ia}^{ct-1} N_{ia}^{ct} \right] - \left[P_{ia}^{ct-1} N_{ia}^{ct-1} \right] \right\}}{\sum_a \left[P_{ia}^{+t} / P_{ia}^{+t-1} \right] \left[P_{ia}^{0t-1} \alpha_{ia}^{0} \left(N_{ia}^{1t} - N_{ia}^{0t} \right) + P_{ia}^{1t-1} \alpha_{ia}^{1} \left(N_{ia}^{2t} - N_{ia}^{1t} \right) \right]} \qquad \textbf{(eq. 11)}$$

This now provides a form for the updating function to be fed into the equations (6) to (8). These will then provide estimates, which in each functional zone will both match the new vehicle fleet total, and when summed across car ownership categories will match the demographic population totals by age group.

12.2.9.2 Multi-nomial distribution model

Both the freight and passenger distribution models use a multi-nomial logit distribution model of discrete choice. The model takes demand for a factor (trip purpose/ freight category) in consumption zones as given and then distributes the production amongst the supply zones according to the level of disutility (generalised cost/time) of production in each zone.

This discrete choice model calculates the probability that an activity of type *m* that has been demanded in zone *j* will be allocated from the production zone *i*. This probability is based on:

$f(u_{ij}^m)$ a function of the travel disutility (generalised cost/time) from the production zone *i* to the consumption zone *j*

z_{ij}^m is the residual disutility of travel from production zone *i* to consumption zone *j*

the exponent of these terms is weighted by

S_i^m a measure of the size of the production zone *i* (e.g. population size or production capacity)

The output from this model is an estimate of the **trade** in the trip purpose/ freight category *m* (i.e. the volume of movement measured in physical tonnes or trips) from the production zone *i* to the consumption zone *j*:

$$T_{ij}^{m} = Y_{j}^{m} \frac{S_{i}^{m} e^{-\lambda_{1}^{m}\left(f(u_{ij}^{m}) + z_{ij}^{m}\right)}}{\sum_{i'} S_{i'}^{m} e^{-\lambda_{1}^{m}\left(f(u_{i'j}^{m}) + z_{i'j}^{m}\right)}} \qquad \textbf{(eq. 12)}$$

where:

Y_{j}^{m} is the total demand for consumption of trip purpose/ freight category *m* in zone *j*

T_{ij}^{m} is the amount of trade in trip purpose/ freight category *m* to consumption zone *j* from production zone *i*

λ_{1}^{m} is a concentration parameter which determines the sensitivity of the pattern of distribution of trade to the relative level of disutility in each production zone.

The overall disutility of transport u_{ij}^{m} between zones *i* and *j* is estimated within the TRA sub-module. It includes all aspects relevant to the characteristics of the trip, such as the cost, the travel time, the difficulty and the reliability of the mode, so that it represents the complete generalised cost of transport. The zone pair residual disutility is calculated so as to match the observed patterns between zone pairs in the base year. These terms are retained with constant values in the future years.

12.2.9.3 Spatial Coefficients

As the ASTRA SDM operates with two types of zones at times it may be necessary to convert data between the zone types to allow the data to go into another sub-module. For example to calculate the employment/ unemployment split the labour force by functional zone must be convert to the macro regions so that it can be input into the MAC. These coefficients were calculated from STREAMS model data for 1994 and are regarded as fixed through time.

Table 21: Population Coefficients

		Functional Zone					
		LSA	**MPH**	**HDU**	**HDD**	**MDR**	**LDR**
Macro Region	**MR1**	0.057	0.063	0.501	0.279	0.100	0.000
	MR2	0.147	0.122	0.071	0.339	0.309	0.012
	MR3	0.152	0.229	0.197	0.119	0.228	0.076
	MR4	0.083	0.087	0.328	0.313	0.101	0.088

Table 22: Labour force Coefficients

		Functional Zone					
		LSA	**MPH**	**HDU**	**HDD**	**MDR**	**LDR**
Macro Region	**MR1**	0.060	0.070	0.485	0.287	0.099	0.000
	MR2	0.156	0.116	0.078	0.330	0.312	0.010
	MR3	0.169	0.233	0.221	0.102	0.206	0.069
	MR4	0.084	0.087	0.333	0.344	0.067	0.086

12.2.9.4 Intermediate inputs and outputs

The following table provides more detail on the inputs and outputs of each of the stages in the passenger and freight demand modelling described in section 6.2 on the REM sub-module.

Table 23: Data flows into and out of demographic model in REM sub-module

Variable	Type	Dimension(s)	Units	Source	Comments
Inputs					
Base year population (1986)	X	Functional zone; Age cohort	Thousands		
Area	X	Functional zone	km_	GIS Database	
Birth rates	X	Functional zone	Births per thousand population	Demographic data	
Death rates	X	Functional zone; Age cohort	Deaths per thousand population	Demographic data	
Life expectancy	X	Functional zone	Years	Demographic data	
Activity rates	X	Functional zone	Proportion	Demographic data	
Employment/ Unemployment	S (MAC)	Functional zone	Thousands	MAC	
Outputs					
Births	A	Functional zone	Thousands		
Deaths by age cohort	A	Functional zone	Thousands		
Labour force	A, B (MAC)	Functional zone	Thousands	REM	
Population density	C	Functional zone	Persons per km_	REM	
Population by age/ economic cohort	A				Passed to car owner-ship model
Population by age cohort	A	Functional zone; Age cohort	Thousands	REM	
Employment	Z (MAC), A	Functional zone	Thousands	MAC	
Unemployment	Z (MAC), A	Functional zone	Thousands	MAC	
Economically inactive population	C	Functional zone; Age cohort	Thousands	REM	

Note: i. X – Exogenous input (outside ASTRA SDM); Y – Endogenous input (from REM); Z – Endogenous input (other sub-module)
ii. A – Output used in other part of REM; B – Output used in other sub-module; C – Descriptive output (not used elsewhere)

Table 24: Data flows to and from car ownership model in REM sub-module

Variable	Type	Units	Source	Comments
Inputs				
Population cohorts	N		Calculated by REM	
Change in car fleet	N		ENV	
Average cars per person	X			
Alpha parameters	X			Calibrated parameters
Outputs				
Population by demand segment				
Cars per head population				
Persons by car availability				
Cars per thousand adults				

Note: i. X – Exogenous input (outside ASTRA SDM); Y – Endogenous input (from REM); Z – Endogenous input (other sub-module)
ii. A – Output used in other part of REM; B – Output used in other sub-module; C – Descriptive output (not used elsewhere)

Table 25: Inputs into trip generation model of REM

Variable	Type	Dimension(s)	Units	Source	Comments
Passenger demand segments	N	Functional Zone	Thousands	Calculated by REM	
Trip rates	N	Trip purpose; Passenger demand segment		ENV	
Average cars per person	X	n/a			

Note: i. X – Exogenous input (outside ASTRA SDM); Y – Endogenous input (from REM); Z – Endogenous input (other sub-module)
ii. A – Output used in other part of REM; B – Output used in other sub-module; C – Descriptive output (not used elsewhere)

Table 26: Inputs into trip distribution model of REM

Variable	**Type**	**Dimension(s)**	**Units**	**Source**	**Comments**
Total trips	N	Functional zone; Trip purpose	Thousands	Calculated by REM (Trip generation)	
Generalised time	N	OD pair; Trip purpose	ECU's per hour	TRA	
Base year residual disutility	X	OD pair; Trip purpose		STREAMS model	
Size term	X			STREAMS model	
Lambda parameter	X	OD pair; Trip purpose		STREAMS model	Parameter affecting distribution amongst destination zones

Note: i. X – Exogenous input (outside ASTRA SDM); Y – Endogenous input (from REM); Z – Endogenous input (other sub-module)
ii. A – Output used in other part of REM; B – Output used in other sub-module; C – Descriptive output (not used elsewhere)

Table 27: Data flows into and out of industrial production model in REM sub-module

Variable	**Type**	**Dimension(s)**	**Units**	**Source**
Inputs				
Initial distribution of GDP by Industrial sector (1986)	X	Macro region; Industrial sector	Proportion	STREAMS
GDP Goods	Z (MAC)	Macro region	Millions ECU	
Sector growth rates				
Outputs				
GDP by Industrial sector	A	Macro region; Industrial sector	Millions ECU	

Note: i. X – Exogenous input (outside ASTRA SDM); Y – Endogenous input (from REM); Z – Endogenous input (other sub-module)
ii. A – Output used in other part of REM; B – Output used in other sub-module; C – Descriptive output (not used elsewhere)

Table 28: Data flows into and out of freight generation model in REM sub-module

Variable	Type	Dimension(s)	Units	Source	Comments
Inputs					
Production	Y	Macro region; Industrial sector	Millions ECU	REM	
Value to volume ratio	X	Macro region; Industrial sector	Millions ECU per thousand tonnes	STREAMS	
Outputs					
Tonnes lifted	A	Macro region; Industrial sector	Thousand tonnes		

Note: i. X – Exogenous input (outside ASTRA SDM); Y – Endogenous input (from REM); Z – Endogenous input (other sub-module)
ii. A – Output used in other part of REM; B – Output used in other sub-module; C – Descriptive output (not used elsewhere)

Table 29: Data flows into and out of freight distribution model in REM sub-module

Variable	Type	Dimension(s)	Units	Source	Comments
Inputs					
Tonnes lifted	Y	Macro region; Industrial sector	Thousand tonnes	REM	
Generalised cost	Z (TRA)	OD pair; Industrial sector		TRA	
Base year residual disutility	X	OD pair; Trip purpose		STREAMS model	
Size term	X			STREAMS model	
Lambda parameter	X	OD pair; Trip purpose		STREAMS model	Parameter affecting distribution amongst destination zones
Outputs					
Tonnes lifted	A	OD pair; Industrial sector;	Thousand tonnes		

Note: i. X – Exogenous input (outside ASTRA SDM); Y – Endogenous input (from REM); Z – Endogenous input (other sub-module)
ii. A – Output used in other part of REM; B – Output used in other sub-module; C – Descriptive output (not used elsewhere)

Table 30: Data flows into and out of freight aggregation model in REM sub-module

Variable	Type	Dimension(s)	Units	Source	Com ments
Inputs					
Tonnes lifted	Y	OD pair; Industrial sector;	Thousand tonnes	REM	
Outputs					
Tonnes lifted	B (TRA)	OD pair; Freight flow	Thousand tonnes		

Note: i. X – Exogenous input (outside ASTRA SDM); Y – Endogenous input (from REM); Z – Endogenous input (other sub-module)
ii. A – Output used in other part of REM; B – Output used in other sub-module; C – Descriptive output (not used elsewhere)

12.2.10 Data sources

12.2.10.1 STREAMS model

The STREAMS model has been used as a benchmark model for the development of the REM and TRA sub-modules and its role is expanded on in this section.

The STREAMS multi-modal, network based transport model of the European Union has been developed as part of a research project for the European Commission (DG VII) co-ordinated by ME&P[4]. Part of the aim of this project has been to provide a strategic level analysis of how European transport systems will cope with possible future levels of demand and produce base reference forecasts of transport in the EU in 2020.

In the context of ASTRA the STREAMS model is used as a benchmark model for the calibration of base data and relationships/ trends within both the REM and the transport sub-modules. The benchmarking covers :

- Identification of key elements of demand segmentation from the STREAMS model. This allows more aggregate categories to be used in the REM and TRA sub-modules, which are sufficiently disaggregate to distinguish categories with relatively homogeneous trip making characteristics but at the same time aggregate enough to allow inclusion within the ASTRA modelling framework. For example trip purposes, freight categories, demographic and car availability categories
- Initialisation of the model for base year of SDM 1986 through interpolation between the STREAMS 1975 and 1994 model data information and,
- Establishing trends/ reference patterns for exogenous relationships in the SDM e.g. trip rates.
- Using data from the forecast year of STREAMS, 2020 can also be used to validate the ASTRA SDM.

[4] Marcial Echenique and Partners Ltd

Table 31: Correspondence between ASTRA "Trip purposes" and STREAMS "Trip purposes"

ASTRA		STREAMS
Trip purpose	**Trip purpose name**	**Trip purpose**
1	Commuting & business	11-13, 22
2	Personal	14-17
3	Tourism	18-20, 23-26

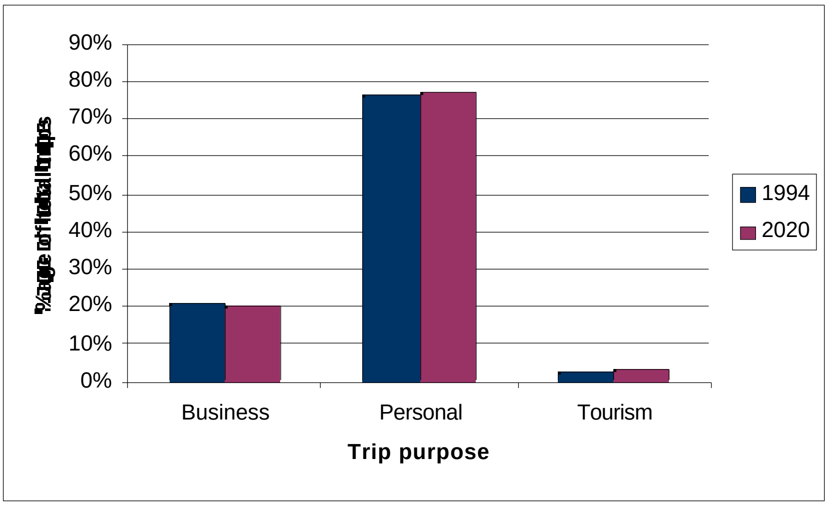

Figure 4: Comparison of distribution of passenger trips by purpose (STREAMS model – 1994 & 2020)

Table 32: Correspondence between ASTRA "REM Industrial sectors" and STREAMS "Trades"

ASTRA		**STREAMS**	**NACE/ CLIO R59 Code**
REM-Industrial Sector	**Industrial sector name**	**Trade No.**	
1	Agriculture, forestry and fishing products	11	010
2	Coal	12	031-033-050
3	Crude petroleum	13	071
4	Petroleum products	14	073
5	Other energy	15-16	075, 095-110
6	Ores	19	157
7	Mineral products	17	135-137
8	Chemical products	20	170
9	Cement	18	151-153-155
10	Metal products	21	190
11	Paper	28	471
12	Food, beverages & tobacco	26	310-330-350-370-390
13	Manufactured articles	22-25, 27, 29-30	210-230-250,270-290,410-430-450,490,473-510

Note: NACE-CLIO is the Eurostat system of industrial classifications

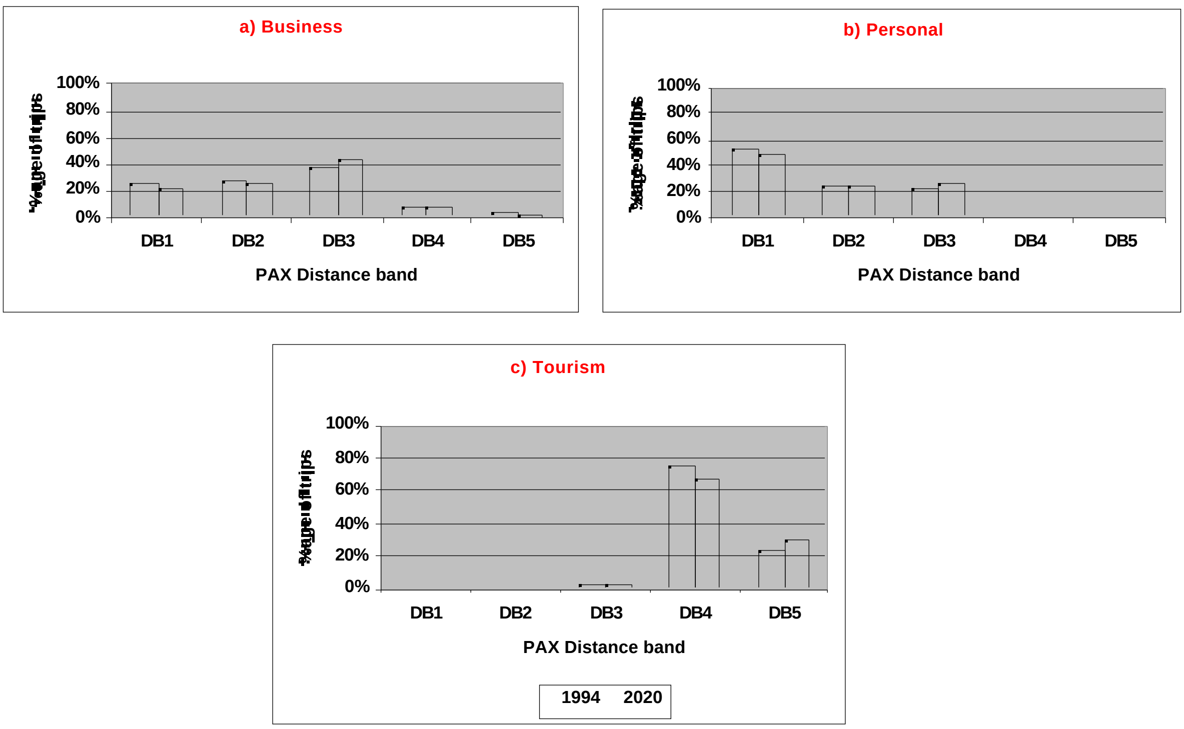

Figure 5: Comparison of distribution of passenger trips lifted by distance bands by passenger trip purpose (STREAMS model – 1994 & 2020)

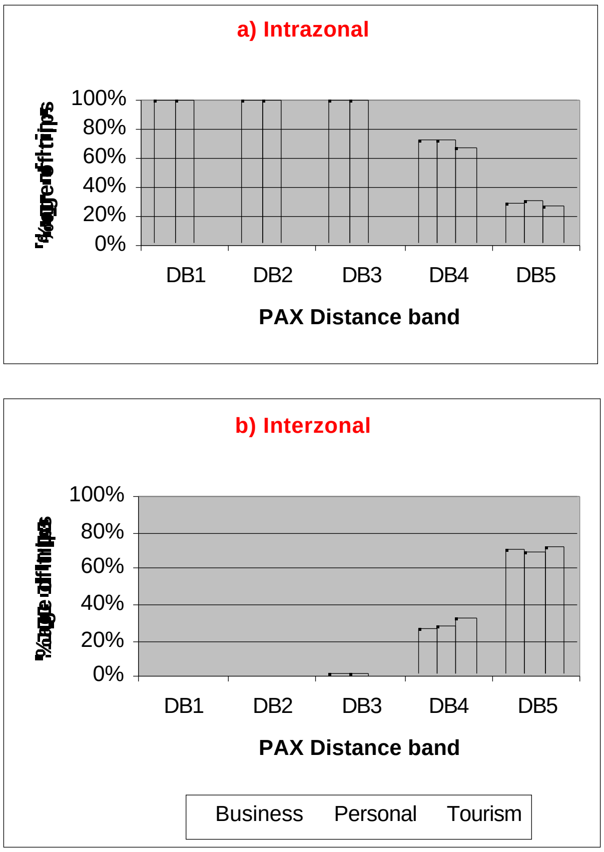

Figure 6: Comparison of distribution of trips by direction and distance bands (all purposes) - (STREAMS model – 1994 & 2020)

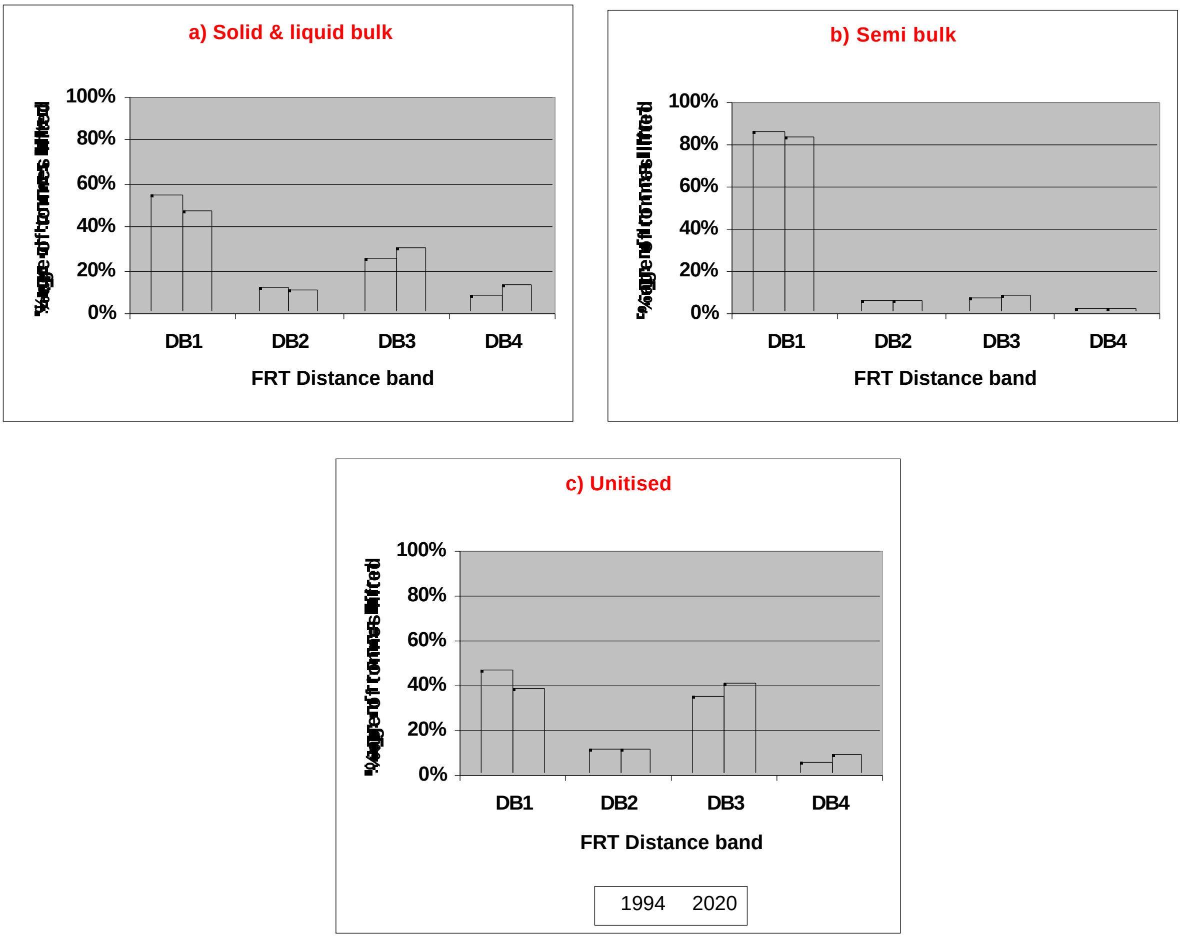

Figure 7: Comparison of distribution of tonnes lifted by distance bands by freight flow (STREAMS model – 1994 & 2020)

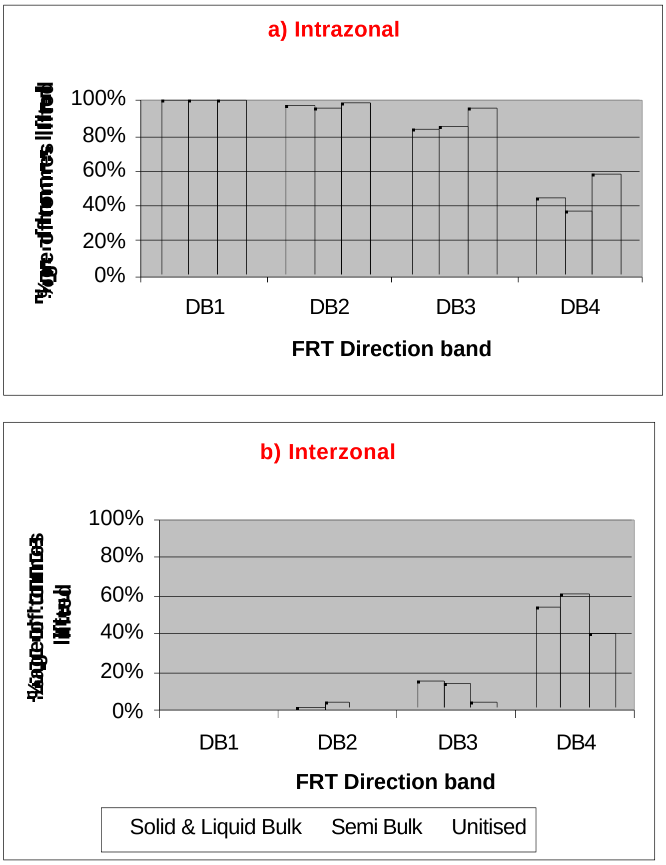

Figure 8: Comparison of distribution of tonnes lifted by direction and distance bands (all freight) - (STREAMS model – 1994 & 2020)

12.3 TRA Sub-module

This appendix includes a detailed explanation of the following issues:

- Process to extract data from the STREAMS transport model,
- Calibration data from ASTRA model.

12.3.1 From the STREAMS model to the ASTRA transport sub-module

12.3.1.1 Aggregation of flows and modes of transport

ASTRA transport flows were defined aggregating the STREAMS detailed trip purposes and freight categories as described by table 33 and table 34. Table 35 and table 36 make reference to the aggregation of transport modes.

Table 33: Correspondence of passenger trip purposes between STREAMS and ASTRA

STREAMS trip purposes	ASTRA trip purposes
11Commuting & Business - short, no car 12Commuting & Business - short, part car 13Commuting & Business - short, full car 22Commuting & business - long	**Commuting&Business**
14Children - shopping/ education/ personal - short, no car 15Adult - shopping/ education/ personal - short, no car 16Adult - shopping/ education/ personal - short, 1 car 17Adult - shopping/ education/ personal - short, 2+ cars	**Personal**
18Visit friends/ day trip/ independent holiday - long, no car 19Visit friends/ day trip/ independent holiday - long, car 20Holiday - air charter 23International holidays - no car availability 24International holidays - partial and full car availability 25Domestic holidays - no car availability 26Domestic holidays – partial and full car availability	**Tourism**

Table 34: Correspondence of freight categories between STREAMS and ASTRA

STREAMS freight categories	ASTRA freight categories
Agriculture and food – bulk	**Liquid and solid bulk**
Solid fuels and ores	
Petroleum products	
Metal products	**Semi-bulk**
Mineral and building materials – bulk	
Paper pulp	
Agriculture and food – unitised	**Unitised**
Mineral and building materials – unitised	
Machinery and miscellaneous articles	
Fertilisers and chemicals	

Table 35: Correspondence of passenger transport modes between STREAMS and ASTRA

STREAMS modes	ASTRA modes
1 Car	**Car**
2 Coach	**Bus**
3 High Speed train 4 Train 13 International Train	**Train**
11 Slow	**Slow**
16 Chartered Air 17 Independent Air	**Air**

Table 36: Correspondence of freight transport modes between STREAMS and ASTRA

STREAMS modes	ASTRA modes
Long distance truck	**Truck**
Short distance truck	
Bulk rail	**Train/iww**
Container rail Bulk waterway	
Container waterway	
Container ship	**Ship**
Bulk ship	

12.3.1.2 From the geographic to the functional zoning system

Most of the required data were directly extracted from the STREAMS model, however the calculation of the transport average costs and times by distance band, by mode and by trip purpose involved the processing of the STREAMS results in order to transfer data between different zoning systems.

Two different databases were set up (one for passenger and one for freight) into which the STREAMS model results were imported, the data were then disaggregated into 5 or 4 separate tables based on the origin/destination distance following the classification adopted by the distance band sectors. In this way, each record in the imported file was assigned to a table based on the trip length of each OD pair, mode and flow combination; for example the local trips table contained all records where the distance is < 3.2 km.

These tables were then exported from the database and a utility was used to aggregate the data by mode, flow and OD pair according to the definitions used in ASTRA. For this task a FORTRAN based utility was used to define the aggregations of modes, flows and zones and then each of the distance band sector data sets from the database was run through it. The output from this procedure were a specific summary tables for each distance band sector, showing data on volume, total travelled distance, cost, time and disutility, disaggregated by trip purpose/freight category, mode and origin/destination pair as defined in ASTRA.

12.3.2 The calibration data

The STREAMS passenger model has supplied data needed for the calibration of the speed-flow curves.

Speed-flow functions coefficients have been calibrated according to the data on average speed calculated by the STREAMS passenger model. α, β, χ and δ parameters, which determine the shape of the curve, are reported in table 37 and the corresponding functions are illustrated in figure 9 and figure 10. It is important to note that the shape of the curve influences the response elasticity of the function: the local road network has a steeper curve as urban roads react more quickly (increasing the transit time) to an increase of the traffic volume; on the other hand motorways (which belong to the long distance network) normally are capable to absorb higher increases of traffic volumes before showing congestion effects.

Table 37: Cost-flow function parameters

	α	β	χ	δ
Local Road Network	1,5	1,5	1	1,5
Inter-urban Road Network	1,5	1,5	0,75	1.5

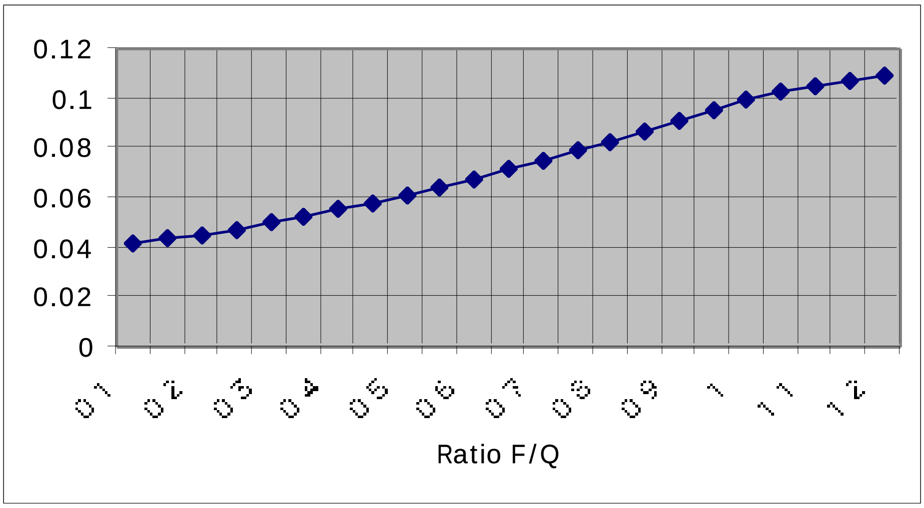

Figure 9: Speed-flow function for the local road network sector

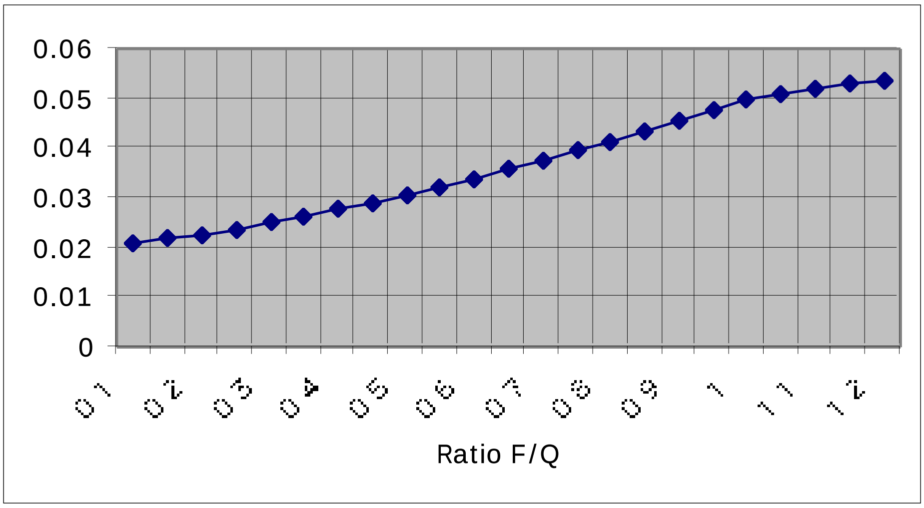

Figure 10: Speed-flow function for the long distance road network sector

Another important parameter which influences the transit time on the road link is the free flow speed v_0, which is ideally the highest speed a single vehicle could safely achieve on the road link under examination. According to the STREAMS data, v_0 is equal to 25 km/h on the local distance road network, while v_0 is equal to 50 km/h on the inter-urban road network.

The dimensional homogenisation coefficient makes it possible to add up cars, buses, vans and trucks to calculate the share of capacity occupied by the traffic flow. Capacity is usually calculated taking car as the unit of measure and then the coefficient is used to calculate the space occupied by buses or others in terms of car units. In all passenger distance bands sectors of the ASTRA transport sub-module, the bus homogenisation coefficient is 2 (each bus is equal to 2 cars), while in all freight distribution sectors the coefficient is 1,5 for van and 2 for truck.

Buses, like vans and trucks, are normally bigger and slower than cars. Within the model the two transport modes have to be treated in the same speed-flow functions and then time homogenisation coefficients are needed. The time homogenisation coefficients are used to derive bus speed starting from the car speed calculated by the speed-flow function. An example of the coefficients adopted in some passenger distance bands sectors is reported in table 38. Similar coefficients are also applied in the freight distribution sectors for vans and trucks.

Table 38: Bus road time factors by distance band

Functional zone	Local	Very Short	Short
LSA	7	2	1,1
MPH	7	2,4	1,1
HDU	10	2,5	1,1
HDD	12	3,5	1,1
MDR	11	3,5	1,1
LDR	10	4	1,1

Car occupancy factors and bus occupancy factors are used to transform passengers in road vehicles. These are differentiated by trip purpose and are derived by the STREAMS model (see table 39).

Table 39: Road passenger vehicles occupancy factors

Mode	Trip purpose	Persons
Car	Business&Commuting - Local road network	1.18
Car	Business&Commuting - Long distance road network	1.2
Car	Personal	1.91
Car	Tourism	2.73
Bus	All trip purposes	13

As for the passengers' modules in the freight distribution sectors, van and truck load-factors are used to transform tons in road vehicles. These are differentiated by freight categories and are derived by the STREAMS model (see table 40).

Table 40: Road freight vehicles load factors

Mode	Freight categories	Tons
Van	Bulk - Local network	7,6
	Semi-bulk - Local network	7,9
	Unitised - Local network	3,5
Truck	Bulk - Inter urban network	15
	Semi-bulk - Inter urban network	15,5
	Unitised - Inter urban network	13,5

In the local network sector a conversion table is used to convert functional zoning data into macro regions zoning data. The table works on both directions, to transform cars by functional zones produced by the TRA passenger sectors into cars by macro-regions and to translate the speed calculated by the sector into the figures by functional zones for the passenger sectors.

*Table 41: Distribution weights based on the vehicles*km - local network*

	MAC 1	MAC 2	MAC 3	MAC 4
LSA	0.108	0.189	0.627	0.076
MPH	0.060	0.215	0.416	0.309
HDU	0.427	0.023	0.308	0.241
HDD	0.321	0.292	0.133	0.254
MDR	0.136	0.384	0.357	0.123
LDR	0.000	0.051	0.393	0.557

In the inter-regional distance network sector a conversion table is used to convert the two-dimension arrays produced by passenger sectors and freight sectors into a single dimension array, and for passengers to change from the functional zoning to the macro-regions system.

In order to convert the truck traffic matrix (two-dimension arrays: macro-regions by macro-regions) in a vector (single dimension array: macro-regions) a simple rule is adopted: the load of each o/d cell of the matrix is assigned to both the cell corresponding to the origin and the cell corresponding to the destination in the vector. The conversion of the passenger traffic matrix is a little bit different, as it is a two-dimension array based on the functional zones.

The distribution of each functional zone in the four macro-regions weighted by the vehicles*km is calculated according to the STREAMS zoning system and is attached to the zone. Thus each functional zone has its own vector for the distribution across the macro-regions. It is then assumed then to each o/d cell of the functional zones matrix of passenger traffic it is possible to associate a distribution vector which is the average of the origin and destination vectors (see next table)

Table 42: Distribution vector for the old cell

O/D cell (HSA, LSA):

LSA =		MPH =		Average =	
	20		60		40
	30		10		20
	40		10		25
	10		20		15

Following such approach each cell of the functional zone matrix has its distribution vector. The final load vector (cars and buses per macro-region) is then obtained as sum of the results of the multiplication of the load in each cell times the corresponding distribution vector. A symmetric approach is adopted for the reverse flow, i.e. average speed from macro-regions to functional zones.

*Table 43: Distribution weights based on the vehicles*km*

	MAC 1	MAC 2	MAC 3	MAC 4
LSA	0.067	0.431	0.489	0.014
MPH	0.089	0.229	0.416	0.265
HDU	0.397	0.042	0.321	0.239
HDD	0.307	0.306	0.160	0.227
MDR	0.122	0.425	0.353	0.101
LDR	0	0.044	0.396	0.560

In synthesis, the total road traffic volume in the TRA sub-module is assigned to two vectors of four elements (EU macro-regions): one for local traffic and one for the long distance traffic. There are differences in their calculation due to the different zoning systems and the dimensions of the arrays.

In brief the four components of the total road traffic volume are calculated in the following way:

- Freight local road traffic: the freight local sector estimates the van load directly in terms of a macro-region vector and then this load is transferred to the local traffic vector;
- Freight long distance road traffic: there are three freight long distance sectors and these estimate the truck load in terms of a macro-regions matrix; then this load is transferred to the long distance traffic vector according to the following rule: traffic going from region 1 to region 2 is assigned to both region 1 and region 2, while intra-regional traffic for region 1 (diagonal) is obviously assigned to region 1;
- Passenger local road traffic: the three local passenger sectors estimate the car and bus load in terms of a functional zones vector and then this traffic is transferred to the macro-regions long distance traffic vector according to a set of distribution weights: i.e. each functional zone load is spread among the 4 macro-regions according to the vehicles-km;

- Passenger long distance road traffic: the two long distance passenger sectors estimate the car and bus load in terms of a functional zones matrix and then this load is transferred to the macro-regions long distance traffic vector according to a set of distribution weights defined for each cell: i.e. each functional zone matrix cell load is spread among the 4 macro-regions according to a distribution weights vector (which is the average of the distribution weights vectors of the origin and destination zones); the weight is based on the vehicles-km.

12.4 ENV Sub-module

12.4.1 Categorisation of Vehicle Fleet

To reflect the technical development of road vehicles in the model the vehicle fleet is structured into groups with specific characteristics. The categorisation considers the vehicle type (e.g. car, bus), the engine type (e.g. gasoline, diesel), the cubic capacity and the emission characteristics in dependency of the corresponding emission legislation. Based on these categorisation emissions, fuel consumption and car purchase expenditures are calculated in the model.

Table 44: ASTRA vehicle categorisation with three levels

level 1	level 2	level 3	
vehicle type	cubic capacity (weight Bus/LKW)	exhaust emission legislation	valid in years 1)
gasoline passenger car (GPC)	0l - 1,4l 1,4l - 2,0l more than 2,0l	ECE 15/03 and previous ECE 15/04 EURO I EURO II EURO III EURO IV	< 81, 81 - 85 86 - 91 92 - 96 97 – 2000 2001 – 2005 2006 - 2026
diesel passenger car (DPC)	< 2,0l > 2,0l	PreEuro EURO I EURO II EURO III EURO IV	< 91 92 - 96 97 – 2000 2001 – 2005 2006 - 2026
light duty vehicles (LDV) (gasoline & diesel)		PreEuro EURO I EURO II EURO III EURO IV	≤91 92 - 96 97 - 2000 2001 – 2005 2006 - 2026
heavy duty vehicle (HDV) (lorry, truck and trailer, articulated lorry)	(< 7,5t 7,5t - 14t 14t - 20t 20t - 28t 28t - 32t 32t - 40t)	80ies EURO I EURO II EURO III EURO IV	<80, 80 - 91 92 - 96 2001 – 2005 2006 - 2026
buses (regular buses, coaches)	(< 20t > 20t < 16t > 16t)	80ies EURO I EURO II EURO III EURO IV	<80, 80 - 91 92 - 96 97 - 2000 2001 – 2005 2006 - 2026

1) Currently future reductions after 2010 are included as percentage reductions in the model. However it can be expected that further EURO categories will by introduced, while the point of time is not yet fixed.

Within the above table some information about vehicle types and weight classes is presented in brackets. This is done to indicate that there are possibilities for deeper categorisation of LDV, HDV and buses. For example if necessary HDV can be classified into lorries, articulated lorries and truck and trailers or into different weight categories.

12.4.2 Initial Values for Vehicle Fleets

As described in chapter 6.4.3.1 the vehicle fleets are implemented in the ENV with a conveyor of which the number of slots corresponds to the vehicle life time. In the following tables the initial values for passenger cars (PC) are presented. On European level aggregated data is available for the years 1973 to 1985, which directly fits to the ASTRA vehicle categorisation. However the aggregated data for EU15 (see table 45) has to be split into the ASTRA categories. For this purpose a comparison with the German shares of the vehicle categories has been made. With some adjustments this led to the initial values presented in table 46.

Table 45: New registration of passenger cars in EU15 between 1973 and 1985[5]

New Registration of Passenger Cars in EU	1973	1975	1977	1979	1981	1983	1985
Germany	2,031,001	2,106,048	2,561,278	262,399	2,330,335	2,426,774	2,379,261
France	1,745,830	1,482,343	1,906,990	1,976,391	1,834,826	2,017,617	1,766,328
Italy	1,449,100	1,050,947	1,219,172	1,397,039	1,808,476	1,451,512	1,653,217
Belgium	340,942	364,781	428,806	429,096	360,273	356,537	378,239
Luxembourg	15,948	17,356	20,956	22,708	22,724	26,092	28,894
Netherlands	429,931	450,312	551,932	568,841	390,990	459,379	495,682
Denmark	122,043	115,561	141,230	126,952	71,888	116,238	157,474
United Kingdom	1,661,639	1,194,088	1,323,524	1,716,275	1,484,713	1,791,699	1,832,027
Ireland	74,132	53,066	82,779	95,938	106,070	60,769	60,593
Greece			110,413	96,063	54,879	75,222	109,435
Spain	595,176	572,188	662,859	620,707	505,716	550,436	575,051
Portugal	79,000		76,485	51,892	79,194	92,294	104,195
Austria	186,982	185,167	295,936	214,297	198,659	256,676	242,670
Sweden	225,722	285,328	241,374	215,325	188,522	217,123	263,033
Finland	117,969	117,021	90,546	100,132	105,629	120,174	138,272
EU15	9,075,415	7,994,206	9,714,280	7,894,055	9,542,894	10,018,542	10,184,371

[5] VDA (1976), VDA (1980), VDA (1984), VDA (1986)

Table 46: New registration differentiated into regions and ASTRA PC vehicle categories[6]

ASTRA Initial Values [cars]:	**1973**	**1975**	**1977**	**1979**	**1981**	**1983**	**1985**
E1 (A, D)	**1973**	**1975**	**1977**	**1979**	**1981**	**1983**	**1985**
GPC1	1153465	1289158	1233087	1203215	1096557	1068534	991787
GPC2	795880	727820	1218305	1032539	872325	1094331	936922
GPC3	105986	98457	179603	312333	161110	168602	110561
DPC1	47393	54466	73419	114967	195802	161107	315007
DPC2	24415	28058	37822	59225	100867	82994	162276
E2 (B, F, L, NL)	**1973**	**1975**	**1977**	**1979**	**1981**	**1983**	**1985**
GPC1	1275949	1261724	1216072	1231480	1095817	1103102	978094
GPC2	880393	712332	1201494	1056794	871736	1129733	923987
GPC3	117240	96361	177125	319670	161001	174056	109034
DPC1	52426	53307	72405	117667	195669	166319	310658
DPC2	27007	27461	37300	60616	100799	85679	160036
E3 (E, GR, I, P)	**1973**	**1975**	**1977**	**1979**	**1981**	**1983**	**1985**
GPC1	1518292	1255734	1227720	1263062	1459636	1187818	1270068
GPC2	1047607	708950	1213002	1083897	1161159	1216495	1199809
GPC3	139508	95904	178821	327868	214455	187423	141582
DPC1	62383	53054	73099	120685	260633	179092	403393
DPC2	32137	27331	37657	62171	134265	92259	207809
E4 (DK, FIN, IRL, S, UK)	**1973**	**1975**	**1977**	**1979**	**1981**	**1983**	**1985**
GPC1	1228377	1065533	870258	1026038	910334	985192	994895
GPC2	883196	633346	896402	949697	838923	1113829	1162911
GPC3	131222	97748	145598	301991	192858	209466	225814
DPC1	14844	13241	15240	28835	47809	43689	92939
DPC2	7647	6821	7851	14854	24629	22506	47878

Source: Table 45, own calculations.

The table can be read as follows: in the initial year 1985 in region E1 for gasoline cars with less than 1.4 cubic capacity (=GPC1) the whole first row (plus the not shown values for the years 1974, 1976, ...) give the whole fleet of this car type. Furthermore the value for the year 1985 indicates the number of one year old GPC1 cars, while the value for 1974 indicates the 12 year old GPC1 cars. All cars that are included within these initial values belong to the emission standard ECE 15/03 (and previous) because they were new registered before the subsequent emission standard ECE 15/04 came into force. The fleet model currently does not consider that a small share of the car segment for each year is scrapped before it reaches the average age as well as that some cars are used longer than the average age as instead an average life time for all cars is assumed.

The following tables 47 and 48 present the initial values for the bus vehicle fleet in the years 1973 to 1985 and the calibration values for the period 1986 to 1995.

[6] The values in the model are implemented as yearly values. The tables with the historic fleet data (also buses, HDV, LDV) present the values for every two years to enable a comprehensive and distinct explanation.

Table 47: Development of European bus vehicle fleet[7]

Country	1970	1975	1980	1985
Austria	6,800	8,000	9,000	9,200
Belgium	10,000	12,000	12,500	12,400
Denmark	5,000	6,000	7,000	8,000
Finland	8,100	8,700	9,000	9,000
France	41,000	52,000	65,000	71,000
Germany	47,000	60,000	70,500	69,400
Greece	10,500	13,300	16,000	19,200
Ireland	2,000	2,000	3,000	4,700
Italy	33,100	43,800	58,100	76,300
Luxembourg	600	700	700	700
Netherlands	9,000	10,000	11,000	12,000
Portugal	5,000	6,000	8,000	10,000
Spain	31,000	39,000	43,000	42,000
Sweden	14,200	14,100	12,800	13,700
United Kingdom	80,000	81,200	150,000	148,000
EU 15	303,300	356,800	475,600	505,600
Average Bus Life Time in Germany [years]:	11.7	11.8	11.9	12.0
Yearly Replacement of Buses = Initial Values:	25,923	30,237	39,966	42,133

Table 48: European bus stock between 1987 and 1994[8]

Country	1987	1988	1989	1990	1991	1992	1993	1994
Austria	9,300	9,300	9,400	9,400	9,300	9,400	9,500	9,600
Belgium	11,900	9,900	10,900	15,500	15,200	14,900	14,800	14,900
Denmark	8,000	8,000	8,000	8,000	10,000	11,300	13,000	13,600
Finland	9,200	9,200	9,300	9,300	8,900	8,600	8,300	8,100
France	71,000	72,000	72,000	75,000	77,000	76,000	78,000	79,000
Germany	70,000	70,000	70,200	70,400	69,600	82,600	88,400	88,500
Greece	18,800	19,200	20,700	21,400	22,100	22,700	23,200	24,000
Ireland	5,000	5,000	5,100	4,000	4,400	4,600	4,800	5,000
Italy	77,900	74,100	76,300	77,700	78,600	78,200	77,000	77,000
Luxembourg	700	700	700	800	800	800	900	800
Netherlands	12,000	12,000	12,000	12,000	12,000	12,000	12,000	11,000
Portugal	11,000	11,000	12,000	12,300	12,500	13,000	13,700	14,400
Spain	43,000	44,000	45,000	46,000	46,600	47,200	47,000	47,100
Sweden	13,800	14,100	14,500	15,000	15,000	14,300	14,100	14,300
United Kingdom	78,000	81,000	161,000	162,000	159,000	161,000	160,000	158,400
EU 15	439,600	439,500	527,100	538,800	541,000	556,600	564,700	565,700

[7] ECMT (1998) S.147
[8] ECMT (1998)

Table 49: Initial values for new registration of buses differentiated into regions

ASTRA Initial Values [buses]:	1973	1975	1977	1979	1981	1983	1985
E1: D,A	4598	5763	6130	6497	6655	6602	6550
E2: B,NL,L,F	5179	6331	6797	7263	7598	7803	8008
E3: E,GR,I,P	6803	8653	9397	10141	10868	11580	12292
E4: DK, FIN, IRL, S, UK	9342	9492	11806	14120	15279	15281	15283

Table 50: Initial values for new registration of diesel LDV differentiated into regions

ASTRA Initial Values [LDVD]:	1973	1975	1977	1979	1981	1983	1985
E1: D,A	2182	4636	6345	8055	11400	16382	21364
E2: B,NL,L,F	18182	28455	35327	42200	52582	66473	80364
E3: E,GR,I,P	62761	92919	108565	124211	140268	156736	173203
E4: DK, FIN, IRL, S, UK	4091	9182	12273	15364	20782	28527	36273

Source: Own estimations based on ECMT (1998)

Table 51: Initial values for new registration of gasoline LDV differentiated into regions

ASTRA Initial Values [LDVG]:	1973	1975	1977	1979	1981	1983	1985
E1: D,A	47455	50182	52836	55491	55400	52564	49727
E2: B,NL,L,F	132273	143545	154964	166382	175018	180873	186727
E3: E,GR,I,P	86697	110924	119961	128997	139448	151315	163182
E4: DK, FIN, IRL, S, UK	132727	135091	137091	139091	140764	142109	143455

Source: Own estimations based on ECMT (1998)

Table 52: Initial values for new registration of HDV differentiated into regions

ASTRA Initial Values [HDV]:	1973	1975	1977	1979	1981	1983	1985
E1: D,A	50909	54636	59582	64527	66400	65200	64000
E2: B,NL,L,F	41121	47485	49558	51630	52770	52976	53182
E3: E,GR,I,P	18685	27136	31551	35967	40335	44657	48979
E4: DK, FIN, IRL, S, UK	45606	49197	50124	51052	51921	52733	53545

Source: Own estimations based on ECMT (1998)

12.4.3 Composition of Emission Factors

The base data for the emission factors stem from the Swiss/German handbook on emission factors.[9] Together with the recent update of this database[10] there are now emission factors available for all EURO emission standards (EURO I-IV) for all ASTRA vehicle categories. With the described vehicle categorisation the total number of 142 vehicle categories included in HB-EFAC will be reduced to 48 vehicle categories, which will be modelled within ASTRA. For each vehicle category at least five different emission factors are needed within the SDM to represent the five ASTRA distance bands. This leads to 240 emission factors in total.

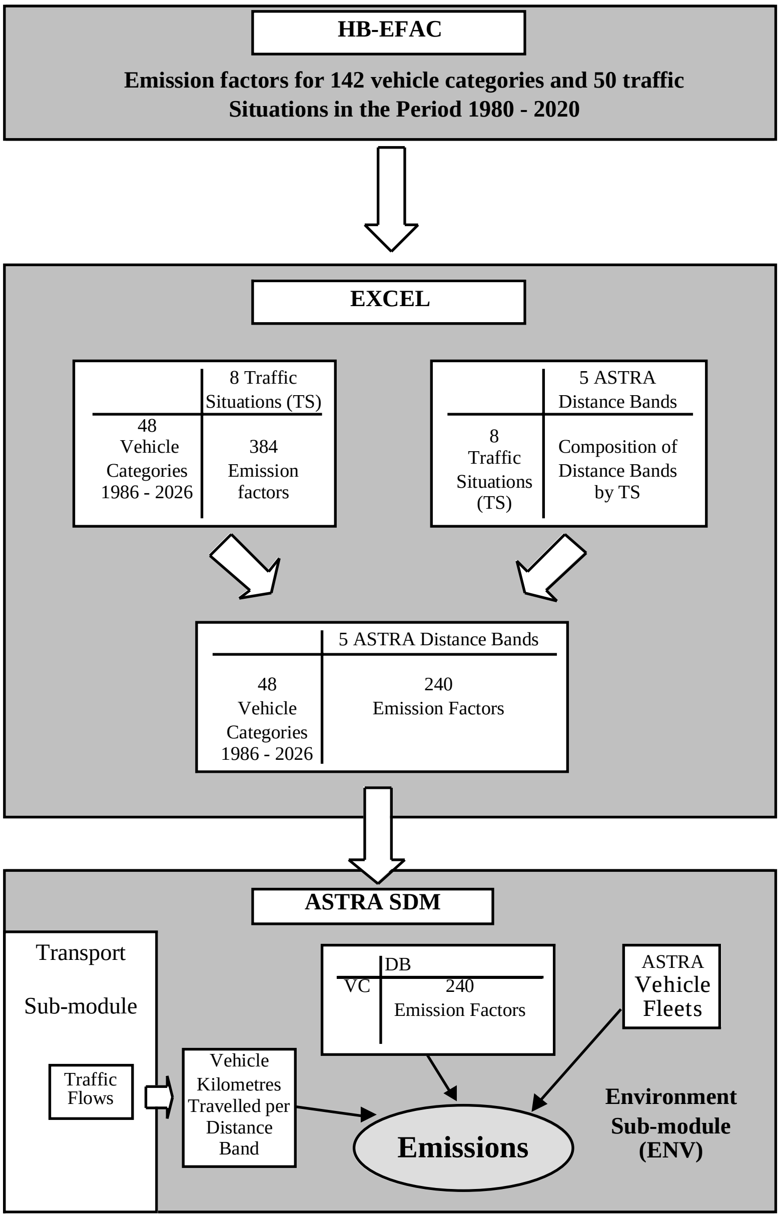

Figure 11: Composition of emission factors for the ASTRA environment sub-module

[9] BUWAL at al. (1995), KNÖRR et al. (1997)
[10] BUWAL et al. (1999)

12.4.4 NO_x Hot Emission Factors

With the scheme presented in figure 11 the following NO_x emission factors are calculated for the five ASTRA distance bands for the different road vehicle types (PC, Bus, HDV, LDVG, LDVD).

Table 53: NO_x emission factors for passenger cars

ASTRA Distance Band (DB):	Standard	Local	Very-Short	Short	Medium	Long
Vehicle Categories (VC)		g NOx/km	g NOx/km	g NOx/km	g NOx/km	g NOx/km
Gasoline PC (<1,4)	ECE 15/03	2.076	2.040	2.233	2.920	3.981
Gasoline PC (<1,4)	ECE 15/04	1.138	1.171	1.481	2.050	2.724
Gasoline PC (<1,4)	EURO I	0.185	0.181	0.196	0.323	0.625
Gasoline PC (<1,4)	EURO II	0.151	0.149	0.160	0.265	0.512
Gasoline PC (<1,4)	EURO III	0.055	0.054	0.059	0.097	0.187
Gasoline PC (<1,4)	EURO IV	0.039	0.038	0.041	0.068	0.131
Gasoline PC (1,4-2)	ECE 15/03	2.076	2.040	2.233	2.920	3.981
Gasoline PC (1,4-2)	ECE 15/04	1.847	1.855	2.092	2.822	3.879
Gasoline PC (1,4-2)	EURO I	0.243	0.233	0.243	0.355	0.595
Gasoline PC (1,4-2)	EURO II	0.201	0.193	0.202	0.294	0.493
Gasoline PC (1,4-2)	EURO III	0.073	0.070	0.073	0.107	0.178
Gasoline PC (1,4-2)	EURO IV	0.051	0.049	0.051	0.075	0.125
Gasoline PC (>2,0)	ECE 15/03	2.076	2.040	2.233	2.920	3.981
Gasoline PC (>2,0)	ECE 15/04	2.415	2.255	2.369	2.945	4.090
Gasoline PC (>2,0)	EURO I	0.175	0.174	0.175	0.234	0.398
Gasoline PC (>2,0)	EURO II	0.155	0.154	0.155	0.207	0.351
Gasoline PC (>2,0)	EURO III	0.053	0.052	0.053	0.070	0.119
Gasoline PC (>2,0)	EURO IV	0.037	0.037	0.037	0.049	0.084
Diesel PC (<2,0)	PreEuro	0.700	0.579	0.496	0.487	0.606
Diesel PC (<2,0)	EURO I (XXIII)	0.708	0.579	0.495	0.494	0.612
Diesel PC (<2,0)	EURO II	0.637	0.522	0.445	0.444	0.551
Diesel PC (<2,0)	EURO III	0.347	0.284	0.242	0.242	0.300
Diesel PC (<2,0)	EURO IV	0.241	0.197	0.168	0.168	0.208
Diesel PC (>2,0)	PreEuro	0.986	0.817	0.692	0.618	0.634
Diesel PC (>2,0)	EURO I (XXIII)	0.997	0.818	0.690	0.626	0.644
Diesel PC (>2,0)	EURO II	0.897	0.736	0.621	0.563	0.580
Diesel PC (>2,0)	EURO III	0.488	0.401	0.338	0.307	0.316
Diesel PC (>2,0)	EURO IV	0.339	0.278	0.235	0.213	0.219

Three effects of the above categorisation should be explained. By integrating all cars, which belong to earlier emission categories than ECE 1503 into this category, the real emission factors and also the resulting emissions are underestimated. This effect will disappear during the first years of the simulation period, because these cars will be taken out of the vehicle fleet. A second effect is that also in a certain time period before a new emission legislation comes into force a share of the new registered vehicles belong to the new emission standard. This leads to an overestimation of emissions because this effect is not considered within the ENV. The third effect is the ageing of catalytic converters during their life time. Some estimates assess this increase of emission factors with 20% to 80% over a 12 years period. As this effect is also not considered in the ENV an underestimation of emissions occurs. It is assumed that these effects compensate each other to a certain extent. In principle, future versions of the model could include the second and the third effect.

Table 54: NO_x hot emission factors of buses

	Bus NO_x Hot Emission Factor for ASTRA Distance bands [g NO_x / km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	20.867	17.835	14.753	8.168	8.662
EURO I	14.620	12.505	10.347	5.718	6.064
EURO II	12.395	10.651	8.869	4.901	5.197
EURO III	8.348	7.141	5.910	3.750	3.900
EURO IV	6.261	5.356	4.433	2.808	2.921

Table 55: NO_x hot emission factors of HDV

	HDV NO_x Hot Emission Factor for ASTRA Distance bands [g NO_x / km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	12.491	10.184	9.004	7.746	8.756
EURO I	16.040	13.123	10.367	7.745	7.867
EURO II	8.685	7.094	6.203	5.251	5.821
EURO III	6.241	5.098	4.425	3.708	4.045
EURO IV	4.679	3.823	3.324	2.791	3.039

Table 56: NO_x hot emission factors of LDVG

	Gasoline LDV NO_x Hot Emission Factor for ASTRA Distance bands [g NO_x / km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	2.211	2.525	2.909	3.820	4.392
EURO I	0.368	0.353	0.466	0.432	0.506
EURO II	0.218	0.209	0.225	0.257	0.300
EURO III	0.107	0.103	0.121	0.147	0.192
EURO IV	0.073	0.070	0.087	0.110	0.150

Table 57: NO_x hot emission factors of LDVD

	Diesel LDV NO_x Hot Emission Factor for ASTRA Distance bands [g NO_x / km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	1.374	1.298	1.337	1.506	1.700
EURO I	1.048	0.881	0.778	0.795	0.926
EURO II	0.898	0.755	0.667	0.681	0.794
EURO III	0.673	0.566	0.500	0.511	0.595
EURO IV	0.374	0.315	0.278	0.284	0.331

12.4.5 CO_2 Hot Emission Factors

With the scheme presented in figure 11 the following CO_2 emission factors are calculated for the five ASTRA distance bands for the different road vehicle types (PC, Bus, HDV, LDVG, LDVD).

Table 58: CO_2 emission factors for passenger cars

ASTRA Distance Band (DB):	Standard	Local	Very-Short	Short	Medium	Long
Vehicle Categories (VC)		g CO_2/km	g CO_2/km	g CO_2/km	g CO_2/km	g CO_2/km
Gasoline PC (<1,4)	ECE 15/03	285.686	233.669	190.524	177.327	214.292
Gasoline PC (<1,4)	ECE 15/04	211.504	170.198	141.571	140.445	179.026
Gasoline PC (<1,4)	EURO I	206.923	169.663	142.199	133.726	159.388
Gasoline PC (<1,4)	EURO II	206.923	169.663	142.199	133.726	159.388
Gasoline PC (<1,4)	EURO III	201.750	165.421	138.644	130.383	155.404
Gasoline PC (<1,4)	EURO IV	196.577	161.180	135.089	127.040	151.419
Gasoline PC (1,4-2)	ECE 15/03	285.686	233.669	190.524	177.327	214.292
Gasoline PC (1,4-2)	ECE 15/04	253.475	205.284	167.774	156.002	185.720
Gasoline PC (1,4-2)	EURO I	242.307	198.991	165.839	153.626	179.544
Gasoline PC (1,4-2)	EURO II	242.307	198.991	165.839	153.626	179.544
Gasoline PC (1,4-2)	EURO III	236.249	194.016	161.693	149.785	175.056
Gasoline PC (1,4-2)	EURO IV	230.192	189.041	157.547	145.944	170.567
Gasoline PC (>2,0)	ECE 15/03	285.686	233.669	190.524	177.327	214.292
Gasoline PC (>2,0)	ECE 15/04	327.109	258.319	206.601	182.933	208.089
Gasoline PC (>2,0)	EURO I	291.141	242.520	207.414	193.934	228.081
Gasoline PC (>2,0)	EURO II	291.141	242.520	207.414	193.934	228.081
Gasoline PC (>2,0)	EURO III	283.863	236.457	202.229	189.085	222.379
Gasoline PC (>2,0)	EURO IV	276.584	230.394	197.044	184.237	216.677
Diesel PC (<2,0)	86-88	181.503	152.896	132.516	131.479	160.055
Diesel PC (<2,0)	EURO I (XXIII)	171.131	142.572	123.450	123.256	154.485
Diesel PC (<2,0)	EURO II	169.420	141.146	122.216	122.024	152.940
Diesel PC (<2,0)	EURO III	165.997	138.295	119.747	119.559	149.850
Diesel PC (<2,0)	EURO IV	160.863	134.017	116.043	115.861	145.216
Diesel PC (>2,0)	86-88	241.965	201.269	171.117	162.364	182.513
Diesel PC (>2,0)	EURO I (XXIII)	225.152	182.731	155.424	152.159	176.008
Diesel PC (>2,0)	EURO II	225.870	185.853	157.829	150.637	174.248
Diesel PC (>2,0)	EURO III	218.398	177.249	150.761	147.594	170.727
Diesel PC (>2,0)	EURO IV	211.643	171.767	146.098	143.029	165.447

Table 59: CO_2 hot emission factors of buses

	Bus CO_2 Hot Emission Factor for ASTRA Distance bands [g CO_2 / km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	1291.809	1104.832	921.816	657.297	692.504
EURO I	1228.649	1050.648	876.655	624.432	657.879
EURO II	1228.649	1050.648	876.655	624.432	657.879
EURO III	1251.037	1069.764	892.699	668.587	701.853
EURO IV	1251.050	1069.775	892.706	668.152	701.490

Table 60: CO_2 hot emission factors of HDV

	HDV CO_2 Hot Emission Factor for ASTRA Distance bands [g CO_2 / km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	1018.954	855.396	773.252	704.356	801.443
EURO I	1491.770	1265.569	1041.718	853.435	901.402
EURO II	1060.674	892.767	798.871	719.149	808.658
EURO III	1103.151	931.539	830.951	745.467	830.162
EURO IV	1103.207	931.522	831.903	747.085	831.104

Table 61: CO_2 hot emission factors of LDVG

	Gasoline LDV CO_2 Hot Emission Factor for ASTRA Distance bands [g CO_2 / km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	368.755	315.390	284.359	296.602	342.696
EURO I	356.821	294.188	250.622	258.794	321.529
EURO II	356.821	294.188	250.622	258.794	321.529
EURO III	346.223	285.451	242.880	251.107	311.979
EURO IV	339.333	279.770	238.339	246.110	305.771

Table 62: CO_2 hot emission factors of LDVD

	Diesel LDV CO_2 Hot Emission Factor for ASTRA Distance bands [g CO_2 / km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	407.021	364.976	364.402	410.622	495.807
EURO I	337.986	283.759	247.598	266.696	330.129
EURO II	331.260	278.113	242.671	261.389	323.559
EURO III	321.421	269.852	235.463	253.625	313.949
EURO IV	315.025	264.482	230.777	248.578	307.702

12.4.6 Cold Start Emission Factors

In the case of passenger cars also the cold start emissions are taken into account. This is mainly important because the emission legislation EURO I and II leads to higher cold start emissions for cars equipped with catalytic converters.

Table 63: Emission factors for cold start extra emissions of NO_x

Vehicle Category		15'03	15'04/ PreEuro	EURO I	EURO II	EURO III	EURO IV
NO_x-emission factors		[g per trip]					
Gasoline PC	<1,4		-0,092271	1,449671502	0,723543701	0,143560257	0,14356026
	1,4l - 2l	-0,165731	-0,147421	1,857934556	0,927311355	0,183990346	0,18399035
	>2l		-0,181145	1,475980147	0,736674575	0,146165589	0,14616559
Diesel PC	<2l		0,138086491	0,0902896305	0,090871453	0,081866182	0,08186618
	>2l		0,124471721	0,1289380765	0,129533357	0,116696729	0,116696729

Table 64: Emission factors for cold start extra emissions of CO_2

Vehicle Category		15'03	15'04/ PreEuro	EURO I	EURO II	EURO III	EURO IV
CO_2-emission factors		[g per trip]					
Gasoline PC	<1,4		147,8700	95,0918004	96,052326	96,052326	96,052326
	1,4l - 2l	205,19731	178,27011	111,397483	112,522712	112,522712	112,522712
	>2l		224,930056	134,990866	136,354413	136,354413	136,354413
Diesel PC	<2l		131,739848	87,3739058	84,3360272	84,3360272	84,3360272
	>2l		144,929302	115,287611	111,29258	111,29258	111,2925803

12.4.7 Emission Factors for the Potential Risk Model of Soot Particles (SP)

The applied emission factors for the diesel passenger cars differentiated into cubic capacity and emission legislation are presented in table table 65:

Table 65: Emission factors for soot particles of diesel passenger cars (source: HB-EFAC)

	Emission Standard	Traffic Situation			
		IO_Kern	IO_Nebenstr_dicht	IO_LSA2	IO_HVS1
Vehicle Categories (VC)		g SP/km	g SP/km	g SP/km	g SP/km
Diesel PC (<2,0)	PreEuro	0,117653	0,122753	0,102899	0,086407
Diesel PC (<2,0)	EURO I	0,076154	0,079453	0,068391	0,082703
Diesel PC (<2,0)	EURO II	0,057115	0,059590	0,051293	0,062027
Diesel PC (<2,0)	EURO III	0,038077	0,039727	0,034195	0,041352
Diesel PC (<2,0)	EURO IV	0,019038	0,019863	0,017098	0,020676
Diesel PC (>2,0)	PreEuro	0,140708	0,146812	0,122654	0,133550
Diesel PC (>2,0)	EURO I	0,091077	0,095025	0,081516	0,127826
Diesel PC (>2,0)	EURO II	0,068308	0,071269	0,061137	0,098696
Diesel PC (>2,0)	EURO III	0,045538	0,047513	0,040758	0,063913
Diesel PC (>2,0)	EURO IV	0,022769	0,023756	0,020379	0,031957

Table 66: Emission factors for soot particles of buses

Emission Standard	Traffic Situation			
	IO_Kern	IO_Nebenstr_dicht	IO_LSA2	IO_HVS1
	g SP/km	g SP/km	g SP/km	g SP/km
PreEuro	1,01451	1,18781	0,897032	0,488127
EURO I	0,646566	0,75659	0,571508	0,31155
EURO II	0,298449	0,349211	0,263918	0,143834
EURO III	0,184984	0,216486	0,163576	0,0891
EURO IV	0,048173	0,056377	0,042598	0,023206

Table 67: Emission factors for soot particles of diesel LDV

Emission Standard	Traffic Situation			
	IO_Kern	IO_Nebenstr_dicht	IO_LSA2	IO_HVS1
	g SP/km	g SP/km	g SP/km	g SP/km
PreEuro	1,10354	1,17489	0,862876	0,510279
EURO I	0,106594	0,111218	0,092125	0,112041
EURO II	0,087213	0,090996	0,075375	0,09167
EURO III	0,038761	0,040443	0,0335	0,040742
EURO IV	0,019381	0,020221	0,01675	0,020371

Table 68: Emission factors for soot particles of HDV

Emission Standard	Traffic Situation			
	IO_Kern	IO_Nebenstr_dicht	IO_LSA2	IO_HVS1
	g SP/km	g SP/km	g SP/km	g SP/km
PreEuro	1,00396	1,15742	0,868899	0,456082
EURO I	0,813269	0,924177	0,703639	0,378658
EURO II	0,309191	0,355637	0,267467	0,140648
EURO III	0,199074	0,228724	0,172192	0,090646
EURO IV	0,005414	0,059536	0,04482	0,023594

12.4.8 Fuel Consumption Factors for Road Vehicles

The fuel consumption factors are also taken from the Swiss-German Handbook on Emission Factors.[11] They are composed similarly as the emission factors (see figure 11) to reflect the different situations on the ASTRA distance bands. The values have been adjusted in some cases to reflect differences between the four macro regions.

[11] BUWAL at al. (1995), KNÖRR et al. (1997)

ASTRA Distance Band (DB):		**Local**	**Very Short**	**Short**	**Medium**	**Long**
Vehicle Categories (VC)	Emission Standard	l/100km	l/100km	l/100km	l/100km	l/100km
Gasoline PC (<1,4)	ECE 1503	10,841	8,867	7,230	6,729	8,132
Gasoline PC (<1,4)	ECE 1504	8,026	6,459	5,372	5,330	6,794
Gasoline PC (<1,4)	GKAT/EURO 1	8,233	6,846	5,730	5,372	6,337
Gasoline PC (<1,4)	EURO 2	8,233	6,846	5,730	5,372	6,337
Gasoline PC (<1,4)	EURO 3	8,069	6,709	5,616	5,265	6,211
Gasoline PC (<1,4)	EURO 4	7,908	6,576	5,504	5,161	6,088
Gasoline PC (1,4-2)	ECE 1503	10,841	8,867	7,230	6,729	8,132
Gasoline PC (1,4-2)	ECE 1504	9,619	7,790	6,363	5,914	7,048
Gasoline PC (1,4-2)	GKAT/EURO 1	9,820	8,153	6,277	5,638	6,371
Gasoline PC (1,4-2)	EURO 2	9,820	8,153	6,277	5,638	6,371
Gasoline PC (1,4-2)	EURO 3	9,625	7,991	6,152	5,526	6,244
Gasoline PC (1,4-2)	EURO 4	9,433	7,832	6,030	5,416	6,120
Gasoline PC (>2,0)	ECE 1503	10,841	8,867	7,230	6,729	8,132
Gasoline PC (>2,0)	ECE 1504	12,413	9,802	7,840	6,942	7,896
Gasoline PC (>2,0)	GKAT/EURO 1	12,718	10,450	8,004	7,175	8,278
Gasoline PC (>2,0)	EURO 2	12,718	10,450	8,004	7,175	8,278
Gasoline PC (>2,0)	EURO 3	12,465	10,242	7,844	7,032	8,113
Gasoline PC (>2,0)	EURO 4	12,217	10,038	7,688	6,892	7,952
Diesel PC (<2,0)	Pre EURO	6,824	5,749	4,982	4,943	6,018
Diesel PC (<2,0)	XXIII/FAV1	6,824	5,749	4,982	4,943	6,018
Diesel PC (<2,0)	EURO 2	6,824	5,749	4,982	4,943	6,018
Diesel PC (<2,0)	EURO 3	6,622	5,578	4,835	4,797	5,839
Diesel PC (<2,0)	EURO 4	6,361	5,358	4,644	4,608	5,609
Diesel PC (>2,0)	Pre EURO	9,098	7,568	6,434	6,105	6,862
Diesel PC (>2,0)	XXIII/FAV1	9,098	7,568	6,434	6,105	6,862
Diesel PC (>2,0)	EURO 2	9,098	7,568	6,434	6,105	6,862
Diesel PC (>2,0)	EURO 3	8,827	7,343	6,243	5,923	6,658
Diesel PC (>2,0)	EURO 4	8,480	7,053	5,997	5,690	6,396

Source: HB-EFAC, own calculations.

Table 69: Fuel consumption factors of buses

	Bus fuel consumption factor Factor for ASTRA Distance bands [l / 100km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	51,964	44,430	37,092	26,174	27,545
EURO I	50,019	42,772	35,689	25,400	26,760
EURO II	48,657	41,613	34,718	24,679	26,006
EURO III	47,054	40,236	33,574	24,377	25,675
EURO IV	46,743	39,971	33,352	24,360	25,646

Source: HB-EFAC, own calculations.

Table 70: Fuel consumption factors of diesel LDV

	Bus fuel consumption factor Factor for ASTRA Distance bands [l / 100km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	14,552	12,685	12,821	15,157	18,302
EURO I	13,083	11,188	10,166	11,109	13,641
EURO II	12,718	10,759	9,549	10,350	12,767
EURO III	12,370	10,404	9,114	9,831	12,160
EURO IV	12,210	10,262	8,975	9,676	11,971

Source: HB-EFAC, own calculations.

Table 71: Fuel consumption factors of gasoline LDV

	Bus fuel consumption factor Factor for ASTRA Distance bands [l / 100km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	13,611	11,641	10,495	10,946	12,649
EURO I	12,790	10,726	9,441	9,948	12,105
EURO II	12,776	10,646	9,273	9,741	11,988
EURO III	12,718	10,506	9,009	9,396	11,719
EURO IV	12,644	10,423	8,901	9,257	11,573

Source: HB-EFAC, own calculations.

Table 72: Fuel consumption factors of HDV

	Bus fuel consumption factor Factor for ASTRA Distance bands [l / 100km]				
Emission Standard	**Local**	**Very-Short**	**Short**	**Medium**	**Long**
PreEuro	39,977	33,579	30,086	27,167	30,724
EURO I	40,208	33,744	30,318	27,398	30,828
EURO II	39,523	33,225	29,576	26,519	29,903
EURO III	39,257	33,020	29,496	26,509	29,736
EURO IV	39,174	32,953	29,501	26,563	29,776

Source: HB-EFAC, own calculations.

12.4.9 Parameters for the Car Vehicle Fleet Model

The following table presents the elasticities that are applied in the vehicle fleet model explained in chapter 6.4.3.1 of ASTRA D4. In the rows 2-3 the suggestions of JOHANNSEN/SCHIPPER[12] are shown. However, currently the best fit for the four macro regions is reached with the optimised values of row 5-8.

Table 73: Elasticities for the Car Vehicle Fleet Model

Fleet Elasticity for	**Income** el_Inc	**Population Density** el_PD	**Fuel Price** el_FP
Best Guess	1.0	-0.4	-0.1
Range	0.75 to 1.25	-0.7 to -0.2	-0.2 to 0.0
Vensim-ENV			
E1 (A, D)	2.43	-0.7682	-0.4557
E2 (B, F, L, NL)	1.9481	-0.7029	-0.3797
E3 (E, GR, I, P)	0.7231	-0.5143	-0.5754
E4 (DK, FIN, IRL, S, UK)	1.8867	-0.2655	-0.8294

12.4.10 Cubic Capacity Assignment Model (CCAM)

The following five categories of cubic capacity are considered within the Cubic Capacity Assignment Model (CCAM):

- Gasoline car with less than 1400 ccm cubic capacity (=GPC1)
- Gasoline car with 1400 to 2000 ccm cubic capacity (=GPC2)
- Gasoline car with more than 2000 ccm cubic capacity (=GPC3)

[12] JOHANNSEN/SCHIPPER (1997)

- Diesel car with less than 2000 ccm cubic capacity (=DPC1)
- Diesel car with more than 2000 ccm cubic capacity (=DPC2)

The cubic capacity assignment model (CCAM) consists of two levels. On the **first level** (equations 13, 14 and 15) estimates are made for the share of diesel cars within the new purchased cars and for the share of cars with cubic capacity 1.4-2.0l and cubic capacity >2.0l. The share of diesel cars depends on price differences between diesel and gasoline cars in terms of variable costs (fuel efficiency and fuel price), in terms of vehicle tax and car purchase price. The share of cars with more than 2.0l cubic capacity depends on the income development and a soft factor called *fashion* to represent for instance the tendency to drive off-road cars (e.g. reaching in USA nearly 50% of all registered cars), which mostly belong to this cubic capacity category. However, the influence of this factor is kept small either as in Europe this fashion is not that strong and to limit the influence of this soft factor in the model. Also, it is assumed that because of increasing fuel price and the usual way of fashions this tendency will decrease after 2005 (see table 74).

Table 74: Development of soft factor fashion over time

Time	1985	1995	2005	2026
Fashion Factor	1	1.05	1.1	1

$$\mathbf{SD = f({}_G\Delta_D FP,\ {}_G\Delta_D FC,\ {}_G\Delta_D VP,\ {}_G\Delta_D VT)} \qquad \textbf{(eq. 13)}$$

where:
- SD = share diesel cars
- ${}_G\Delta_D$ = difference between gasoline and diesel cars for the variables:
- FP = fuel price
- FC = fuel consumption
- VP = vehicle price
- VT = vehicle tax

The vehicle price and vehicle tax both indicate the difference in price and taxation between gasoline and diesel cars. Values are taken from German data sources.[13] Fuel consumption is determined by the vehicle fleet model and the specific fuel consumption of cars belonging to certain emission legislation categories. The fuel prices for the calculation of fuel price differences stems from the fuel price model.

The influence of the four determinants of the diesel share on new cars in equation 13 is determined by three elasticities: one for the variable costs, one for the vehicle purchase cost and one for the vehicle tax. The values are shown in table 75. Though the elasticity for the difference in vehicle tax is quite high compared to the other elasticities, its effect is rather low in the model as the changes in difference of vehicle taxation are expected to be small, while the

[13] Verkehrsclub Deutschland (VCD) Auto-Umweltlisten (environmental ranking of cars) several volumes between 1992 and 1999. ADAC (1992).

difference in fuel taxation affecting the variable costs at least in some policies changes significantly.

Table 75: Elasticities for the share of new diesel cars model

Diesel Share Elasticity for	Δ Variable Costs el_VC	Δ Vehicle Cost el_VhcC	Δ Vehicle Tax el_VT
E1 (A, D)	0.1111	0.1518	3
E2 (B, F, L, NL)	0.2988	0.4555	1.8335
E3 (E, GR, I, P)	0.4117	0.356	1.508
E4 (DK, FIN, IRL, S, UK)	0.6954	0.5216	2.8962

Source: Own calculations with optimising tool.

CC>2.0 = f(INC, fashion) **(eq. 14)**

where: CC>2.0 = cars with more than 2000 ccm cubic capacity

INC = personal income

Fashion = Fashion to drive certain cars belonging to this category

CC1.4-2.0 = f(BS) **(eq. 15)**

where: CC1.4-2.0 = cars with 1400 to 2000 ccm cubic capacity

BS = base share of cars with 1400 to 2000 ccm in dependency of the region

On the **second level** the share of diesel cars is split into the two categories DPC1 and DPC2. The remainder of the shares for cubic capacity 1.4-2.0l and cubic capacity >2.0l cars provides the share for GPC1, which implies the assumption that no diesel cars with less than 1400 ccm are produced. The shares for GPC2 and GPC3 are calculated as the non-diesel cars within these categories.

DPC1 = SD * splitD **(eq. 16)**

where: SD = share diesel cars

splitD = share of DPC1 cars of diesel cars (according to MEET D4, national statistics)

DPC2 = SD – DPC1 **(eq. 17)**

where: SD = share diesel cars

DPC1 = share of DPC1 cars in fleet

$$GPC1 = 1 - CC{>}2.0 - CC1.4\text{-}2.0 \qquad \text{(eq. 18)}$$

where: CC>2.0 =cars with more than 2000 ccm cubic capacity

CC1.4-2.0 = cars with 1400 to 2000 ccm cubic capacity

$$GPC2 = CC1.4\text{-}2.0 - DPC1 \qquad \text{(eq. 19)}$$

where: CC1.4-2.0 = cars with 1400 to 2000 ccm cubic capacity

DPC1 = share of DPC1 (diesel cars with CC<2.0l) cars in fleet

$$GPC3 = CC{>}2.0 - DPC2 \qquad \text{(eq. 20)}$$

where: CC>2.0 =cars with more than 2000 ccm cubic capacity

DPC2 = share of DPC2 (diesel cars with CC>2.0l) cars in fleet

A different approach, which includes similar influencing factors is presented by Hayashi.[14] He develops a choice model for car purchase with four different cubic classes. The choice is calculated with an aggregate multinominal logit. The logit depends on the cost differences for purchasing, owning and using between the four classes.

12.4.11 Parameters for the other vehicle fleet models

The main parameter besides the transport demand and the vehicle scrappage that influence the purchase of new vehicles in the bus, HDV and LDV fleet is the average annual mileage. The mileage is estimated with the Vensim optimisation tool to get the best fit to real fleet data. Results are compared with MEET data for plausibility check. The applied values are shown in table 76.

Table 76: Average annual mileage for different vehicle types

Region	LDVG	LDVD	HDV	Bus
	[km/(year*vhc)]	[km/(year*vhc)]	[km/(year*vhc)]	[km/(year*vhc)]
E1: A,D	29500	27900	50500	62000
E2: B,D,L,NL	9500	10000	43500	49000
E3: E,GR,I,P	15000	14070	90000	67000
E4: DK,FIN,IRL,S,UK	26500	24425	67000	47000

Source: own calculations, MEET D15 (ANDRE et al. 1999)

14 HAYASHI (1998)

12.4.12 Rail Emissions

12.4.12.1 Approach developed by the MEET project

In the MEET project a simplified approach is developed, which includes the characteristics engine type, train weight, speed and occupancy.[15] This approach is briefly explained in the following. For passenger transport equation 21 is developed:

$$\mathbf{EQ_t} = ECM_t * \frac{TP}{OC} * spTW_t * spEF_t * 0,0036 \qquad \textbf{(eq. 21)}$$

where:
- EQ = emission quantity [g]
- ECM = energy consumption per train mass per distance [kJ/tkm]
- TP = transport performance [pass*km]
- OC = occupancy [pass/seat]
- spTW = specific train weight per seat [t/seat]
- spEF = power specific emission factor [g/kWh]
- t = types of trains and engines e.g. local diesel, local electric

A similar equation is developed for freight transport. The energy consumption per train mass (ECM) can be calculated train specifically in dependency of the average speed and the distance between the train stops with equation 22.

$$\mathbf{ECM_t} = \alpha_t * \frac{(V)^2}{\ln(DIST)} + \beta_t \qquad \textbf{(eq. 22)}$$

where:
- ECM = energy consumption per train mass per distance [kJ/tkm]
- V = average train speed [km/h]
- DIST = distance between the stops [km]
- α_t, β_t = train specific coefficients

If one looks at equations 21 and 22 it is obvious that four train specific values (spTW, spEF, α, β) are needed for the application of this model. But the MEET project offers only a few data sets especially for the European high speed trains (TGV, ICE, AVE, HST) and for some Danish trains. That means, data for other European train types are not available and have to be estimated, which does not seem to be possible yet. Therefore the model can not be applied in ASTRA though it would fit to the needs of some policies e.g. it would react on changes in train speeds or train weight.

12.4.12.2 Rail Emission Factors

Instead of using the MEET equations in ASTRA a calculation based on the train-kms and the emission factors, which are differentiated for the different distance bands is developed. It is explained in section 6.4.3.2 of ASTRA D4. In the following the applied emission factors for rail are listed. First as assignment of train categories to the different distance bands has to be developed:

[15] JORGENSON/SORENSON (1997)

- Local: No train transport available
- Very Short: Light rails and local trains
- Short: Local and regional trains
- Medium: Interregional and intercity trains
- Long: Intercity and international trains

The emission factors corresponding to this assignment are derived from several projects (e.g. MEET, PROGNOS, ECMT[16]). Based on the global information on travelled distance and energy consumption given in ECMT a first approximation for EU15 and for the 4 Macro Regions in the year 1990 is calculated and shown in table 77. The values present plausible order of magnitudes for rail emission factors.

Table 77: Estimated global emission factors for railway transport (1995)

Macro Region	Traction	g CO_2/ km	g NO_x/km	g PM/km
MR1: A,D	Electric	9466	14,84	2,65
MR2: B,NL,L,F	Electric	2550	6,21	0,62
MR3: E,GR,I,P	Electric	8203	7,76	2,53
MR4: DK,FIN,IRL,S,UK	Electric	8212	28,67	3,06
EU15:	Electric	6887	17,42	2,09
EU15:	Diesel	7938	1000g Diesel	3078g CO_2

Source: Own calculations based on ECMT (1998)

The aforementioned assignment of certain train categories to the ASTRA distance bands leads to the following emission factors for diesel passenger trains, which are estimated on the basis of the MEET data.

[16] JORGENSON/SORENSON (1997), PROGNOS (1995), ECMT (1998)

Table 78: Emissions factors for diesel passenger trains and share of diesel traction (1995)

	Diesel Traction [g/train-km]			Share Diesel
	CO_2	NO_x	PM	[%]
Very Short:	6700	120	10	40
Short:	6500	160	9	40
Medium:	6000	160	7	24
Long:	7000	140	5,5	16

Source: Own calculations and MEET D17

Table 79: Emission factors of electric passenger trains[17]

	Electric Traction Energy Consumption	Resulting Emission Factors [g/train-km]		
	[kWh/km]	CO_2	NO_x	PM
Very Short:	5,4	*3780*	*8,1*	*0,76*
Short:	10	*7000*	*15*	*1,4*
Medium:	14	*9800*	*21*	*1,96*
Long:	19	*13300*	*28,5*	*2,66*
Power Plant	[g/kWh]:	700	1,5	0,14

Source: Own calculations and Lewis (1997)

The calculation of emissions for diesel freight trains is based on the following equation considering the average train weight, the specific energy consumption per tkm and the emission factor per consumed unit of energy.

$$EQ_{FT} = spEC / 3600 * EC\_EFAC * avTW * TV \qquad \text{(eq. 23)}$$

where: EQ = emission quantity [t]
spEC = specific freight train energy consumption [kJ/tkm]
EC_EFAC = energy consumption related emission factor [g/kWh]
avTW = average weight of freight train [t]
TV = traffic volume [Mio*train*km]

Base values for the emission factor per consumed unit of energy are for NO_x 10.7 g/kWh and for CO_2 640 g/kWh. The specific energy consumption and the emission factor per unit of

[17] JORGENSON/SORENSON (1997), LEWIS (1997)

energy decrease over time. The average freight train weight with 341t corresponds to the data in the TRA.

For electric freight trains the specific electric energy consumption (with a base value of 65 kJ/tkm) and emission factors of powerplants are used. The latter the base values for 1994 are shown in table 80. Both variables decrease over time.

Table 80: Applied emission factors of powerplants

Macro Region	g CO_2/ kWh	g NO_x/kWh
E1: A,D	593.85	0.93
E2: B,NL,L,F	187.6	0.46
E3: E,GR,I,P	551.04	1.84
E4: DK,FIN,IRL,S,UK	437.02	1.49

Source: MEET D18

12.4.13 Base Data for Calculation of Ship Emissions

In section 6.4.3.2 of ASTRA D4 the calculation of ship emissions based on three ship categories corresponding to the ASTRA goods categories is explained. To calculate the specific emission factors of the relevant ship categories the following input data is used (see table 81) and results are obtained (see table 82).

Table 81: Input data for estimation of ship emission factors

Ship Fleet	Number of Ships	Share for ASTRA Goods	Diesel Consumption	Average Speed	Daily Distance	Spec. Diesel Cons.
Unit			[t/day]	[naut. Miles/h]	[km]	[t Diesel/km]
(Liquid) Bulk	2542	1.000	41.15	14.2	631.1616	0.0652
Solid Bulk	2206	1.000	33.80	14.32	636.49536	0.0531
General Cargo	3450	0.801	21.27	14.29	635.16192	0.0335
Container	858	0.199	65.88	19.09	848.51232	0.0776

Source: MEET D19

Table 82: ASTRA Ship Emission Factors

ASTRA Goods Categories	Correction Maneuvering	**EFAC NO_x**	**EFAC CO_2**	**EFAC PM**	**Diesel Cons.Fac**
Unit		[kg NO_x/km]	[kg CO_2/km]	[kg PM/km]	[t Diesel/km]
Bulk BK	1.05	5.956	219.063	0.082	0.068
Semi-bulk SBK	1.10	3.330	186.924	0.070	0.058
Unitised DU	1.15	3.305	155.596	0.058	0.049

Source: Own calculations based on MEET D19

12.4.14 Emission Factors for Air Emissions

The approach for the calculation of air emissions is explained in section 6.4.3.2 of ASTRA D4. To complete the list of EFAC data in the annex the emission are also listed in table 83.

Table 83: Fuel consumption and emission factors for air transport

Trip Purpose	Flight Stage	Unit	Fuel Consumption	CO_2	NO_x
Business	LTO-Cycle	kg/LTO	900	3000	8
	Cruising	kg/plane-km	2,2	7	0,041
Tourism	LTO-Cycle	kg/LTO	1400	4400	22
	Cruising	kg/plane-km	7,8	24	0,33

12.4.15 Data from the Accident Model

Blood alcohol limit and speed limit based on macro regions are an input data for the accident model, which could be varied in policies. The base data is shown in table 84.

Table 84: Blood alcohol limit and speed limit based on macro regions

	Blood alcohol limit		**Speed limit**	
Macro Region	averaged	vhc-km weighted	urban	non-urban
	mg/l	mg/l	km/h	km/h
E1: A,D	0.5	0.50	50.00	117.36
E2: B,NL,L,F	0.575	0.50	50.00	99.83
E3: E,GR,I,P	0.65	0.76	50.00	102.30
E4: DK,FIN,IRL,S,UK	0.56	0.69	48.52	98.82

Source: Own calculation based on EUROSTAT (1999)

Base data of the passenger car accident rates (parameter AR in equation 26 in ASTRA D4) are given in the following table.

Table 85: Base accident rates for fatalities caused by passenger cars (only occupants) and using slow modes

[cases / (Bio*vhc*km)] [cases / (Bio*km)]	Fatalities cars		Fatalities slow mode	
Macro Region	urban	non-urban	urban	non-urban
E1: A,D	32	30.5	90	-
E2: B,NL,L,F	34	29	85	-
E3: E,GR,I,P	36.5	52	117	-
E4: DK,FIN,IRL,S,UK	19.5	11	75	-

Source: Own calculations, IRTAD (1999), BMV.

For all other modes the base accident rates could not be split into the macro regions such that average values from various sources have to be taken.

Table 86: Base accident rates of passenger cars and slow mode

[cases / (Bio*vhc*km)]	Serious injuries		Light injuries		Material damages	
	urban	non-urban	urban	non-urban	urban	non-urban
Base accident rate car	540	160	1150	640	1390	350
Base accident rate slow mode	780	-	780	-	-	-

Source: Own calculations, IRTAD (1999), BMV.

Table 87: Base accident rates for other transport means

Transport mean	Unit	Fatality	Serious injury	Light injury	Material damage
Bus	Cases/(Mio*vhc*km)	0.05	0.1	1.5	1.9
LDV	Cases/(Bio*vhc*km)	8	94	436	436
HDV	Cases/(Bio*vhc*km)	13	91	389	389
Air	Cases/(Mio*vhc*km)	0.00015	0.00015	0.0004	8e-005
Passenger Rail	Cases/(Mio*vhc*km)	0.0017	0.17	0.262	0.262
Freight Rail	Cases/(Mio*vhc*km)	0.01	0.083	0.084	0.168
Ship	Cases/(Mio*vhc*km)	0	0	0	0.01

Source: Own estimations based on FISCUS (1998), IRTAD (1999), IWW/infras (2000), PETS D7

All base accident rates are altered by a mode specific development over time. For ship mode only material damages are very roughly estimated (e.g. oil tanker accidents).

Road quality can also have an impact on the accident rates in case that roads are deteriorated over time because of an insufficient investment in road maintenance. This is considered in the model in dependency of the road lengths of the different road types, the necessary investment per length unit of road and the actual investment. The values for the maintenance costs per length unit of road are taken from a German study (Maerschalk). The actual maintenance investments are calculated as a share of total road investments. Comparing the necessary investments for a stable road quality with the actual investments it seems that in Europe maintenance is neglected because of high new construction efforts as the necessary investments are not reached in any of the regions. However, it should be mentioned that the model represents a quite aggregated consideration.

Table 88: Necessary maintenance investments to preserve a constant road quality per road km

Road Type	**Necessary Maintenance Investments [EURO/(km*year}]**
Motorways	45.000
Dual Carriage Way	24.540
Single Carriage Way	9.000
Local Roads	6.750

Source: own calculations based on Maerschalk (FGSV study)

Table 89: Share on total road investments used for maintenance investments of roads

Region	**Share on Investments used for Maintenance [%]**
E1: A,D	12
E2: B,D,L,NL	15
E3: E,GR,I,P	26
E4: DK,FIN,IRL,S,UK	40

Source: IRF (1999)

12.4.16 From TRA to ENV

As the major final output of the TRA are transport performances (pkm, tkm) per transport mean while the ENV models are consequently based on vehicle-km the interface between TRA and ENV has to perform the translation of the unit of measurement. The main variables that are needed for the transfer are the occupancy rates for passenger transport respectively the load factors for freight transport. For car, bus and road freight the variables are given in the previous section 12.3. The remaining variables are presented in the following table.

Table 90: Occupancy rates and load factors for air, train and ship transport

Transport mean	Occupancy rate	Load factor
Passenger train	90 pers/train	
Air business trips	100 pers/plane	
Air tourism trips	150 pers/plane	
Ship bulk and semi-bulk goods		31500 t/ship
Ship unitised goods		28250 t/ship
Freight Train		341 t/train

The multi-nominal logit models in the TRA require for the modal-split calculation the consideration of trips with the same trip distance. However, this homogenous trip distance can not be used for all modes respectively all OD-relations for the calculation of vehicle-kms from the modal split based on trips. So, in case that the real distance is much different from the homogenous distance individual distances have to be applied. The following tables present the applied values for different modes, which are obtained from the STREAMS model.

Table 91: OD travelling distances for long distance tourism bus trips

OD-relations [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
TOURISM						
LSA	497.96	186.39	276.02	258.23	342.1	205.52
MPH	193.71	216.78	359.23	235.84	221.91	374.64
HDU	438.32	427.68	201.29	299.13	295.57	455.98
HDD	307.5	323.14	291.64	246.68	266.03	529.24
MDR	342.45	221.46	281.62	315.42	236.1	290.72
LDR	227.88	450.02	343.81	500.97	274.05	265.45

Table 92: OD travelling distances for long distance business and tourism train trips

OD-relations [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
BUSINESS						
LSA	461.13	486.37	325.54	301.36	274.2	273.49
MPH	511.76	313.22	397.32	347.7	258.61	268.63
HDU	283.87	365.2	240.94	254.82	278.32	225.64
HDD	281.53	315.65	266.59	251.56	336.29	521.65
MDR	305.63	270.62	331.22	355.77	303.26	234.9
LDR	344.92	261.71	225.76	643.79	226.3	213.53
TOURISM						
LSA	571.17	554.1	296.49	334.73	260.16	226.24
MPH	550.89	271.95	392.76	394.43	236.31	222.19
HDU	374.51	493.3	209.48	349.07	414.17	541.45
HDD	307.42	683.44	340.53	270.78	386.68	765.95
MDR	304.33	289.65	382.25	375.15	313.31	332.72
LDR	257.17	287	379.29	559.2	321.58	245.26

Table 93: OD travelling distances for business and tourism air trips

OD-relations [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
BUSINESS						
LSA	601.27	559.5	472.65	586.14	562.2	806.31
MPH	550.99	581.5	393.9	520.21	524.97	504.96
HDU	468.96	402.54	458.48	535.78	655.72	488.17
HDD	650.27	327.79	464.5	608.65	668.35	887.04
MDR	596.01	541.71	629.64	667.04	633.77	590.88
LDR	350.31	480.2	581.02	1025.4	611.37	510.94
TOURISM						
LSA	1461.41	738.57	1210.4	1149	1309.22	1645.79
MPH	817.98	1035.66	831.72	786.52	1339.2	1806.52
HDU	1424.84	1291.29	1271.8	1466.83	1834.03	2058.06
HDD	1182.87	909.44	897.57	1472.49	1643.8	1924.11
MDR	889.97	733.93	1060.28	1348.64	1526.14	1830.73
LDR	1399.46	1901.89	1699.94	1803.12	2135.52	2493.87

Table 94: OD travelling distances for long and medium distance car trips (all purposes)

OD-relations [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
Long						
LSA	526.33	264.48	322.25	304.79	370.9	222.33
MPH	266.51	270.64	378.92	309.54	272.8	403.69
HDU	347.01	469.48	267.2	304.73	405.55	427.72
HDD	315.88	422.52	294.22	285.88	357.52	656.51
MDR	372.14	316.66	324.85	347.55	291.51	287.16
LDR	254.8	419.57	349.7	475.7	276.82	279.76
Medium						
LSA	58.52	146.9	1000	75.05	95.62	131.99
MPH	146.9	60.2	93.01	96.87	151.94	141.44
HDU	159.3	82.12	71.72	75.91	110.27	69.89
HDD	77.66	105.97	82.14	73.58	110.16	1000
MDR	90.91	149.7	115.39	105.62	64.66	134.71
LDR	130.17	149.78	69.89	1000	134.47	66.68

Table 95: OD travelling distances for medium distance business, private and tourism train trips

OD-relations [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
BUSINESS						
LSA	59.35	147.38	143.9	63.5	96.39	92.84
MPH	147.26	66.18511	123.3	80.31	0	120.6
HDU	143.9	123.3	71.31861	91.89	116.66	69.42
HDD	64.86	88.76	80.29	85.23	115.98	0
MDR	99.47	0	117.98	115.31	120.59	133.7
LDR	92.84	120.6	74.67	0	133.7	122.6
PRIVATE						
LSA	54.55	147.29	0	47.75	62.04	92.84
MPH	147.37	54.56	0	62.58	0	120.6
HDU	0	0	46.94241	49.71	104.01	69.25
HDD	47.51	62.62	48.64	46.34	116.06	0
MDR	61.88	0	120.14	115.54	91.7	133.7
LDR	92.84	120.6	69.25	0	133.7	122.6
TOURISM						
LSA	54.96	147.75	143.9	62.05	105.63	85.42
MPH	147.42	57.63514	122.8	65.48	0	120.6
HDU	143.9	123.27	68.63334	68.09	112.83	69.3
HDD	69.3	71.96	77.05	83.49	103.38	0
MDR	95.07	0	108.96	83.69	104.25	133.7
LDR	88.32	120.6	74.82	0	133.7	122.6

Table 96: OD travelling distances for medium distance bus trips (all purposes)

OD-relations [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
All purposes						
LSA	54.56	1000	1000	66.66	100.23	123.76
MPH	146.9	54.63	60.54	87.2	153.46	141.27
HDU	1000	57.43	75.7	67.65	105.3	69.89
HDD	71.64	100.97	76.51	68.91	128.91	1000
MDR	95.76	152.16	114.65	102.98	60.22	129.57
LDR	125.44	149.05	69.89	1000	140.22	61.83

Table 97: Travelling distances for short distance business and private train trips

Zones [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
BUSINESS						
	18.81	18.67	19.11	36.72	29.88	0
PRIVATE						
	20.21	19.91	20.48	0	0	0

Table 98: Travelling distances for very short distance train trips (all purposes)

Zones [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
All purposes	4.7	4.7	4.7	0	0	0

Table 99: Travelling distances for local, very short and short distance bus trips (all purposes)

Zones [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
Local						
	1.35	1.38	1.39	1.42	1.43	1.44
Very short						
	4.74	4.74	4.74	4.74	4.74	4.74
Short						
	12.1	11.69	12.28	14.43	15.38	15.79

Table 100: Travelling distances for local, very short and short distance car trips (all purposes)

Zones [km/trip]	LSA	MPH	HDU	HDD	MDR	LDR
Local						
	1.27	1.34	1.35	1.36	1.38	1.38
Very short						
	4.74	4.74	4.74	4.74	4.74	4.74
Short						
	14.82	14.2	15.33	15.94	17.01	17.35

Table 101: OD average haulage distances for long freight distance band (all transport modes)

OD relations [km/(t*haul)]	E1	E2	E3	E4
Bulk goods				
E1	1140.28	1176.19	3267.45	1291.31
E2	992.79	1433.3	1663.06	1410.77
E3	2699.8	1780.84	1464.75	2431.82
E4	1710.3	2251.06	4091.04	1426.43
Semi-bulk goods				
E1	1276.28	1258.16	2816.25	1824.25
E2	1114.6	1065.08	1749.95	1558.82
E3	3012.99	1358.65	1313.32	3758.62
E4	1613.28	1305.36	3851.31	1778.48
Unitised goods				
E1	893.87	1148.54	2712.57	1781.26
E2	1082.45	966.89	1894.32	1539.09
E3	2484.81	1343.07	1172.85	3840.48
E4	1842.23	1852.99	4114.07	1355.41

Table 102: OD average haulage distances for medium-long distance band (all transport modes)

OD relations [km/(t*haul)]	E1	E2	E3	E4
Bulk goods				
E1	**326.19**	**431.25**	**483.07**	**473.45**
E2	**431.08**	**303.22**	**473.92**	**443.92**
E3	**486.63**	**497.38**	**360.07**	**431**
E4	**492.29**	**416.52**	**800**	**300.19**
Semi-bulk goods				
E1	**331.89**	**354.98**	**496.7**	**516.21**
E2	**371.5**	**273.44**	**479.54**	**441.83**
E3	**506**	**493.23**	**330.2**	**800**
E4	**406.22**	**563.45**	**800**	**253.02**
Unitised goods				
E1	**348.51**	**389.9**	**540.86**	**540.02**
E2	**380.98**	**332.2**	**510.07**	**478.91**
E3	**545.46**	**515.41**	**357.6**	**700**
E4	**499.35**	**490.38**	**700**	**303.79**

Table 103: Regional haulage distances for medium short distances (all transport modes)

Regions [km/(t*haul)]	E1	E2	E3	E4
Bulk goods				
	94.05	95.05	124.96	102.41
Semi-bulk goods				
	95.27	95.55	123.27	90.76
Unitised goods				
	100.2	100.12	125.23	97.05

As especially the occupancy rates and the load factors seem to be rather rough adjustments are made to reach a sufficient fit for the resulting vehicle-kms to real data in the calibration period 1985 to 1995.

12.4.17 Defensive and Externality Cost Values

The cost values are mostly taken as constant respectively as developing similar to the development of GDP. It should be paid attention to the fact that over the long run these values might change, because of other reasons. This could either be changes in the environmental situation or non-linearities of the damages.

Table 104: Cost values for defensive costs and externalities

Environmental Impact	Cost Value	unit of measurement	Source
CO_2 emissions	205	EURO / ton	IWW et al. (1998)
NO_x emissions: before 2010: after 2010:	 163 207	EURO / ton	IWW et al. (1998)
Fatality	1,4	Mio EURO per case	Swedish National Road Association
Serious Injury	30670	EURO per case	BMV (1993)
Light Injury	2650	EURO per case	BMV (1993)
Material Damage	5000	EURO per case	BMV (1993)

12.4.18 Data Sources Used for Calibration of ENV

The following sources were considered for calibration:

[1] ECMT/OECD (1998): “Statistical Trends in Transport 1965 – 1994”, Paris.

[2] ECMT/OECD (1995): “Statistical Trends in Transport 1965 – 1990”, Paris.

[3] IRF (1986): “World Road Statistics 1985/86”, Geneva.

[4] IRF (1999): “World Road Statistics 1999”, Geneva.

[5] EUROSTAT (1993): “Transport Annual Statistics 1970 – 1990”, Brussels.

[6] OECD (1997): “OECD Environmental Data Compendium 1997”, Paris.

[7] CORINAIR (1990): Web-Database at http://www.aeat.co.uk/netcen/corinair/94/

[8] CORINAIR (1994): Web-Database at http://www.aeat.co.uk/netcen/corinair/94/

[9] IRTAD (1998): International Road Traffic Accidents Database of the OECD, Bergisch-Gladbach.

[10] VDA (several years): “Tatsachen und Zahlen aus der Kraftverkehrswirtschaft”, Frankfurt/Main.

[11] KBA (several years): “Statistische Mitteilungen des Kraftfahrtbundesamtes”, Flensburg.

[12] MEET D4 (1997): “Road Traffic Characteristics for Estimating Pollutant Emissions”, Berkshire.

With the listed data sources it is possible to calibrate or at least to get an idea for the right order of magnitude of the following variables of the ENV:

- LDV and HDV Fleet (1,2,3,4,6,10,12)
- PC Fleet (10, 12, 1)
- Bus Fleet (1,2,10)
- Road Fuel Consumption (1,2,4,5)
- Car, Bus, LDV&HDV Traffic Volume (1,4,6)
- Hot NO_x-emissions of Road Transport and Total Transport (6,7,8)
- Hot NO_x-emissions of Car, LDV, HDV, Railway Transport for 1994 (8)
- Hot CO_2-emissions of Road Transport and Total Transport for 1980, 1990, 1994, 1995 (6,7,8).
- Fatalities and Injuries of Road Accidents and Slow Mode Accidents (9)

12.5 File Structure of the Vensim ASP

The Vensim ASP consists of six files, which have slightly different formats if they are used for IBM-PC or MacIntosh-PC. Additionally, seven datasets, each representing the model results of one model run for the base scenario or one of the policy packages, are calculated and stored in separate files. The files for the complete datasets representing yearly values for all variables are quite big with 10.8 MB each. The files are named as follows:

- ASTRA_Final.vmf (or .mdl): Vensim model file that contains all equations and the graphical representation of the model structure in the sketch level.
- Exogenous_Var.vdf: Vensim dataset that is imported from Exogenous_Var.xls. It contains the values of all exogenous data variables like gasoline fuel prices.

- Histories.vdf: Vensim dataset that is imported from Histories.xls. It contains all historical values that are needed mainly for the representation of the initial vehicle fleets.
- CheckVars.vdf: Vensim dataset that is imported from CheckVars.xls. It contains all data that can be used for calibration purposes e.g. vehicle fleet stock.
- P0921_data1.vdf: Vensim dataset that is imported from P0921_data1.xls. It contains all exogenous data taken from the ithink core ASP. The data mainly stems from the arrayed graph variables of the REM sub-module (e.g. exogenous and calibration data).
- P0921_data2.vdf: Vensim dataset that is imported from P0921_data2.xls. It contains all exogenous data taken from the ithink core ASP. The data mainly stems from the arrayed graph variables of the REM sub-module (e.g. exogenous and calibration data).
- The datasets storing the results are named: Base Scenario.vdf, Emission and Safety.vdf, Increased Tax.vdf, Balanced Tax.vdf, Tax for TEN.vdf, Integrated Policy.vdf.

As REM and TRA have been mainly developed within the core ithink ASTRA model a transfer from ithink to Vensim has to be performed. For this purpose the equations of the core ithink model are translated into the equations syntax of Vensim. The translation is undertaken semi-automatically, which means the main part is translated automatically but certain structures (e.g. conveyors, graph variables that consist of arrays with differentiated definition for each array-element) and a few translation errors have to be implemented in Vensim manually. A big part of work, is the display of the Vensim sketch, as the translator can only translate the equations but can not build the modeller and expert user interface (called “sketch” in Vensim).

Furthermore an ENV stand-alone version as well as an ENV plus TRA stand-alone version is developed in Vensim during the modelling and translation process. They are used for testing and calibration. For their use at least four files are required:

- ENV_Alone_V6.mdl respectively ENV_TRA_Alone_V10.mdl: Vensim model-files of the stand-alone models.
- Exogenous_Var.vdf: Vensim dataset that is imported from Exogenous_Var.xls. It contains the values of all exogenous data variables like gasoline fuel prices.
- Histories.vdf: Vensim dataset that is imported from Histories.xls. It contains all historical values that are needed mainly for the representation of the initial vehicle fleets.
- CheckVars.vdf: Vensim dataset that is imported from CheckVars.xls. It contains all data that can be used for calibration purposes e.g. vehicle fleet stock.

13 Annex B: Details of Reference Scenario and Policies

The basics of the ASTRA reference scenario are described in section 7.3.1 of ASTRA D4. In the following sections further details for the ASTRA reference scenario are described. They are structured into four sections each belonging to one sub-module. Subsequently details of the policy packages are described. Two types of trends or future developments (both summarised as trends in the following) can be distinguished. The first are exogenous trends that are input or reference to the model . The second are endogenous trends that evolve because of the exogenous trends and the structural behaviour of the model.

13.1 Trends in the MAC

The following table 105 and table 106 provide data from the SCENARIOS reference scenario[18] that are considered for the ASTRA reference scenario.

Table 105: Percentage annual growth rates of GDP in EU15

Country	1994-2000	2000-2005	2005-2020	2020-2040
Austria	2.39	2.33	2.67	1.97
Belgium	2.27	2.32	2.74	2.03
Denmark	2.46	2.36	2.91	2.29
Finland	2.99	2.45	2.97	2.37
France	2.40	2.33	2.75	2.15
Germany	2.81	2.44	1.95	1.13
Ireland	3.66	2.55	3.48	3.53
Italy	2.33	2.30	2.51	1.64
Luxembourg	2.82	2.90	3.18	2.59
Norway	2.87	2.56	2.91	2.34
Spain	2.74	2.80	2.98	2.70
Sweden	2.19	2.11	2.51	1.80
Switzerland	1.90	2.05	2.44	1.65
The Netherlands	2.34	2.36	2.67	1.98
UK	2.56	2.36	2.74	2.05
Greece	2.04	2.41	2.77	1.92
Portugal	2.92	2.99	4.00	2.99
Total	2.54	2.39	2.55	1.89

Note: Given according to the constant hypothesis - 1992 prices. SCENARIOS (1998)

[18] SCENARIOS (1998)

Table 106: Export / Import values in 1994, 2020 and 2040

[Billion US$]	Export			Import		
1990 prices	1994	2020	2040	1994	2020	2040
Austria	72,333	193,52	305,424	72,333	200,08	310,272
Belgium	165,825	433,44	664,355	158,589	417,96	652,801
Denmark	53,62	142,8	233,306	42,84	123,2	215,698
Finland	42,036	126,91	215,488	33,604	106,19	194,768
France	316,455	869,04	1440,543	292,876	820,76	1403,606
Germany	677,1	1661,58	2164,149	538,02	1433,52	2000,817
Greece	20,23	61,64	101,816	28,07	80,4	121,396
Ireland	39,852	135,89	281,829	30,564	113,03	246,283
Italy	293,447	887,88	1288,76	248,127	782,18	1230,18
Luxembourg	10,153	27,6	47,151	9,878	26,88	46,345
Netherlands	176,67	440,04	668,07	158,55	422,67	650,94
Portugal	23,598	90,63	181,897	32,292	114,57	209,644
Spain	123,662	439,52	804,408	123,151	418,08	767,844
Sweden	84,071	224,95	332,994	71,806	192,23	297,942
United Kingdom	272,766	815,08	1313,532	292,032	854,84	1343,385

Source: SCENARIOS (1998)

The following two figures present the development of fuel prices including pure fuel price, fuel tax and VAT on fuel for the base scenario.

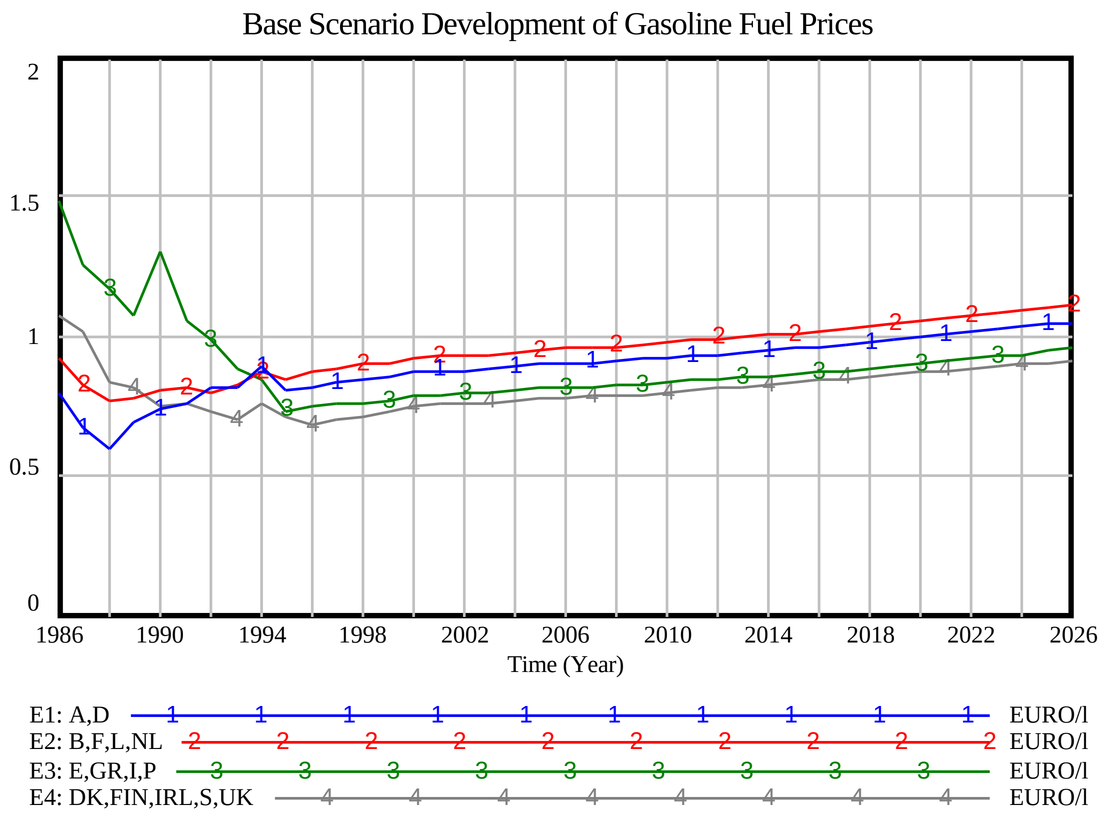

Figure 12: Development of gasoline fuel prices in the base scenario for the 4 regions

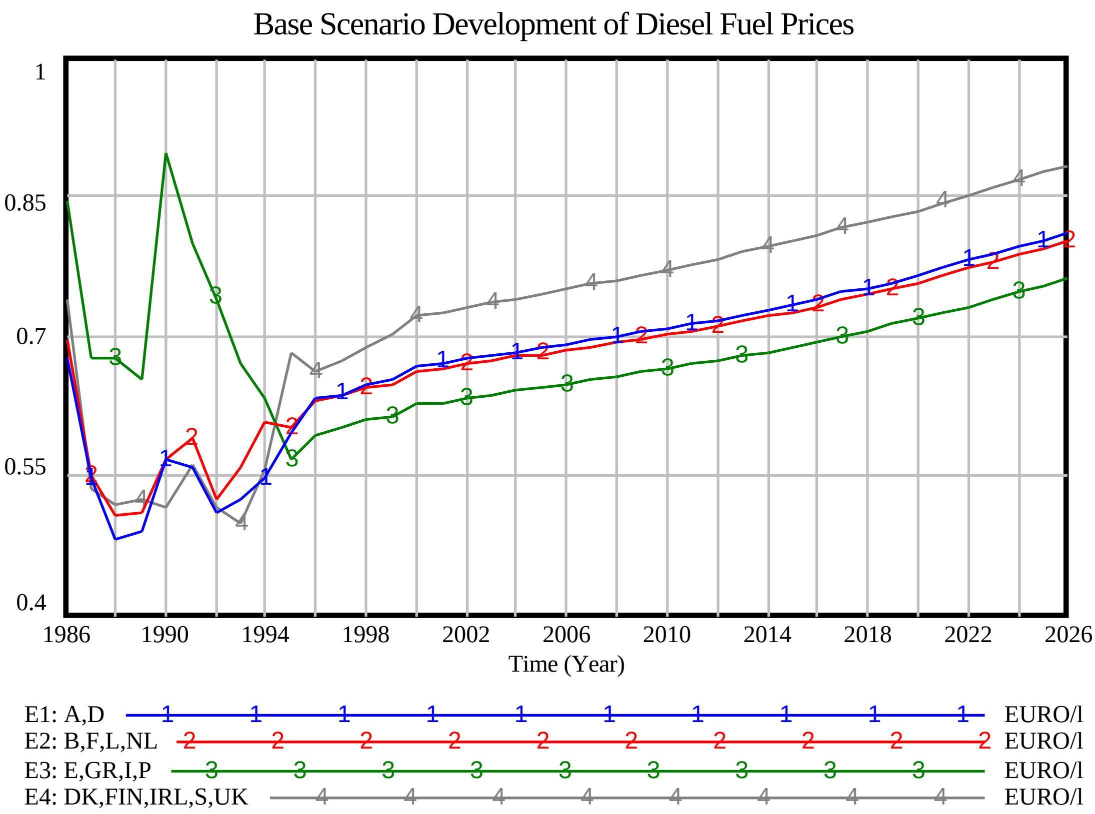

Figure 13: Development of diesel fuel prices in the base scenario for the 4 regions

It can be seen that until 1996 the historic data with all its fluctuations caused by one of the parts of the price e.g. the crude oil price is taken, while afterwards the assumed growth rates determine the development of the prices. Sudden shocks e.g. because of strong crude oil price increases have not been assumed, though they surely will occur as we have seen during the year 2000. This could be a matter of further policy testing. It should be reminded that the values are given in real 1995 prices.

The development of vehicle prices used for the calculation of investments is assumed to be stable for duty vehicles and buses, while for cars because of the value added strategy of the car manufacturers and the introduction of new technologies it is assumed that car prices increase by 20% from 1995 to 2030.

A major influence on employment is the labour productivity or in inverse terms the employment per gross value added (GVA). This is included in the model on a sectoral level and differentiated for the four regions. The baseline data is given by the EUROSTAT R25 I-O-Tables and the development is derived from the ESCOT data. The general tendency is a decrease of employees per GVA. The development of sectoral employment per gross value added for the four regions is shown in the following four figures.

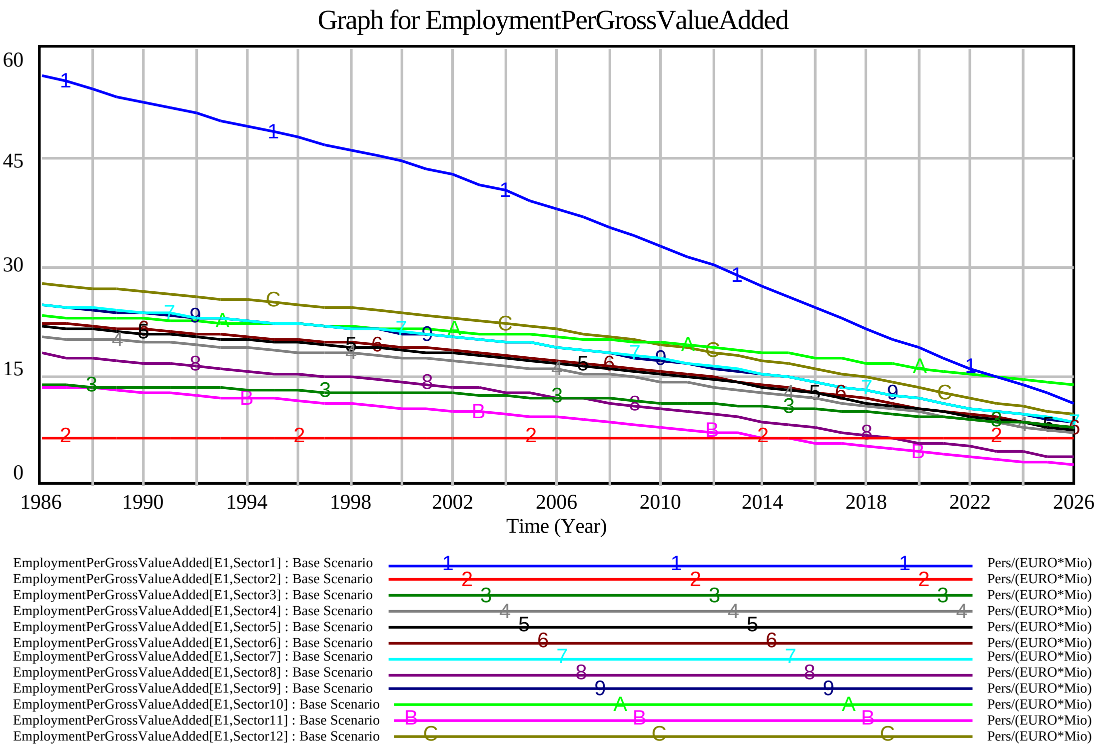

Figure 14: Emyployment per gross value added in region 1 (A, D)

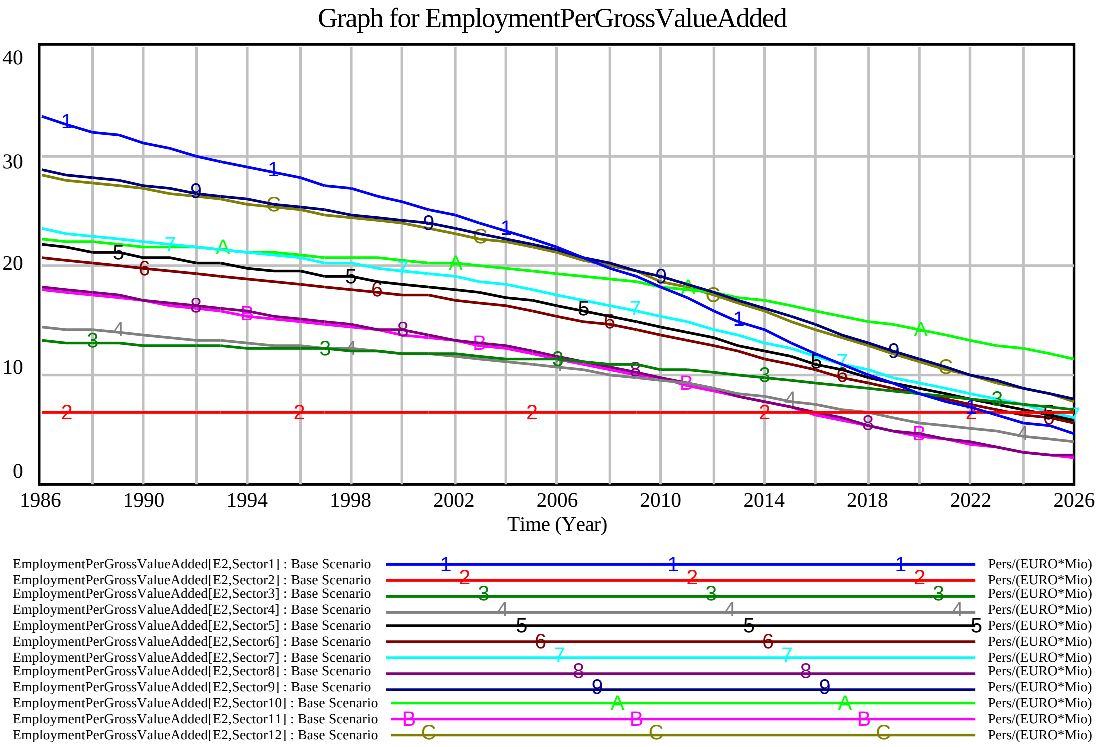

Figure 15: Emyployment per gross value added in region 2 (B, F, L, NL)

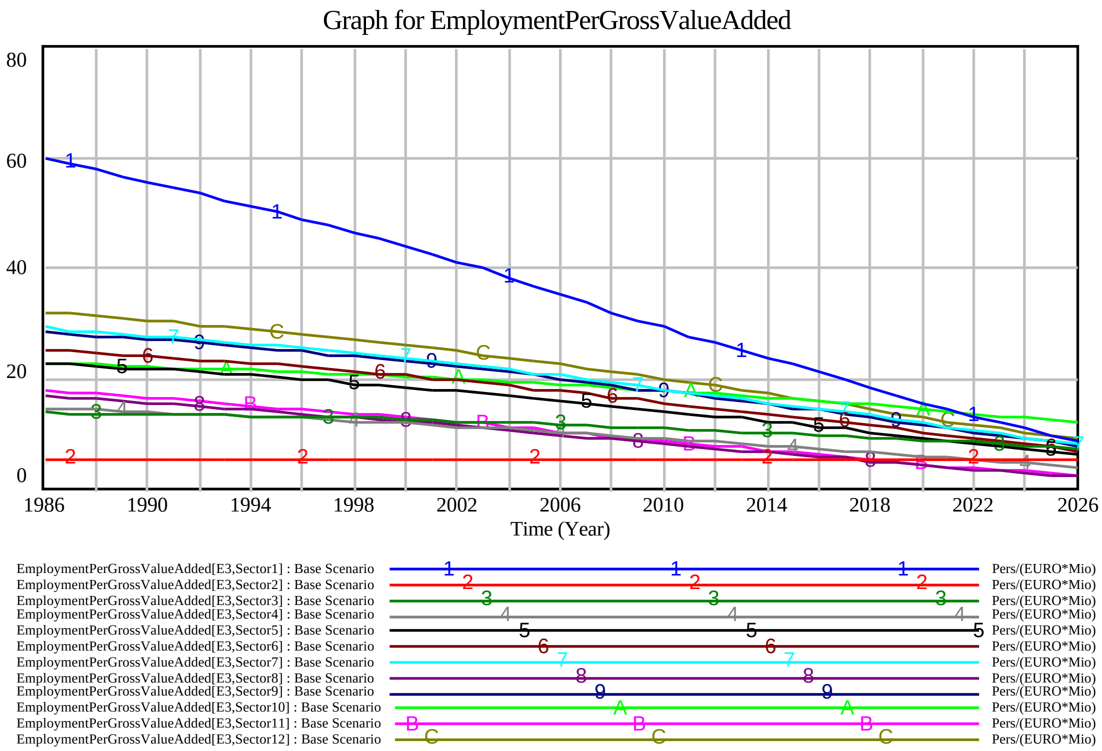

Figure 16: Emyployment per gross value added in region 3 (E, GR, I, P)

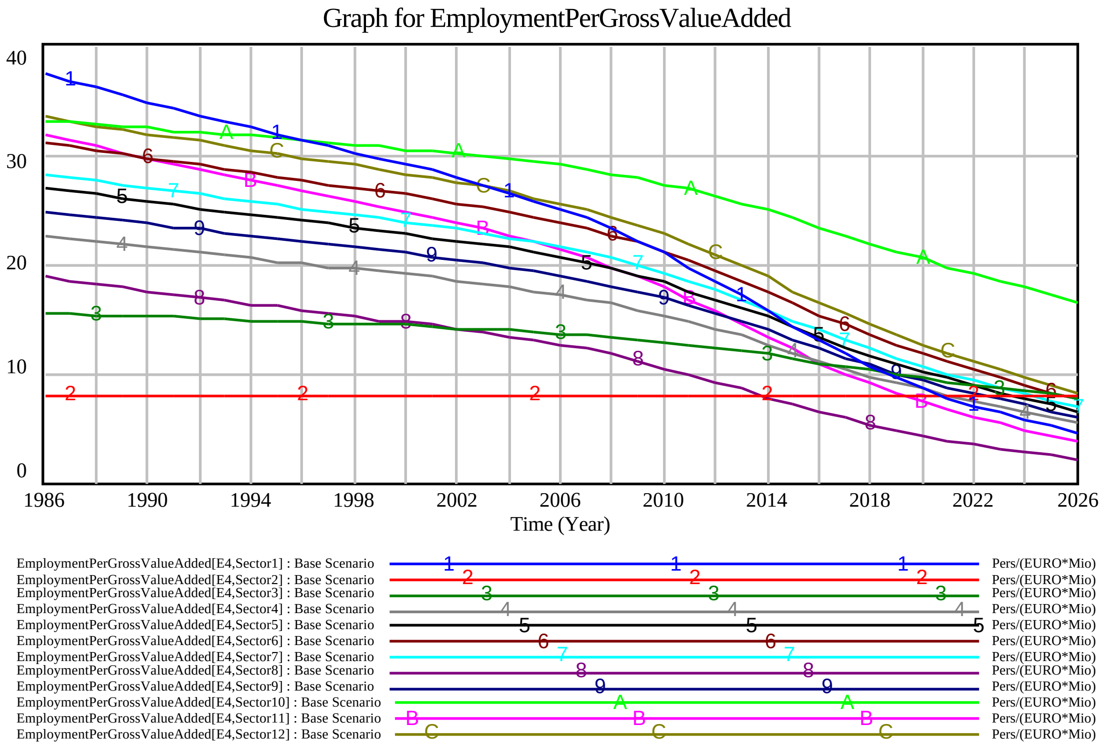

Figure 17:Emyployment per gross value added in region 4 (DK, FIN, IRL, S, UK)

For the calculation of disposable income besides the endogenously modelled indirect taxes also direct taxation and social protection payments have to be considered. They are considered in the model as percentage of GDP. For both the development of this share until 1995 is taken from statistics. After 1995 a more or less stable development is assumed with a slight tendency to decrease as future taxation might be more focussed on the consumption of natural resources e.g. for energy production.

Table 107: Percentage of direct taxes on GDP

[%]	1986	1990	1995	2030
E1: A,D	12.37	12.64	11.41	11.3
E2: B,F,L,NL	11.19	11.00	11.29	11.2
E3: E,GR,I,P	10.75	12.87	13.02	12.9
E4: DK,FIN,IRL,S,UK	16.62	18.09	16.77	16.6

Source: Statistisches Bundesamt (1997b), own hypothesis.

Table 108: Percentage of social protection payments on GDP

[%]	1986	1990	1995	2030
E1: A,D	40.24	38.89	41.86	40
E2: B,F,L,NL	43.58	43.06	43.75	40
E3: E,GR,I,P	32.78	36.16	37.63	40
E4: DK,FIN,IRL,S,UK	40.28	39.80	38.55	40

Source: Statistisches Bundesamt (1997b), own hypothesis.

13.2 Trends in the REM

This section describes the baseline assumptions made in the REM sub-module about the key variables over the forecasting horizon of the ASTRA model i.e. 1996-2026. These trends can be grouped into the following categories;

- Demographic (population size and profile, labour force, activity rates)
- Car ownership
- Industrial production (value of production)
- Passenger transport (trip rates)
- Freight transport (value to volume ratios)

The trends described in the following sections are based on several reports from other EU research projects and from EUROSTAT. Table 109 summarises the aspects of the REM trends, which are detailed in the sections below. It is important to note at this stage the difference between the assumptions that are determined exogenously that are *input* to the model and others that *evolve* as a direct result of the behavioural structure of the model and of the set of exogenous inputs.

Table 109: Summary of trends in REM sub-module for Trend scenario (1996-2026)

Model	Future trend	Exogenous inputs	Reference Development Endogenous effects
Passenger model			
Demographic	Change in structure and size of population over time	· Birth rates · Life expectancy · Death rates	· Population growth rate slows and population start to decline · Working age population begins to fall · Fewer younger people · Life expectancy will continue to increase; gender gap may diminish somewhat · Deaths will start to outnumber births · Ageing will accelerate in future · Both the working age and the elderly population will become older · Age dependency will rise drastically
	Labour force change over time	· Activity rates	· Working age population begins to fall · Labour force growth rate slows and starts to decline
Car ownership	Car ownership changes over time – trend towards full car ownership	· Calibrated parameters	· More people in car owning cohorts
Passenger trips/ trip length	Trip rates per person remain relatively stable whilst trip lengths increase	· Trip rates	· Number of trips per person remain relatively stable · Trip lengths tend to increase with falling unit transport costs
Freight model			
Industrial production	Stronger growth in high technology sectors	· Industrial sector growth rates	· Changing industrial structure
Freight volumes/ length of haul	Trends in volume densities of different industrial production	· Value to volume ratios	· Changing levels and mix of freight volumes to be moved · Length of haul tend to increase with falling unit transport costs

13.2.1 Passenger model

In the passenger model the structure of the population in each zone will determine, in part, the number of passenger trips made along with changes in the trip making profile of particular demand segments ie two main factors are at work;

- The number of persons in each demand segment
- The trip making profile of each demand segment

Sections 13.2.1.1 and 13.2.1.2 describe the expected changes in the shape of the demand segments and 13.2.1.3 describes the expected changes in the trip making profile of each demand segment.

13.2.1.1 Demographic

Over the next 30 years the population of the EU15 will continue to grow[19] but will slow and sooner or later the population is expected to stagnate and decline, see figure 18. The baseline scenario according to Eurostat will expect population to peak around 2025 (Eurostat, 1997). However within the Union future population growth will be far from uniform, but what is true is that almost without exception the countries of the EU15 will be facing an increasingly ageing population and this will have a great effect on the demographic profile of the member states. The Eurostat report “Beyond the predictable: demographic changes in the EU up to 2050” identifies several trends that the EU15 will experience in the future:

- Population will start to decline, see above
- Fewer younger people
- Ageing will accelerate in the future especially when the post-war big generations leave the child-bearing age and move into the “old age brackets”. As well as this “bottom-up” effect through fewer births there will be a top-down” effect through extending longevity.
- Both the working age and the elderly population will become older
- Age dependency will rise drastically
- Deaths will start to outnumber births
- Life expectancy will continue to increase; gender gap may diminish somewhat
- The working age population will start to decline

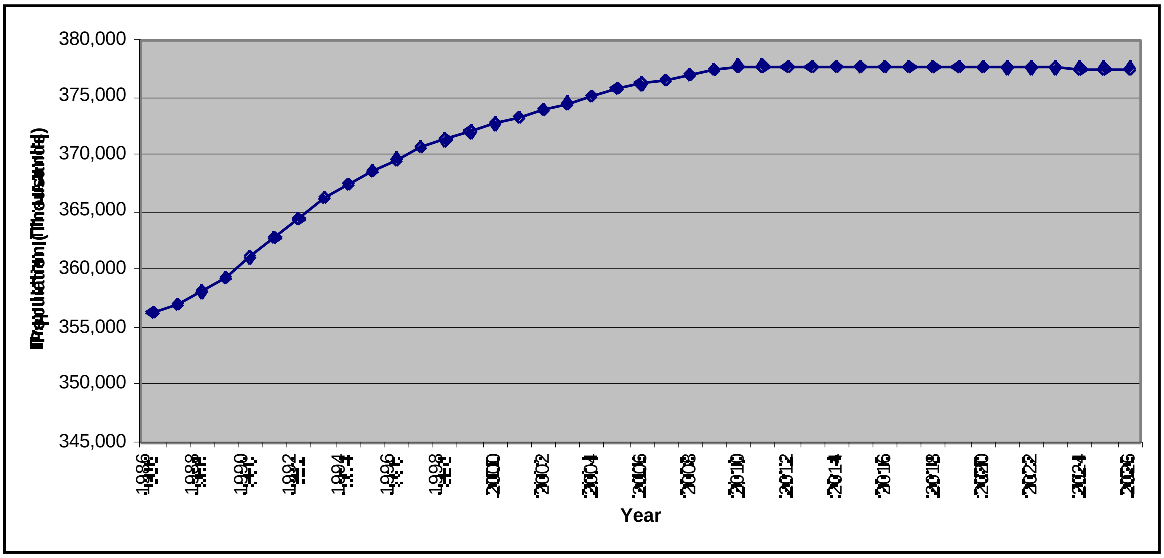

Figure 18: Development of EU15 population (1986-2026)

[19] current level is for EU15 is 2.3% p.a (Eurostat, 1999) but this is one third of that recorded at the beginning of the sixties

Table 110: Forecasted population (1995-2026)[20]

Spatial unit	Population (Thousands)						
	1995	2000	2005	2010	2015	2020	2025
Country							
Austria	8,047	8,149	8,227	8,283	8,319	8,354	8,390
Belgium	10,137	10,229	10,297	10,328	10,333	10,338	10,343
Denmark	5,228	5,323	5,397	5,451	5,487	5,523	5,559
Finland	5,108	5,179	5,222	5,257	5,262	5,267	5,272
France	56,580	57,818	59,015	60,065	60,908	61,751	62,594
Germany	81,661	82,182	81,777	81,036	79,740	78,445	77,149
Greece	10,454	10,643	10,870	11,079	11,174	11,269	11,364
Ireland	3,601	3,690	3,812	3,946	4,054	4,162	4,270
Italy	57,301	57,456	57,602	57,495	56,717	55,939	55,161
Luxembourg	410	426	443	459	474	488	502
Netherlands	15,459	15,801	16,180	16,470	16,684	16,898	17,112
Portugal	9,422	9,494	9,626	9,780	9,884	9,989	10,093
Spain	37,700	37,923	38,144	38,267	38,042	37,817	37,592
Sweden	8,827	8,894	8,970	9,043	9,133	9,222	9,312
UK	58,606	59,398	60,094	60,733	61,399	62,065	62,731
EU15	**368,539**	**372,606**	**375,676**	**377,691**	**377,609**	**377,526**	**377,443**
Macro Regions							
MR1	89,708	90,331	90,004	89,319	88,059	86,799	85,539
MR2	82,585	84,274	85,935	87,322	88,399	89,475	90,551
MR3	114,877	115,517	116,242	116,620	115,817	115,013	114,210
MR4	81,370	82,484	83,495	84,430	85,335	86,239	87,144
EU15	**368,539**	**372,606**	**375,676**	**377,691**	**377,609**	**377,526**	**377,443**
Functional Zones							
LSA	41,146	41,596	42,037	42,363	42,435	42,506	42,578
MPH	49,087	49,541	49,948	50,223	50,141	50,059	49,978
HDU	100,673	101,555	101,918	101,965	101,458	100,950	100,443
HDD	92,561	93,661	94,416	94,868	94,900	94,932	94,964
MDR	67,868	68,853	69,746	70,472	70,785	71,097	71,410
LDR	17,202	17,399	17,611	17,801	17,891	17,981	18,071
EU15	**368,539**	**372,606**	**375,676**	**377,691**	**377,609**	**377,526**	**377,443**

Note: Population totals exclude the following;

1. *France – Department d'outre mer*
2. *Spain – Canary Islands*
3. *Portugal – Azores and Medeira*

Figure 19 and figure 20 based on the above data, show the annual percentage growth rates by country and by functional zone. They show that all countries start to exhibit a decline in the rate of population growth and in the case of Germany, Italy and Spain starts to decline during the forecasting horizon of ASTRA i.e by 2015.

[20] Based on Eurostat (1998) Demographic statistics Data 1995-98 tables I2-I4

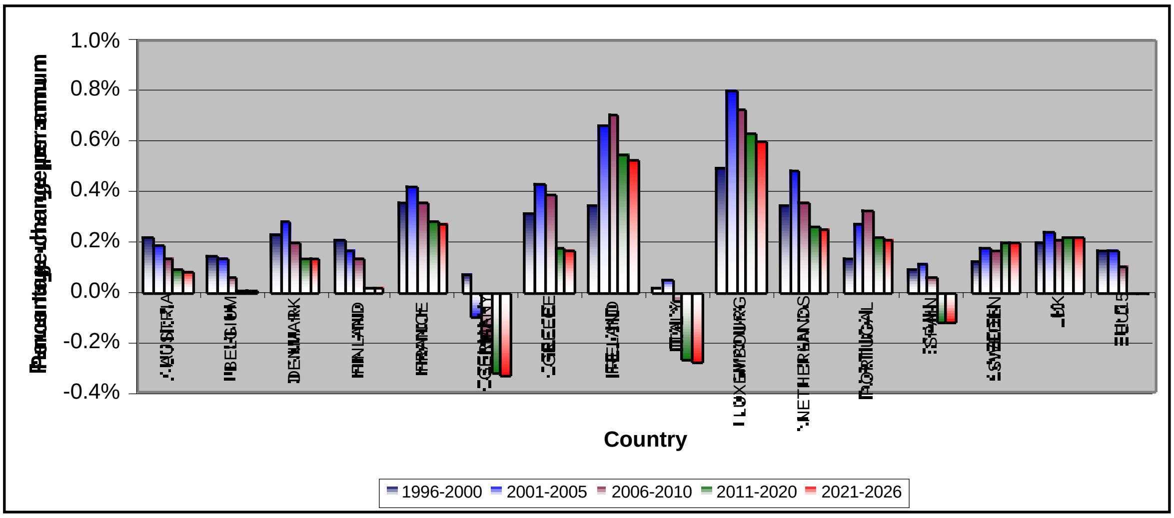

Figure 19: Annual population growth rates (%age p.a) by EU15 country

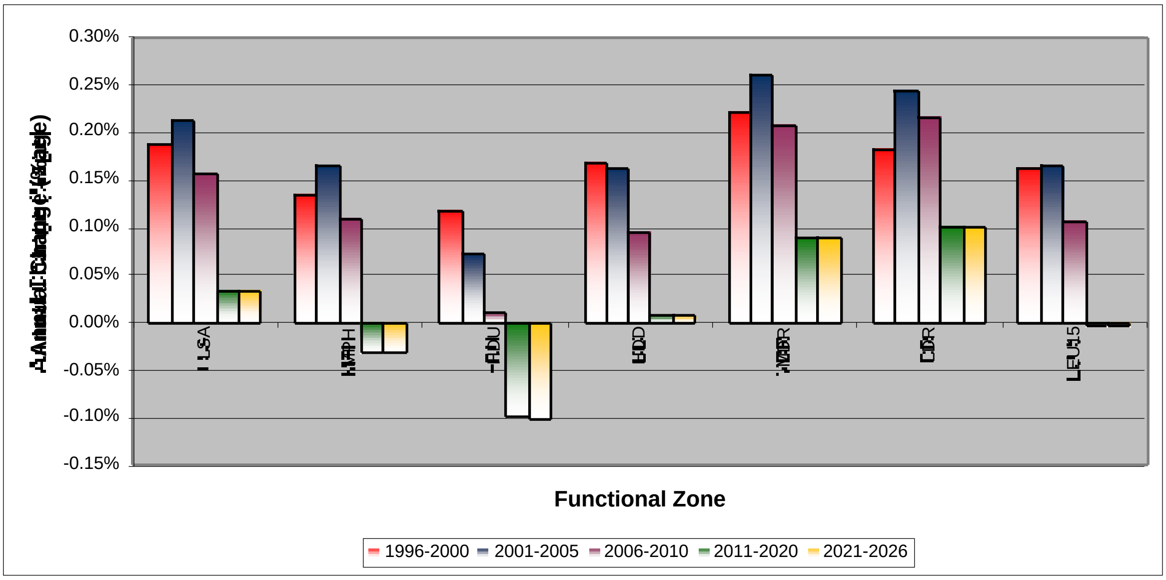

Figure 20: Annual population growth rates (%age p.a) by Functional Zone

The other aspect of the demographic structure that is important in the ASTRA model is the age distribution. The EUROSTAT demographic forecasts also provided data for each country in age cohorts for each of the forecast years. From this data it was necessary to calculate age based cohorts for the forecast years for each of the functional zones. This was done by distributing the age-based cohorts for each country across its component functional zones based on the existing distribution in 1995. This assumes that each region of the country maintains the same proportion of the country's age cohort.

Demographic change depends on three factors:

- Fertility (birth rates)
- Mortality and therefore changes in life expectancy and
- Migration

The mechanisms by which these trends are modelled in the REM sub-module involves assumptions on;

- Birth rates
- Life expectancy and
- Death rates

The effects of migration are roughly considered in the trend scenario, in general it is expected that the net inward migration will decline in the future thereby lessening its influence over the demographic structure of the EU15.

Life expectancy

Life expectancy has risen more than 10 years since 1945; a forecast trend was calculated based on

- Forecast population for EU15 from Eurostat for 1996-2026
- Stable split of male/female population, fixed at 1996 level
- Continuation of existing trend in life expectancy into future

In general females have a higher life expectancy than men do although it is thought that the gap will probably narrow in the future due to advance in medicine etc. However the demographic model in ASTRA does not have a gender dimension and so the life expectancy is for an average person based on the relative split of the male female population. The same forecasted life expectancy is used in all functional zones. Table 111 below summarises the results of this.

Table 111: Forecasted trends in Life Expectancy for EU15 (1996-2026)

Year	Life Expectancy (Years)	Change (Years)	Annual change in Life Expectancy
1970	79.3	N/A	N/A
1980	80.3	1.0	0.13%
1986	81.1	0.8	0.17%
1996	82.4	1.3	0.2%
1997	82.5	0.1	0.2%
1998	82.7	0.2	0.2%
1999	82.8	0.1	0.2%
2000	83.0	0.2	0.2%
2005	83.6	0.6	0.2%
2010	84.3	0.7	0.2%
2015	85.0	0.7	0.2%
2020	85.7	0.7	0.2%
2025	86.4	0.7	0.2%
1986-1996	***N/A***	***1.3***	***0.2%***
1996-2026	***N/A***	***4.0***	***0.2%***

Source: Based on Eurostat (1998) Demographic statistics Data 1995-98 table I-1

Birth and Death rates

It is expected that in the future deaths will start to outnumber births in the EU15. Birth rates, that is the number of births per 1000 population, have declined and it is expected that they will remain far below the replacement level with this contributing to the decline in the number of young persons. Given this and the increasing share of older people, crude mortality rates, and so the rate of natural population decline, will accelerate.

Over the period 1986-1995 there was a 0.8% per annum decline in the number of live births in the EU15 despite a 0.1% per annum increase in the population. Therefore despite an increase in the population and in population of a child bearing age the number of live births is decreasing and therefore it would seem sensible to continue the trend of falling birth rates into the future.

The demographic prospects will certainly have implications for the size and composition of the labour force in the future as described below.

Labour force

The structure of the labour force is influenced by changes in participation as well as demographic trends. Given the wide range of factors affecting participation and the complex nature of the interrelationships between them, any projections of the labour force in future years are considerably more uncertain then those of population and are surrounded by a wide margin of error. Generally there are two main influences over the size of the labour force;

- Demographics i.e. working age population (15-64) and
- Participation rates i.e. activity rates

In the past population growth has contributed significantly to the increase in the labour force especially baby booms. The Eurostat forecasts illustrate clearly that this will not continue to be the case as the working age population will become older with the decline in the number of young people entering the labour market and an increase in participation of those in the older cohorts, especially women. Eventually the working age population will begin to fall during the next 30 years thereby reducing the potential labour force. The decline in the working age population will be partly offset by the increasing participation of women in the workforce. In recent years however, there has also been a trend towards increased participation of young adults in education, which again depresses the labour force.

As stated above the labour force is a function of the

- Working age population and
- Participation/ activity rate

The working age population ie 15-64 is determined endogenously in the model. Table 112 below shows the expected rates of change in the working age population for the EU15. As is shown at the European level the working age population, or potential workforce, starts to contract later in the forecasting horizon.

Table 112: Forecasted trends in working age growth rate for EU15 (1996-2026)

Spatial Unit	**Working age (15-64) population growth rate (%age per annum)**				
	1996-2000	**2000-2005**	**2005-2010**	**2010-2020**	**2020-2026**
EU15	0.16%	0.06%	0.04%	-0.27%	-0.27%

Source: *Based on Eurostat (1999) Demographic statistics Data 1995-98 tables I2-I4*

The other factor is the participation or activity rate which is determined exogenously to the model and input for each functional zone. This is expected to grow during the forecast period and will offset the decline in the working age population as more women and part time workers enter the labour force. According to the DGXVI report “Sixth Periodic Report on the social and economic situation and development of the regions of the European Union”[21], it is expected that in general the participation of men will rise slightly continuing a trend of some years standing. However the major component of the increase in participation predominantly comes from growing numbers of women joining the labour force. For men rates are projected to fall in most member states after 2005, largely because of the ageing of those of working age and a rise in the relative numbers in the older age groups for whom participation tends to be lower. The increased participation of those of a younger working age in education and training of people also acts to suppress the rise in activity rates.

The future activity rates used in the REM sub-module are based on these predicted trends. However in the medium to long term this increase will not be able to cover the shortfall brought about by the decline in the working age population and hence bringing about the eventual decline in the labour force.

The DGXVI report indicates that the labour force of the EU15 will grow at just over 0.5% a year to 2005 and will subsequently slow down considerably and reach its peak size in 2011. After 2011 the labour force is projected to decline at an accelerating rate (exceeding 0.5% a year between 2020 and 2025. Whilst the demographic contribution to labour force growth will start to decline sharply, it will, at least partly, be offset by increase in participation in the medium term. The labour force evolves endogenously within the REM sub-module through the twin mechanisms described and table 113 below summarises the predicted trend.

[21] DGXVI (1999)

Table 113: Forecasted trends in labour force growth rate for EU15 (1996-2026)[22]

Spatial Unit	Labour force growth rate (%age per annum)			
	1996-2005	**2005-2010**	**2010-2020**	**2020-2026**
EU15	0.5%	0.25%	-0.25%	-0.5%

The main assumptions used to develop this scenario in the DGXVI report were as follows:

- Continued growth in the EU economy at just over 2% per year, distributed between regions much as in the past
- Modest increases in labour demand and employment growth as a result with most of the growth going into part time jobs, as in the recent past, and full-time jobs increasing only slightly
- Small increase in labour force participation of young people under 25, in contrast to past trends but centred on part-time work
- Increased participation of women in all member state, except Sweden especially in those where the rate is still low which are assumed to converge towards the rate in Sweden and Denmark
- A limited rise in participation of women with young children, most of these working part-time, reflecting a modest move towards more flexible working-time arrangements and increased child-care facilities
- A rise in the participation of women aged 50 to 64 in the short-term and, in the longer term of men in the same age group as early retirement diminishes.

13.2.1.2 Car ownership

The levels of car ownership are determined endogenously in the car ownership model within the SDM. The trend scenario is taken from the STREAMS model. In general it is expected that there will be a far greater number of car drivers than in past cohorts. This is already evident in the older age cohorts. The mechanism is not that many more of the elderly are learning to drive, but rather it is cohort driven in that those leaving the elderly cohort through, death tend historically to have low rates of licence holding. Whereas those entering the cohort now have higher levels of licence holding and car ownership than those who entered previously. This reservoir of growth is particularly strong among the female population.

Figure 21 below shows the annual growth rates expected in each of the demand segments for each of the functional zones and for the EU15 as a whole based on the results of the STREAMS model.

[22] Based on DGXVI (1999) - Sixth Periodic Report on the social and economic situation and development of the regions of the European Union

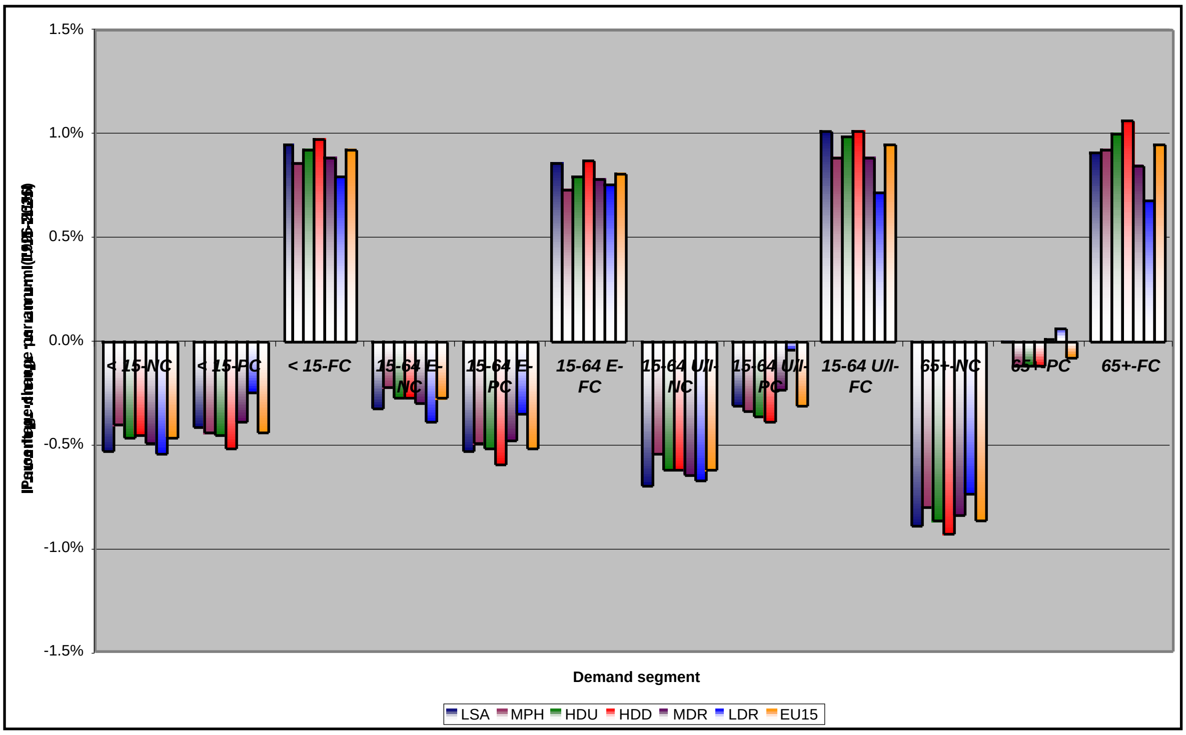

Figure 21: Annual growth rates of demand segments(%age p.a) by functional zone[23]

The following abbreviations are used in figure 21 and figure 22:

- NC = no car availability.
- PC = part car availability
- FC = full car availability
- U/I = unemployed or economically inactive person
- E = employed person.

13.2.1.3 Trip rates

In general it is considered that travel can be measured in terms of either;

- Number of journeys (reflecting access and purpose of travel) or,
- Distance travelled (volume of travel which reflects demand for travel facilities).

The distance travelled will be influenced by the transport costs, which are input into the REM sub-module from the TRA sub-module. The future year assumptions regarding these are presented in the TRA sections. The assumptions regarding the trends in trip rates over the forecast period are based on those used in the STREAMS passenger model.

[23] *STREAMS model results*

The evidence presented in ASTRA D4, section 6.2.3 and in ASTRA D3 expected that the number of passenger kilometres will continue to rise faster than the number of journeys made. This implies that the trip rates per capita will remain relatively stable whilst trip lengths continue to increase. Changes in the total number of trips by purpose will be a function of;

- Changing demographic and car ownership profile of population
- Changes in trips rates

The first of these is dealt with by the assumptions made regarding demography and car ownership presented above.

In the STREAMS project a comprehensive analysis was done of changes in trip rates over time and from this a set of trip rates were developed for the 2020 STREAMS model[24]. The trends in trip rates used in the ASTRA model are therefore derived from the forecast trip rates used in STREAMS by interpolating between the 1994 and 2020 trip rates for each purpose and demand segment to obtain annual growth rates. Figure 22 below presents the annual growth rates in trip rates per person for each of the 3 trip purposes and 12 demand segments. It shows that Commuting and business trip rates are virtually unchanged with tourism trips growing faster than personal trips, this is consistent with the assumptions made in the STREAMS project.

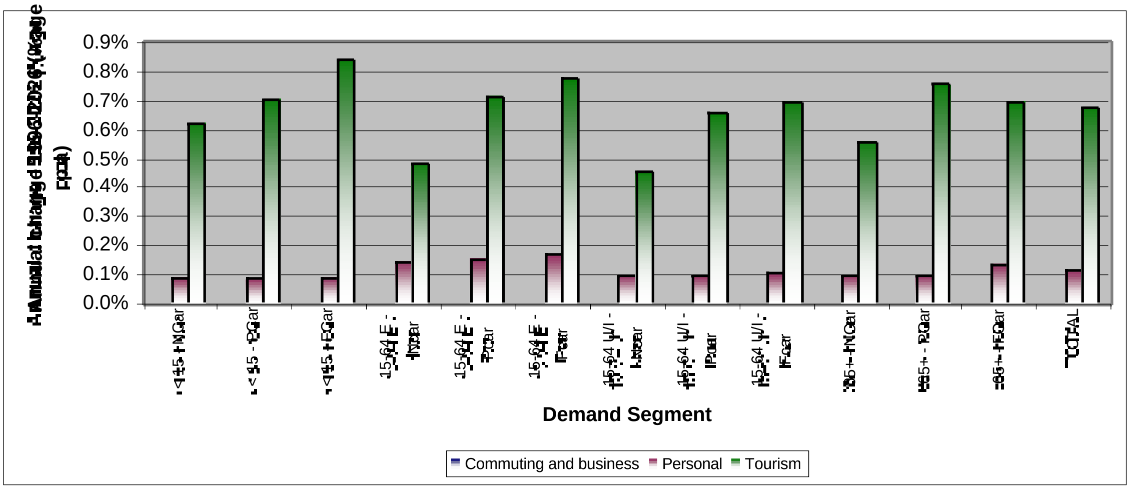

Figure 22: Annual growth in trip rates 1996-2026 (%age p.a)

[24] see STREAMS (1999) Deliverable D8/D10

13.2.2 Freight model

The calculation of the transport volumes are based on two items of information

- Value of production by industrial sector
- Value to volume ratio by industrial sector

The MAC sub-module controls the growth of GDP for the industrial sectors in each macro region. Also a sectoral split is provided by the MAC in terms of several variables like final demand or gross-value-added. However, as this sectoral split is not identical with the commodity split in the STREAMS model and the REM the link between MAC and REM is currently implemented via the aggregated industrial GDP for goods. The aggregated GDP is then split according to STREAMS on the different commodities respectively STREAMS industrial sectors. Furthermore it is necessary to differentiate rates of growth between the different industrial sectors in each macro region. In order to do this the STREAMS regional economic model is used to derive growth rates for the forecast period with the overall GDP of the primary/manufacturing sector controlled by the MAC. The value to volume ratios are more problematic from the point of view of deriving a trend through time. The approach adopted was to use forecast rates of freight volumes by industrial sector from other studies in order to derive some trend in the value of volume ratios. In the review of the STREAMS model results some revisions have been made and taken forward in the continuing work on the SCENES model, in light of this use has been made of forecasts in freight volumes from the EUFRANET project.

13.2.2.1 Industrial production

As stated the overall growth in the economy in each macro-region is determined by the MAC sub-module. Therefore the annual growth in total GDP summed across all the industrial sectors is driven by this rate. However it is expected that the manufacturing sectors of the economy will continue to grow faster than the primary sectors and therefore the growth rates applied to the value of production by industrial sector must be differentiated to allow for this.

The STREAMS model was used to derive growth rates by industrial sector by interpolating between the 1994 and 2020 model output from the STREAMS regional economic model for each of the industrial sectors and macro regions. Table 114 and figure 23 show the annual growth rates derived from the STREAMS model by sector and region. The same growth rates were used through to 2026.

Table 114: Annual growth rates by industrial sector and macro region (1996-2026 %age p.a))

Industrial Sector	**Growth Rate 1996-2026 (%age p.a)**				
	Macro Region				
	1	**2**	**3**	**4**	**EU15**
Agriculture, forestry and fishing products	-1.0%	-0.3%	-0.4%	0.6%	- 0.25%
Coal	-0.1%	0.5%	1.8%	1.2%	0.59%
Crude petroleum	-0.1%	0.5%	1.8%	1.2%	1.20%
Petroleum products	-0.9%	1.8%	1.0%	1.5%	0.94%
Other energy	-0.2%	0.3%	0.8%	1.2%	0.44%
Ores	2.1%	1.9%	3.1%	3.5%	2.63%
Mineral products	-0.9%	-0.9%	0.5%	1.3%	- 0.20%
Chemical products	0.8%	1.5%	0.4%	1.6%	1.04%
Cement	0.9%	2.5%	3.0%	2.5%	2.31%
Metal products	2.1%	2.3%	2.7%	2.3%	2.32%
Paper	0.8%	1.5%	0.4%	1.6%	1.11%
Food, beverages & tobacco	-0.8%	-0.2%	-0.1%	1.2%	0.01%
Manufactured articles	1.4%	1.2%	0.5%	1.1%	1.10%
All industrial sectors	**0.7%**	**0.9%**	**0.7%**	**1.3%**	**0.87%**

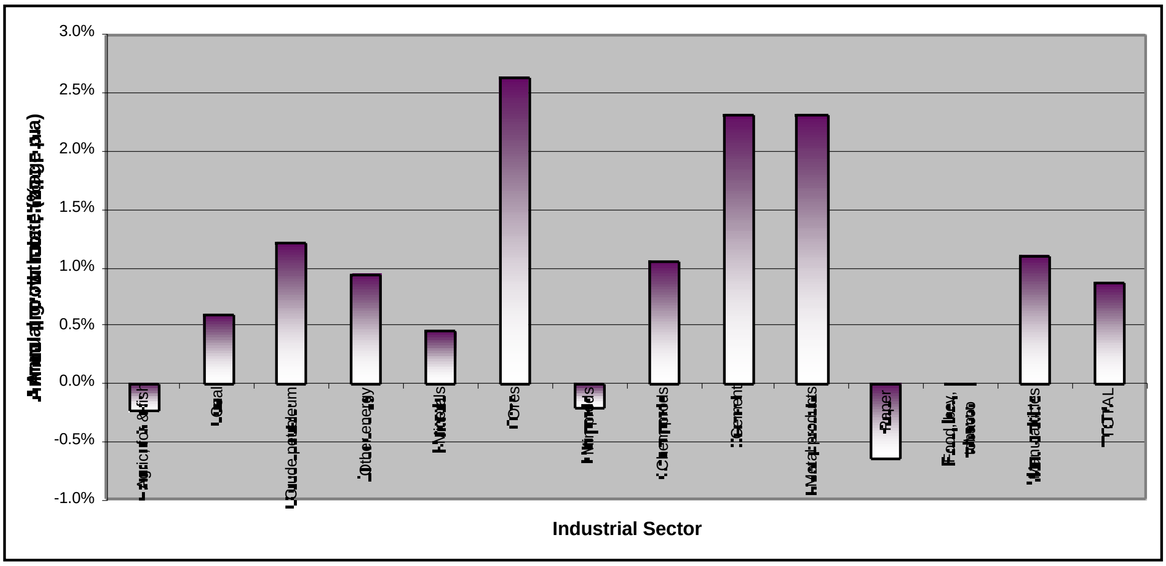

Figure 23: Annual growth rates in value of output by industrial sector in EU15 1996-2026 (%age p.a)

13.2.2.2 Freight lifted

The calculation of the transport volumes are based on two items of information

- Value of production by industrial sector

· Value to volume ratio by industrial sector

As has been noted above attempting to derive a trend in value to volume ratios for each industrial sector is difficult. The methodology adopted was to use forecasts on growth rates in freight volumes by sector to inform the future development of value to volume ratios over the forecast period. Data was used from two studies:

· STREAMS

· EUFRANET

From EUFRANET the growth rates were obtained for each of the industrial sectors, currently these growth rates are the same for each macro region and are presented in table 115.

Table 115: Growth rates in freight volumes by sector for EU15 (1996-2026 %age p.a)

ASTRA Industrial Sector		**EUFRANET Industrial Sector**	**Growth Rate 1996-2020 (%age p.a)**
Agriculture, forestry and fishing products	I1	1 – Agricultural	1.1%
Coal	I2	3 - Solidfuels	-1.3%
Crude petroleum	I3	Not applicable	
Petroleum products	I4	11 – Petrol products	-0.1%
Other energy	I5	Not applicable	
Ores	I6	5 – Ores	0.3%
Mineral products	I7	7 – Minerals	0.2%
Chemical products	I8	9 – Chemicals	1.3%
Cement	I9	7 – Minerals	0.2%
Metal products	I10	6 – Metal	1.0%
Paper	I11	9 – Chemicals	1.3%
Food, beverages & tobacco	I12	2 – Food	0.9%
Manufactured articles	I13	10 – Manufacturing	1.5%
All			**0.9%**

At the EU15 level it is then possible to look at the effects of these growth rates on value to volume ratios. Figure 24 below compares the growth rates of GDP and freight volumes by sector for the EU15.

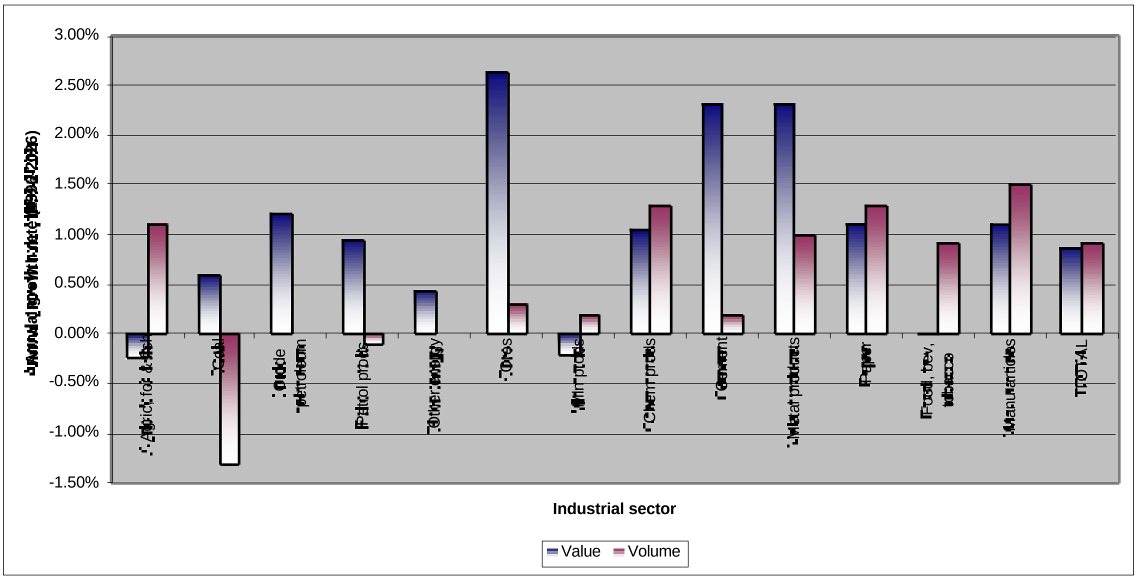

Figure 24: Comparison of annual growth rates in sectoral GDP and generated freight volumes for EU15

Note: "Crude petroleum" and "Other energy" e.g. gas, electricity sectors do not produce volumes to be moved in the transport system that is modelled

13.3 Trends in the TRA

13.3.1 Costs of passenger travel and freight distribution

The growth of passenger travel costs and freight distribution has been taken with reference to SCENES WP 2.4 –Reference scenario, July 1999 (you can find these tables in the appendix) and adjusting trends splitting them between before and later year 1994. This split has been made to better reflect real trends in the past situation (before 1994), while for trends later 1994 they reflect the SCENES Reference Scenario Liberalisation and Harmonisation policies, extending them to year 2026 instead of year 2020. These trends are shown in the following table 116 for passenger and table 117 for freight.

Table 116: Passenger costs (Yearly growth rate)[25]

	Short distance			Long distance	
	Local	**Very short**	**Short**	**Medium**	**Long**
	1986-2026	*1986-2026*	*1986-2026*	*1986-2026*	*1986-2026*
Car	2.5%	2.5%	2.5%	2.0%	2.0%
Bus	1.0%	1.0%	1.0%	0.0%	0.0%
Train		1.0%	1.0%	1.0%	1.0%
Air					-0.5%

[25] Scenes WP 2.4, Reference scenario, July 1999

Table 117: Freight costs (Yearly growth rate)[26]

	Short distance		**Long distance**	
	Local	**Medium-short**	**Medium-long**	**Long**
	1986-2026	*1986-2026*	*1986-2026*	*1986-2026*
Truck	2.0%	1.0%		
Rail/iww		1.5%	1.5%	1.5%
Ship				-1.0%

It should be reminded that these developments form only part of the total development of transport costs, which is completed by the development of fuel prices described in section 13.1.

13.3.2 Passenger and freight value of time

Also the growth in the passenger value of time for the ASTRA transport module has been taken from STREAMS, estimated using the EU15 GDP growth rate of approximately 2.55% per annum for the entire period 1986 – 2026. The growth of the freight flows value of time is differentiated by category: unitised flows have the same rate of the GDP growth, while semi-bulk flows have a smaller increase (50% of the GDP growth rate) and bulk is stable (0% growth rate). Trends are shown in the following table 118 for passenger and table 119 for freight.

Table 118: Passenger value of time[27]

[EURO/(h*pers)]	**Local**				**Long distance**			
	1994	Trend	1986	2026	1994	Trend	1986	2026
	Value	94-2026	value	value	value	94-2026	value	value
Commuting & Business	7.11	2.6%	5.81	16.14	16.63	2.6%	13.60	37.97
Personal	1.93	2.6%	1.58	4.38	1.93	2.6%	1.58	4.41
Tourism					4.15	2.6%	3.39	9.42

Table 119: Freight value of time

[EURO/(h*t)]	1994	Trend	1986	2026
	value	94-2026	value	Value
Solid bulk	2.10	0.0%	2.10	2.10
Semi bulk	2.40	1.3%	2.16	3.63
Unitised	3.90	2.6%	3.19	8.85

[26] Scenes WP 2.4, Reference scenario, July 1999
[27] STREAMS final deliverable D8D10

13.3.3 Passenger vehicle occupancy

Vehicle occupancy information was available from the STREAMS model. These data showed a slow but steady decrease in occupancy from 1994 to 2020. In ASTRA it was kept the same occupancy rates. See them in the following table 120.

Table 120: Passenger car occupancy coefficients (persons per car)[28]

	Local				Long distance			
	1994	Trend	1986	2020	1994	Trend	1986	2020
	Value	94-2020	value	Value	value	94-2020	value	value
Commuting&Business	1.18	-0.3%	1.21	1.08	1.20	-0.3%	1.23	1.10
Personal	1.80	-0.4%	1.85	1.64	1.80	-0.4%	1.85	1.64
Tourism					2.71	-0.4%	2.79	2.47

13.3.4 Truck load factors

Internationalisation and deregulation of cabotage in the road transport sector will promote further competition within the road haulage industry. In the STREAMS model reduction of empty back flows especially for unitised goods was reflected in a reduction of average transport costs and no specific assumptions were made with reference to the introduction of new trucks bigger than the current standards. As a consequence load factors are assumed stable through the years also in the ASTRA model. See table 121.

Table 121: Freight load factors (tons per truck)[29]

	Local	Inter-urban
Solid bulk	7.60	15.00
Semi bulk	7.90	15.50
Unitised	3.50	13.50

13.3.5 Road network

Road network growth rates implemented in the ASTRA model are reported in section 6.3.3.5 of the main text.

13.3.6 Passenger rail performance

A constant improvement of the long distance passenger rail service is implemented in the ASTRA model assuming a yearly decrease (starting from year 1994) of average travel time in the long distance sector of the TRA.

[28] STREAMS (1999) final deliverable D8D10

[29] STREAMS (1999) final deliverable D8D10

Table 122: ASTRA – Long distance rail passenger time[30]

	Long distance sector				
	1986 value	Trend 94-2026	1994 Value	2026 Value	Growth 94-2026
Commuting&Business	4.74	-0.20%	4.74	4.45	-6.62%
Tourism	5.55	-0.15%	5.55	5.29	-4.92%

13.3.7 Trends from SCENES WP 2.4 –Reference scenario-

Table 123: Costs of passenger travel[31]

	(I) Liberalisation	% of total cost/year	(ii) Harmonisation	% of total cost/year	2020 Trend Policy Scenario
Road Long distance	*Cars:* · Constant price of new cars – increase in diesel cars with more efficient engines (↓ unit consumption). · small reduction in car occupancy *Coach:* · increased competition	0 % - 1%	· Generalisation of tolls · ↑ in fuel taxes at least in a first period (internalisation of external costs). · Technical improvement and more stringent pollution norms · congestion problems in some areas of network, particularly during vacations	+ 2 % + 1 %	+ 2 % 0 %
Road Short distance	*Cars:* · ↑ congestion, ↑ in parking prices · ↑ in small urban cars, ↓ in car occupancy *Public transport:* · Budget constraints · ↑ in prices	+1 % +1 %	· More voluntary policies to reduce car use in metropolitan or dense areas · ↑ tax on fuel and tolls *Public transport :* · diversification of services, metro, light rail, buses, small buses and cars for public use · development of land use policy	+ 1.5 % 0 %	+ 2.5 % + 1 %
Rail:	· ↑ in charges for infrastructure (including new infrastructure for HST).	+1%	· development of HST network (including tilting technologies) · harmonisation of price increases	0 %	+1 %
Air	· ↓ in price due to competition after full liberalisation in 1998	- 1 %	· More congestion and environmental problems in dense areas · improvement of aircraft (noise and pollution)	+ 0.5 %	- 0.5 %

[30] Note: The figures in this table make reference to the LSA-LSA cell of the long distance sector

[31] SCENES WP 2.4 – Reference scenario, July 1999

Table 124: Costs of freight transport[32]

	(I) Liberalisation	% of total cost/year	(ii) Harmonisation	% of total cost/year	2020 Trend Policy Scenario
Road: **Long distance**	· ↑ in productivity (with +30% more if 44t is generalised) and ↑ in quality of service · quick adaptation to logistics changes · decrease in prices due to strong competition at national and international level	- 1%	· Harmonisation of social conditions · ↑ fuel taxes to internalise of external costs (affects local traffic more than international/interregional traffic) technological improvements → diminution of external effects	+1 %	0 %
Road: **Short distance**	· ↑ cost of local transport due to weaker competition (monopoly situation of trucks) · More difficult traffic flow in dense areas · ↑ in costs due to congestion	+0.5%	· ↑ fuel taxes to internalise of external costs (5% of cost over 10 years) · More stringent conditions for urban circulation. · Increase in salaries (up to 50% of total costs) · development of light trucks and increasing development of city logistics	+1.5 %	+ 2%
Rail: **Long distance**	· ↑ competition (particularly with road transport) and development of commercial strategy · ↑ in infrastructure charges (budget equilibrium) · improvement of operating systems (long trains, better use of wagons, network specialisation)	+ 2%	· harmonisation of tariffs and social costs at European level	0 %	+2%
Waterways: **Long distance**	· liberalisation and ↓ in price for some specific traffics where competition is possible (main waterway basins) · ↑ in infrastructure charges	+1%	· development of specialised logistics for bulks or containers	0 %	+1 %
Maritime and ports	· ↑ productivity with use of bigger containerships and information technologies · strong competition · significant ↓ in freight prices · liberalisation of SSS	- 1%	· Internalisation of costs · improved quality in ports	0 %	- 1 %
Combined transport	· improvement in transhipment terminals (maritime and inland) - low cost overall · adaptation to market requirements in logistics · but significant ↑ in rail infrastructure charges	+1.5%	· ↑ in road terminal transport in dense areas · harmonisation of rail tariffs at European level	0 %	+1.5%

[32] SCENES WP 2.4 – Reference scenario, July 1999

13.4 Trends in the ENV

13.4.1 Technical Progress after 2010 for Road Transport Emissions

For car emissions the development of emissions is determined at least until 2010 by the future emission legislation (EURO I-IV). After this period assumptions on further reductions are made. However, if future legislation (EURO V, VI) is clarified this can be implemented in the model. Currently the following improvements are implemented in the model:

Table 125: Technical Improvements for Road Transport after 2010

Emission	Transport Mean	2010 [%]	2030 [%]
CO_2			
	Car	100	85
	LDVG	100	80
	LDVD	100	85
	HDV	100	90
	Bus	100	85
NO_x			
	Car	100	75
	LDVG	100	80
	LDVD	100	75
	HDV	100	70
	Bus	100	65
Soot Particles			
	Diesel Car	100	85
	LDVD	100	85
	HDV	100	80
	Bus	100	70

The development of fuel consumption runs in parallel to the development of the CO_2 emission factors presented in table 125.

It should be mentioned that the vehicle fleet models do not consider the introduction of alternative engine technologies (e.g. fuel cell cars, hydrogen powered vehicles) in the fleet. That means the improvements are reached by improved gasoline (and to some extent diesel) engine technology (e.g. reduced cubic capacity plus high pressured fuel injection). To consider the possible emerging new technologies additional policy simulations will be undertaken in the future work with ASTRA.

13.4.2 Development of Rail Transport Emissions

For the emissions of diesel railways it can be assumed that the development of harmful emissions (e.g. NO_x) will show a strong decrease in the next decades as technologies developed for road transport will also diffuse into the rail engine fleet. Energy efficiency will be increased for diesel and electric trains similarly. However, emissions of electric trains are also affected by the emission factors of powerplants shown in table 127.

Table 126: Development of train emission factors and train consumption factors

Effect	Product	1985 [%]	1995 [%]	2005 [%]	2030 [%]
CO_2 Emissions					
	Diesel Train	110	100	95	80
NO_x Emissions					
	Diesel Train	110	100	95	60
Energy Consumption					
	Passenger Electric Train	105	100	95	80
	Freight Electric Train	110	100		85
[kJ/tkm]	Freight Diesel Train	*315*	*220*		*160*

Table 127: Regional development of electricity generation emission factors

Effect	Electricity in Region	1985 [%]	1994 [%]	2010 [%]	2030 [%]
CO_2 Emissions					
	E1: A,D	110	100	90	70
	E2: B,D,L,NL	120	100	90	85
	E3: E,GR,I,P	130	100	85	75
	E4: DK,FIN,IRL,S,UK	120	100	90	80
NO_x Emissions					
	E1: A,D	110	100	90	80
	E2: B,D,L,NL	120	100	90	85
	E3: E,GR,I,P	130	100	85	65
	E4: DK,FIN,IRL,S,UK	120	100	90	80

13.4.3 Development of Air Transport Emissions

The future development of air emissions is discussed nonuniform. This is especially valid for the emission factors of NO_x. KALIVODA ET AL. estimate for the MEET project within the base emission scenario that the emission factors for NO_x decrease by 20% from 1998 to 2020 while DINGS ET AL. estimate an increase by 18% from 1992 to 2025 within their business-as-usual scenario. For fuel consumption as well as for the strongly to fuel consumption related emissions of CO_2 both estimate a decrease in consumption factors respectively emission factors (KALIVODA ET AL. improvement of fuel consumption from 1998 to 2020 by 25,4%; DINGS ET AL. reduction of fuel intensity from 1992 to 2025 by 29%).[33] Based on this estimates the applied improvement factors for air traffic caused by technical progress are given in the table 128:

Table 128: Base Trend in Air Emission Factors

Emission	Base Year 1985 [%]	Final Year 2026 [%]
NO_x	102	98
CO_2	110	75
Fuel Consumption	110	75

[33] KALIVODA/KUDRNA/FITZGERALD (1998), DINGS/DIJKSTRA/WIT (1997)

13.4.4 Development of Ship Transport Emissions

For the gaseous emissions of maritime shipping the emission quantities of CO_2, NO_x and Particulate Matter (PM) are calculated. It is assumed that the future development of the emission factors is different for these emissions. The improvement factors caused by technical progress are given in the following table 129. The level values for the emission factors are calculated for the year 1994, such that in the base year 1985 the development multipliers are greater than 1.

Table 129: Development for base trend of ship emission factors

Emission	Base Year 1985 [%]	Final Year 2026 [%]
NO_x	120	80
PM	120	70
CO_2	110	90
Fuel Consumption	110	90

13.4.5 Development of Fuel and Vehicle Production Emissions

Also the process of extracting and producing fuel and vehicles is affected by technical developments that might reduce the emissions during theses stages of the life-cycle of these products. For the fuel production emissions shown in table 130 a slight reduction is assumed that is produced by two overlaying effects. First, technological improvements will reduce the emission factors and second the extraction process will become more energy intensive and therefore increase emissions as oil drilling and extraction will be increased at locations with high requirements on complex technologies (e.g. deep-sea offshore oil rigs).

Table 130: Development of fuel production emission factors

Emission	Product	1995 [%]	2030 [%]
CO_2			
	Gasoline Fuel Production	100	90
	Diesel Fuel Production	100	90
NO_x			
	Gasoline Fuel Production	100	90
	Diesel Fuel Production	100	90

The production emission factors of vehicle production are also influenced by two effects. First again technological improvements (especially of the energy supply technologies) will reduce the emission factors but second the car manufacturers follow a value added strategy that tries to equip each new generation of cars with new service equipment (e.g. air conditioning, route guidance telematics). This increases the production factors of future cars.

Table 131: Development of production emission factors for vehicles

Emission	Product	1985 [%]	1994 [%]	2010 [%]	2030 [%]
CO_2					
	VehicleProduction	102	100	98	90
NO_x					
	Vehicle Production	140	100	80	65

13.4.6 Developments in the Accident Model

The accident model is driven by three endogenous influences, which are the vehicle-kms, the investments in road maintenance and the implementation factor of airbags that is modelled in the car fleet model. Furthermore a set of exogenous parameters is affecting the accident model. Their development in the base scenario is shown in the following figures. The first two figures present the usage of safety-belts for urban car transport (figure 25) and rural car transport (figure 26), which both reaches a level above 90% (besides urban car transport in E3 region). In general the safety-belt usage for rural transport is higher than for urban transport.

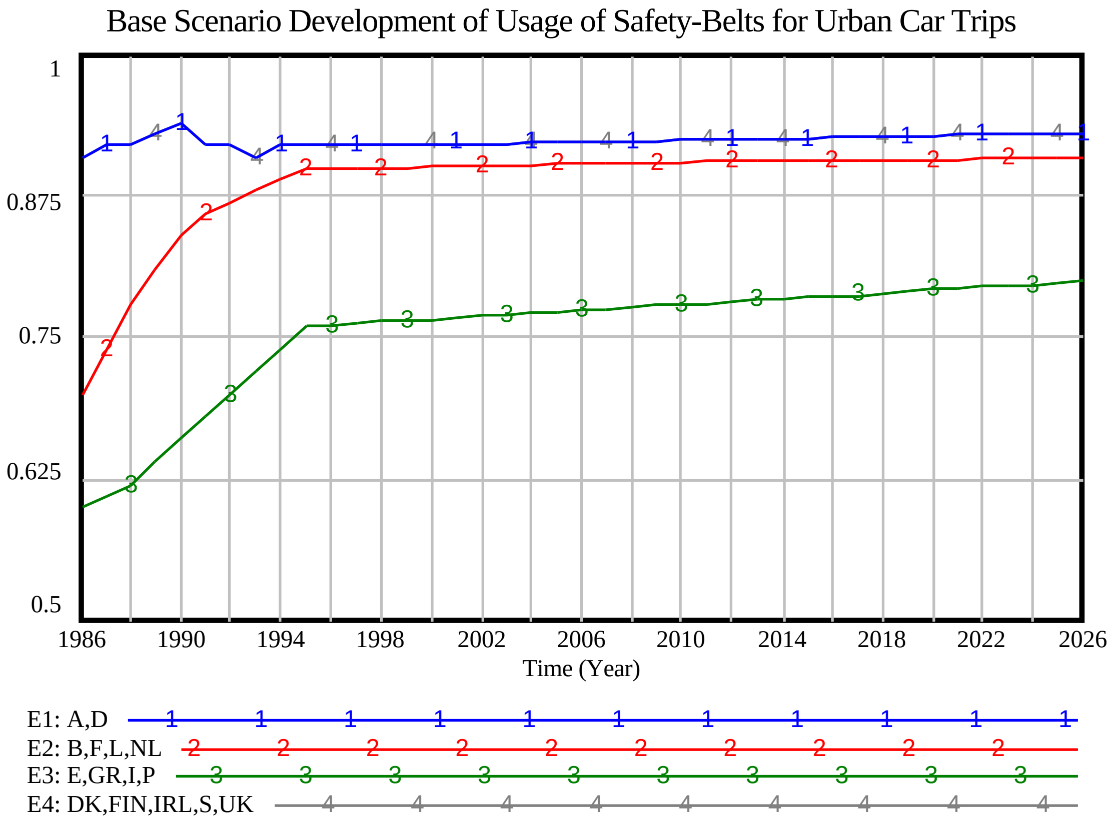

Figure 25: Usage factor of safety-belts for urban car trips

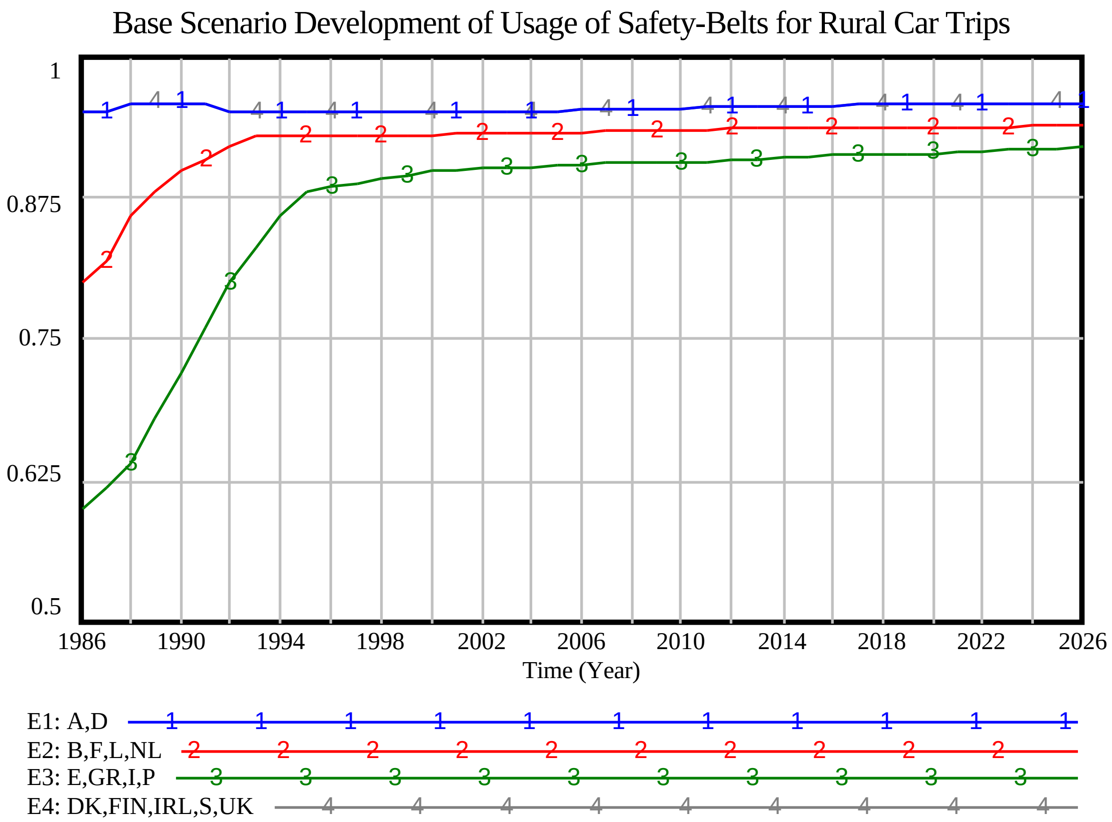

Figure 26: Usage factor of safety-belts for rural car trips

The implementation of airbags in the fleet assumes that starting at 1988 a small but growing share of new cars will be equipped with airbags. After 2000 nearly all new cars will have an airbag. The resulting implementation factor in the fleet is shown in figure 27.

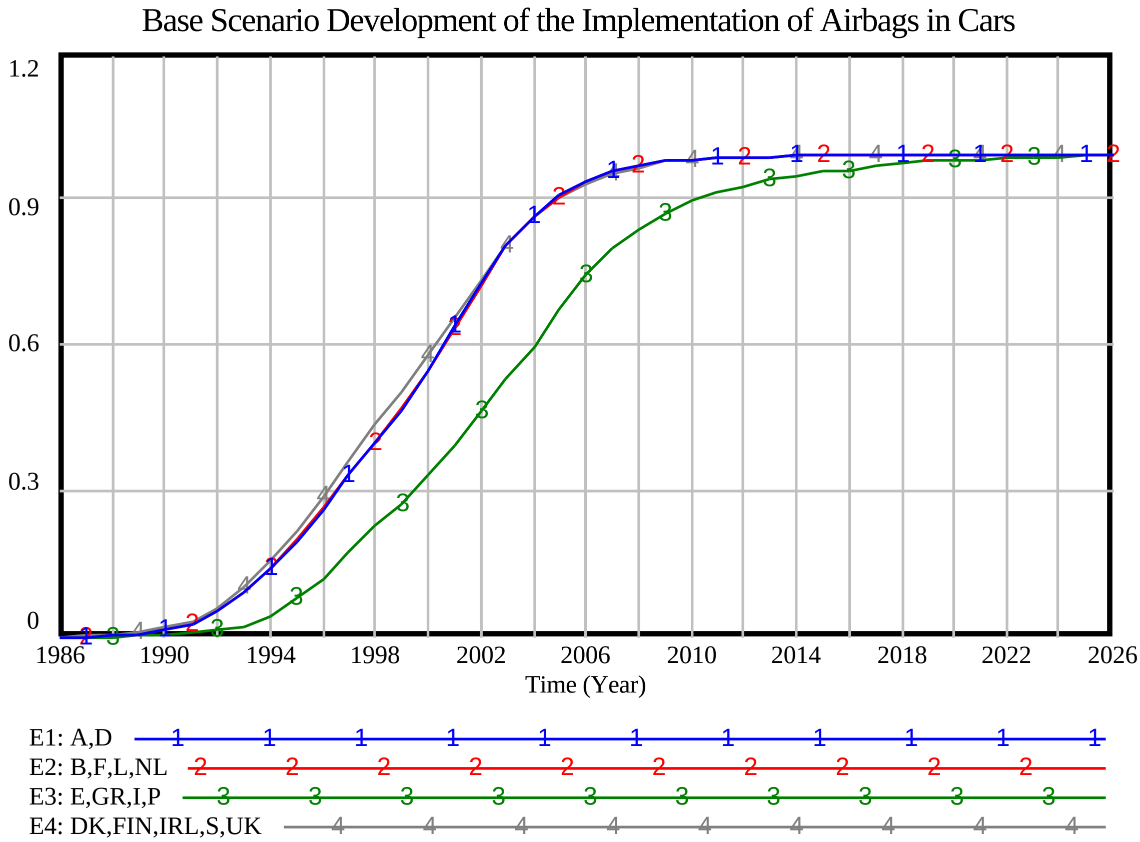

Figure 27: Implementation ratio of airbags in the car vehicle fleet

As empirical results have shown that driving with daytime running lights can reduce significantly the number of accidents this is included in the model. In first versions of the model it is expected that the policy of requiring generally daytime running lights will be adopted in all regions. However, in the course of the project it seemed that only in region 4 this is a relevant policy. The result is that the effect of daytime running lights is only remarkable in this region, which is shown in figure 28.

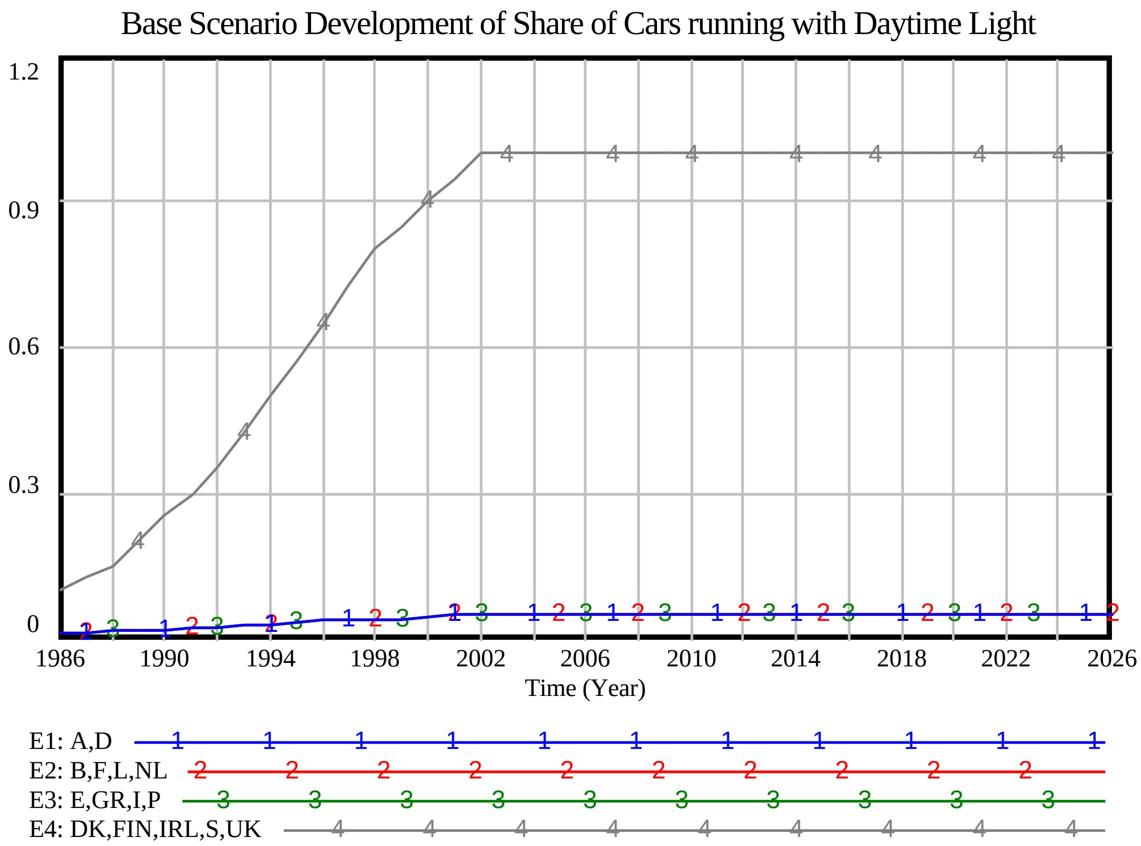

Figure 28: Share of cars driving with daytime-light

One might argue that besides the positive effects of maintenance investments considered in the model also general investments in infrastructure improvements have a small but steady effect on safety as for instance crossings are replaced by bridges, lanes are separated from each other. This is not considered in the accident model. Furthermore, some new technologies are promoted by the car manufacturers that should increase car safety, for instance electronic distance keeping systems or electronic cohort driving systems. However, from the literature it seems that these influences are small compared with the effects considered in the model (e.g. safety-belts, airbags, blood alcohol limit, daytime running lights, speed limit, road quality).

An approach that could reduce the accident impacts significantly in terms of the fatality or injury risk, would be to reduce the vehicle weights significantly, which would require in parallel a reduction of the speed limit to 100-120 km/h. Besides reduced accident impacts this would also be advantageous in terms of energy consumption. However, this seems not to be a realised policy option and is therefore not considered in the model.

13.5 Details of the Policy Packages

The following sections describe the changes of exogenous variables or in some cases variables of special relevance for the ASTRA policy packages.

13.5.1 Policy Package 1: Improving Safety and Emissions Situation

This package required the highest number of changes for the policy simulation. Adjustments have been made for

- Speed limits (see also section 7.3.2.1 in ASTRA D4),
- Emission factors,
- Safety-belt usage,
- Emission legislation (see also section 7.3.2 in ASTRA D4),
- Car prices,
- Accident rates HDV.

The strengthened speed limit only has an impact in the longer distance bands (> 40 km passenger, > 50 km freight) as it only affects motorways and non-urban roads. For these distance bands reductions in emission factors are calculated with speed dependency functions from the COPERT II project.[34] The applied reductions of emission factors for CO_2 and NO_x are shown in table 132. Reduction of fuel consumption is the same as for CO_2 emissions and therefore not especially listed in the table.

[34] EEA (1997)

Table 132: Reduction of emission factors because of strengthened speed limit

Transport Mean	Region	Speed Reduction [%]	Percentage Emissions Reduction (100% = Normal Speed) [%]
CO_2			
Car	E1: A,D	18	80
Car	E2: B,D,L,NL	5	95
Car	E3: E,GR,I,P	6	93
Car	E4: DK,FIN,IRL,S,UK	4	96,5
HDV	All regions	7	94
LDV	E1: A,D	8,5	88
LDV	E2: B,D,L,NL	5	94
LDV	E3: E,GR,I,P	6	92
LDV	E4: DK,FIN,IRL,S,UK	4	95
NO_x			
Car	E1: A,D	18	75
Car	E2: B,D,L,NL	5	91
Car	E3: E,GR,I,P	6	89
Car	E4: DK,FIN,IRL,S,UK	4	93
HDV	All regions	7	92
LDVG	E1: A,D	8,5	90
LDVG	E2: B,D,L,NL	5	95
LDVG	E3: E,GR,I,P	6	93
LDVG	E4: DK,FIN,IRL,S,UK	4	96
LDVD	E1: A,D	8,5	86
LDVD	E2: B,D,L,NL	5	92
LDVD	E3: E,GR,I,P	6	90
LDVD	E4: DK,FIN,IRL,S,UK	4	94

The enforced emission legislation consists of two elements. First, for cars the EURO II, III and IV legislation is introduced three years earlier than originally planned. Second, after 2010 when in the base scenario further reductions e.g. by future EURO V or VI standards will be introduced an additional reduction that goes beyond these future standard is assumed. These additional reductions are shown in table 133.

Table 133: Technical improvements with enforced emission legislation for car transport after 2010

Emission	Transport Mean	2010 [%]	2030 [%]
CO_2			
	Car	100	55
NO_x			
	Car	100	65

The emission requirements respectively the fuel efficiency requirements make it necessary earlier to introduce new technologies, which increases the car prices. As stated above the car prices in the base scenario increase by 20% from 1995 to 2030. As with the policy EURO II legislation would have been introduced at 1993 the price increase is advanced to this date such that the 20% increase is reached in 2028. For instance this means for the year 2000 that car prices are 1,5% higher than in the base scenario.

The usage factor for safety-belt use in the emission and safety policy are shown in figure 29 (urban) and figure 29 (rural).

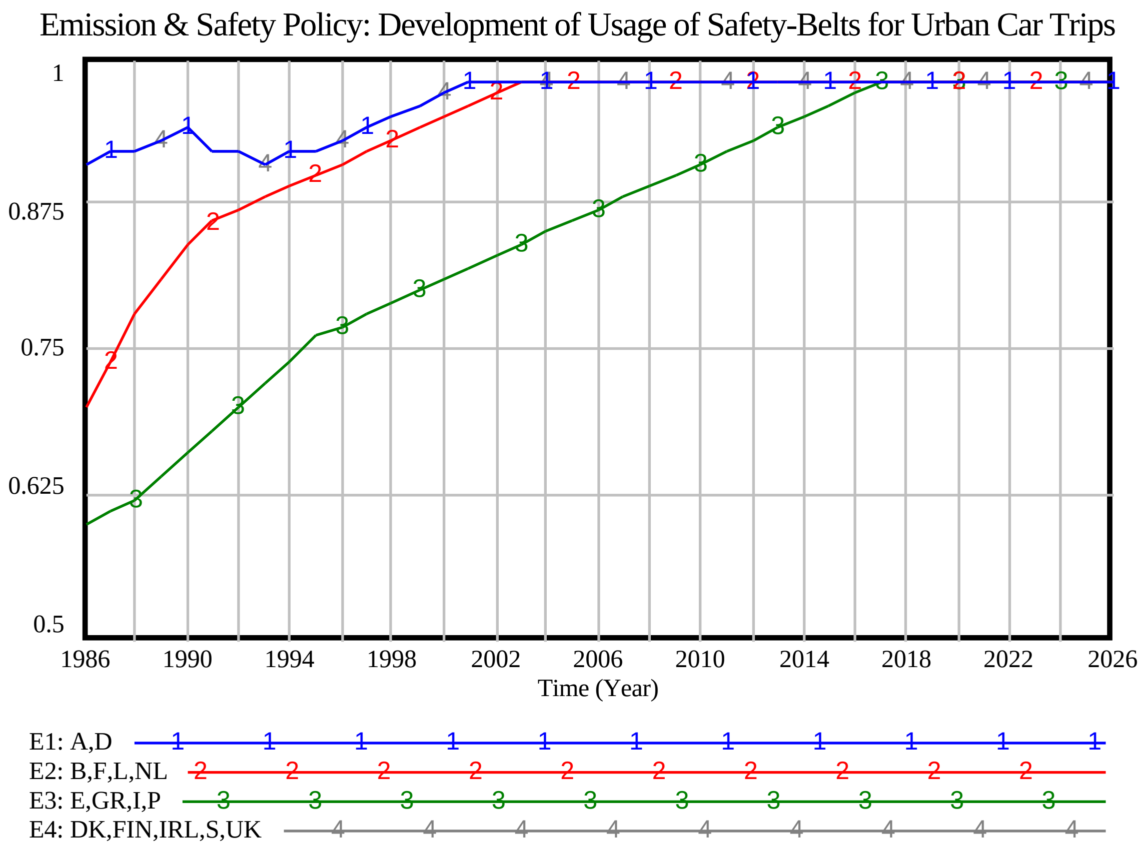

Figure 29: Usage factor of safety-belts for urban car trips in emission and safety policy package

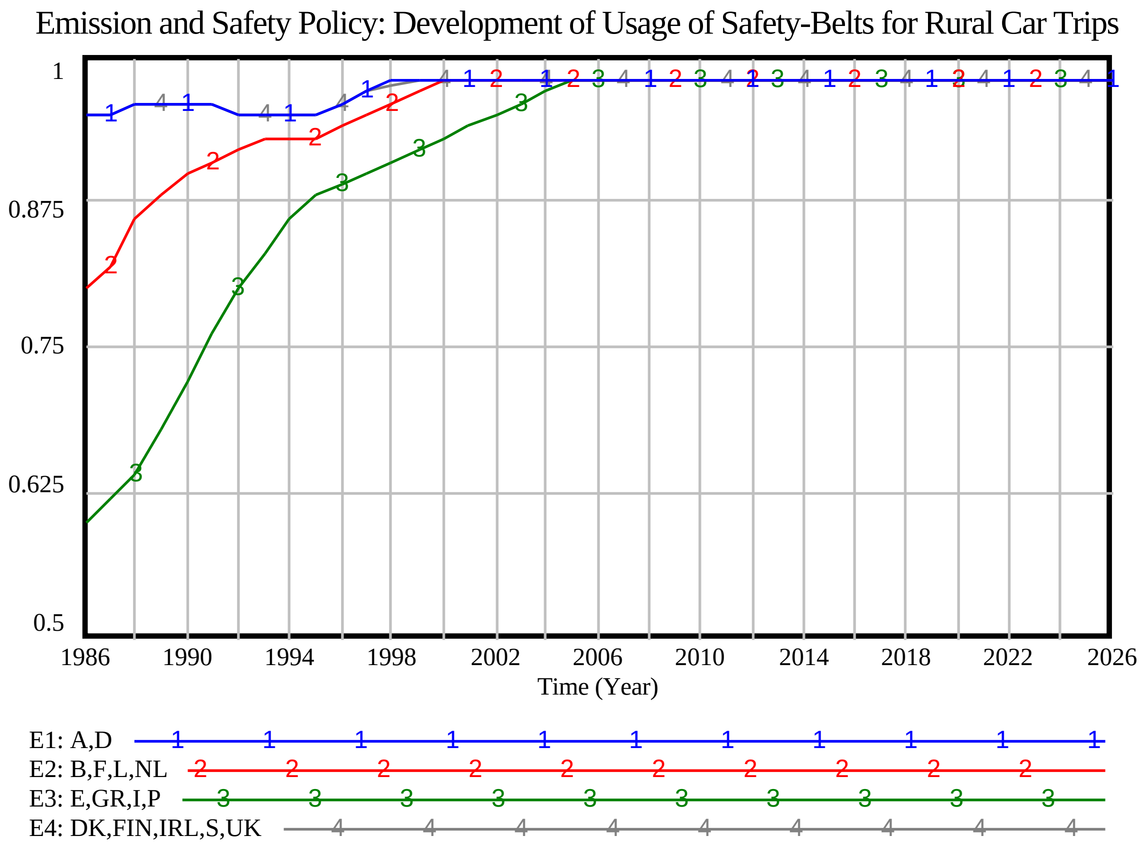

Figure 30: Usage factor of safety-belts for rural car trips in emission and safety policy package

The safety effect of the severely controlled speed limit of 80 km/h for trucks is estimated to be a reduction of 5% of the accident rate.

13.5.2 Policy Package 2: Increased Fuel Tax Plus Reduction of Labour Costs (IFT)

This policy increases the fuel price for gasoline and diesel by a stepwise increase in fuel tax. The additional revenues are mainly used to reduce the labour cost thus resulting in an increased GVA per economic sector. These changes are shown in the following figures and tables. Figure 31 and figure 32 show the development of the gasoline and the diesel fuel price in the policy.

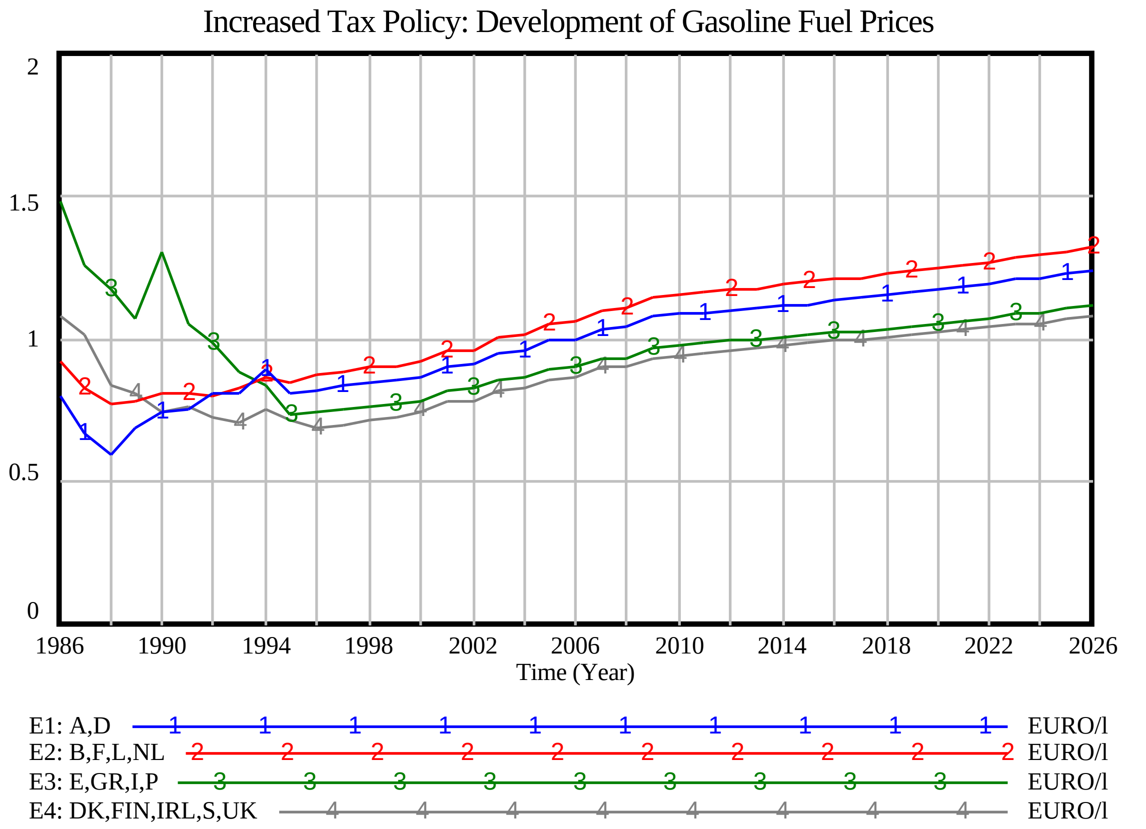

Figure 31: Development of gasoline fuel prices with increased fuel tax policy for the 4 regions

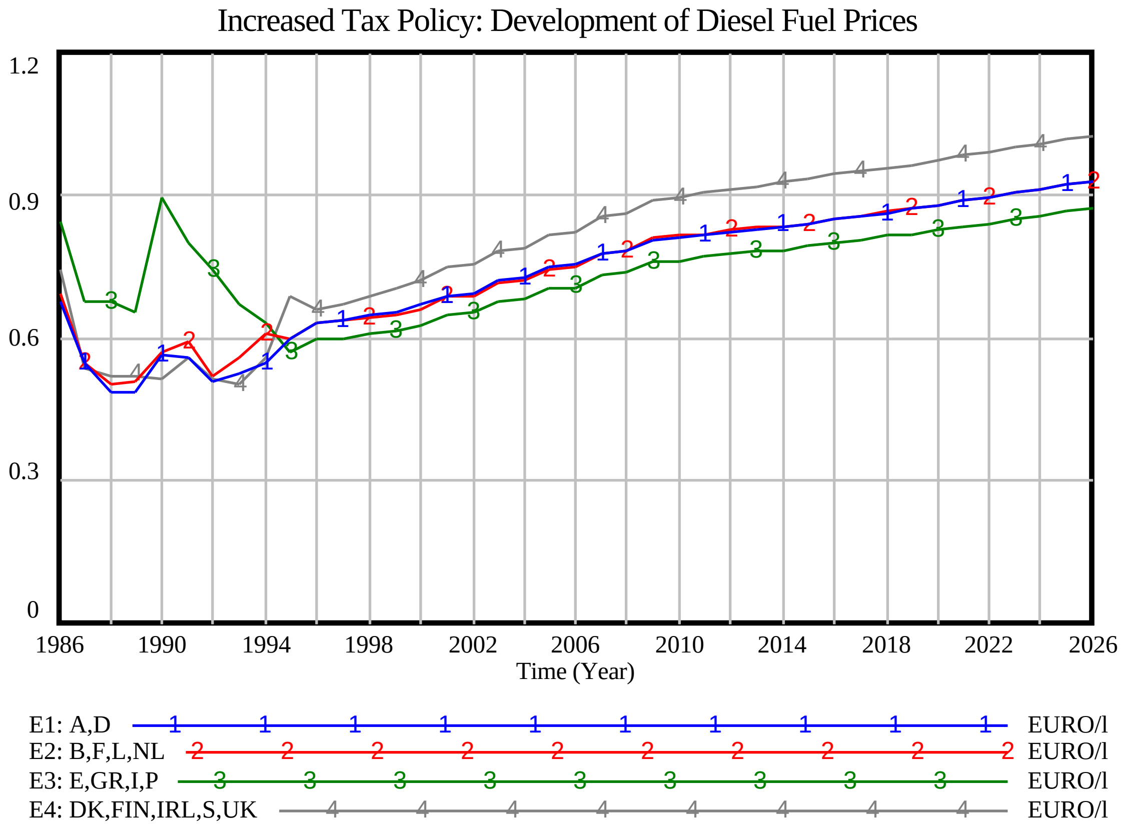

Figure 32: Development of diesel fuel prices with increased fuel tax policy for the 4 regions

The next figure 33 presents the resulting additional tax revenues generated by the above described increase of fuel price.

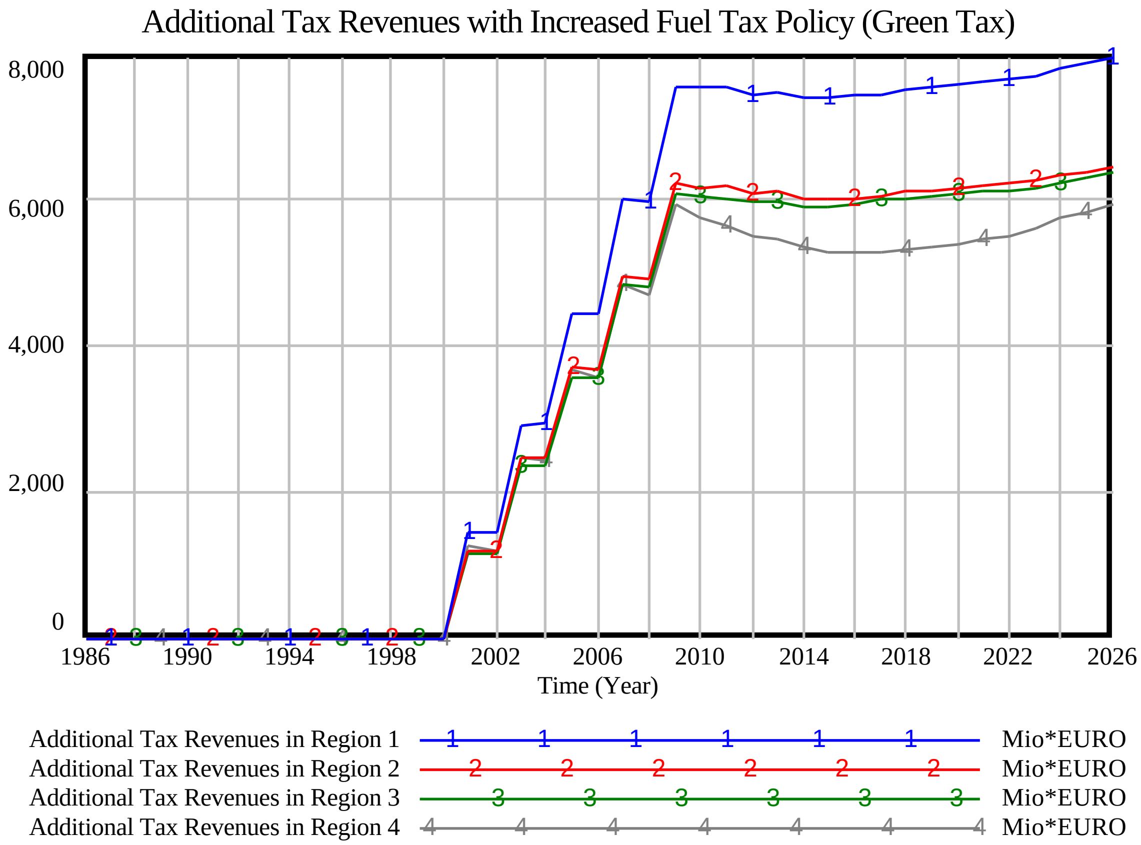

Figure 33: Additional tax revenues generated by the fuel tax increases for gasoline and diesel

These additional revenues are used to reduce the labour cost and produce additional sectoral GVA, which is shown in table 134. The sectors in the table are explained in more detail in table 1.

Table 134: Sectoral additional GVA caused by the reduction of labour cost

Region [Mio*EURO]	Economic Sector	2000	2004	2008	2010	2020
E1: A,D	Agriculture	0	7.86	15.57	19.41	17.15
	Energy&Resources	0	19.25	40.01	51.1	52.41
	Chemical Products	0	61.16	124.03	156.51	151.48
	Ores, Metals	0	11.82	23.48	29.22	26.92
	Machinery	0	88.31	174.21	213.42	213.88
	Electrical Goods	0	33.64	67.9	85.61	83.18
	Textiles	0	30.75	62.9	79.77	78.89
	Food	0	32.31	69.11	89.99	101.32
	Construction	0	42.42	85.52	107.55	101.55
	Service Sales	0	120.84	245.5	310.81	307.45
	Service Financial	0	12.37	30.8	42.55	58.71
	Non-market Services	0	122.27	250.84	318.65	322.26
E2: B,F,L,NL	Agriculture	0	14.56	28.73	35.9	33.07
	Energy&Resources	0	17.99	36.99	47.08	48.25
	Chemical Products	0	48.15	96.1	120.44	115.68
	Ores, Metals	0	9.867	19.1	23.29	21.4
	Machinery	0	42.3	79.11	91.49	83.6
	Electrical Goods	0	18.18	36.16	45.23	43.72
	Textiles	0	24.51	49.07	61.74	59.42
	Food	0	33.23	71.28	92.86	105.21
	Construction	0	37.6	73.27	91.11	81.26
	Service Sales	0	117.47	238.88	302.54	303.39
	Service Financial	0	26.05	54.45	69.93	76.57
	Non-market Services	0	96.91	198.5	253.23	260.35
E3: E,GR,I,P	Agriculture	0	13.06	26.45	33.33	31.15
	Energy&Resources	0	16.82	35.9	45.9	47.99
	Chemical Products	0	42.41	86.09	107.91	102.68
	Ores, Metals	0	7.858	15.56	18.43	16.05
	Machinery	0	38.75	74.26	82.85	75.1
	Electrical Goods	0	17.27	35.58	45.09	45.21
	Textiles	0	31.53	64.21	81.19	79.24
	Food	0	27.36	59	76.52	84.4
	Construction	0	31.36	63.77	80.88	77.57
	Service Sales	0	109.1	227.06	288.94	294.95
	Service Financial	0	30.82	68.73	89.94	104.96
	Non-market Services	0	99.7	203.99	259.22	254.44
E4: DK,FIN,IRL,S,UK	Agriculture	0	11.75	22.56	27.58	23.19
	Energy&Resources	0	15.36	31.62	39.92	40.59
	Chemical Products	0	41.42	78.09	94.75	80.37
	Ores, Metals	0	4.656	8.599	10.24	8.401
	Machinery	0	56.38	102.82	118.04	99.1
	Electrical Goods	0	18.27	34.93	42.74	37.95
	Textiles	0	28.31	54.45	66.69	58.7
	Food	0	29.58	61.26	78.24	84.57
	Construction	0	33.29	62.47	75.55	61.35
	Service Sales	0	105.87	209.3	260.56	250.68
	Service Financial	0	20.46	44.22	57.37	65.27
	Non-market Services	0	120.02	232.89	287.26	265.65

13.5.3 Policy Package 3: Balanced Fuel Tax Plus Reduction of Labour Costs (BFT)

This policy increases the fuel price for kerosene and diesel by a stepwise increase in fuel tax such that the differences in taxation between gasoline, diesel and kerosene are balanced. The additional revenues are mainly used to reduce the labour cost thus resulting in an increased GVA per economic sector. These changes are shown in the following figures and tables. Figure 34 and figure 35 show the development of the diesel and the kerosene fuel price in the policy. In contrast to the regionalised diesel and gasoline prices the kerosene price is assumed to be the same for all regions and therefore is presented only for EU15.

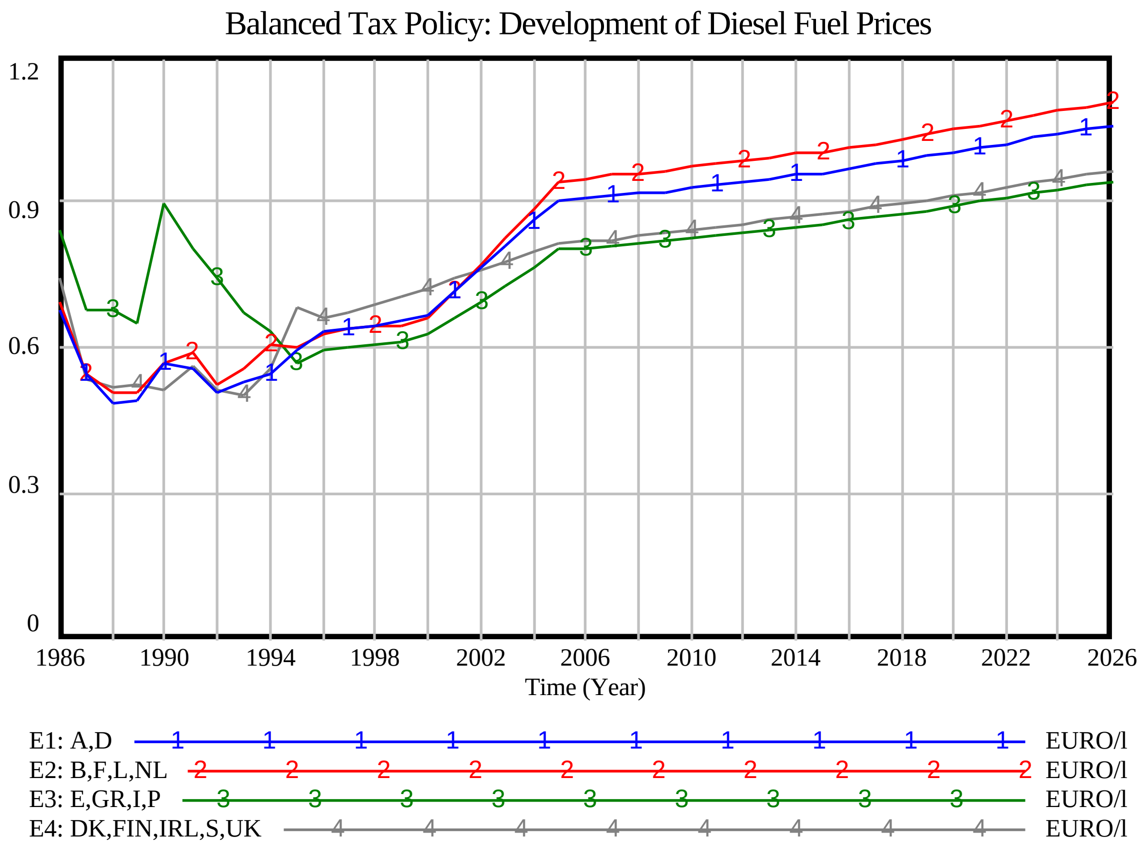

Figure 34: Development of diesel fuel prices with balanced fuel tax policy for the 4 regions

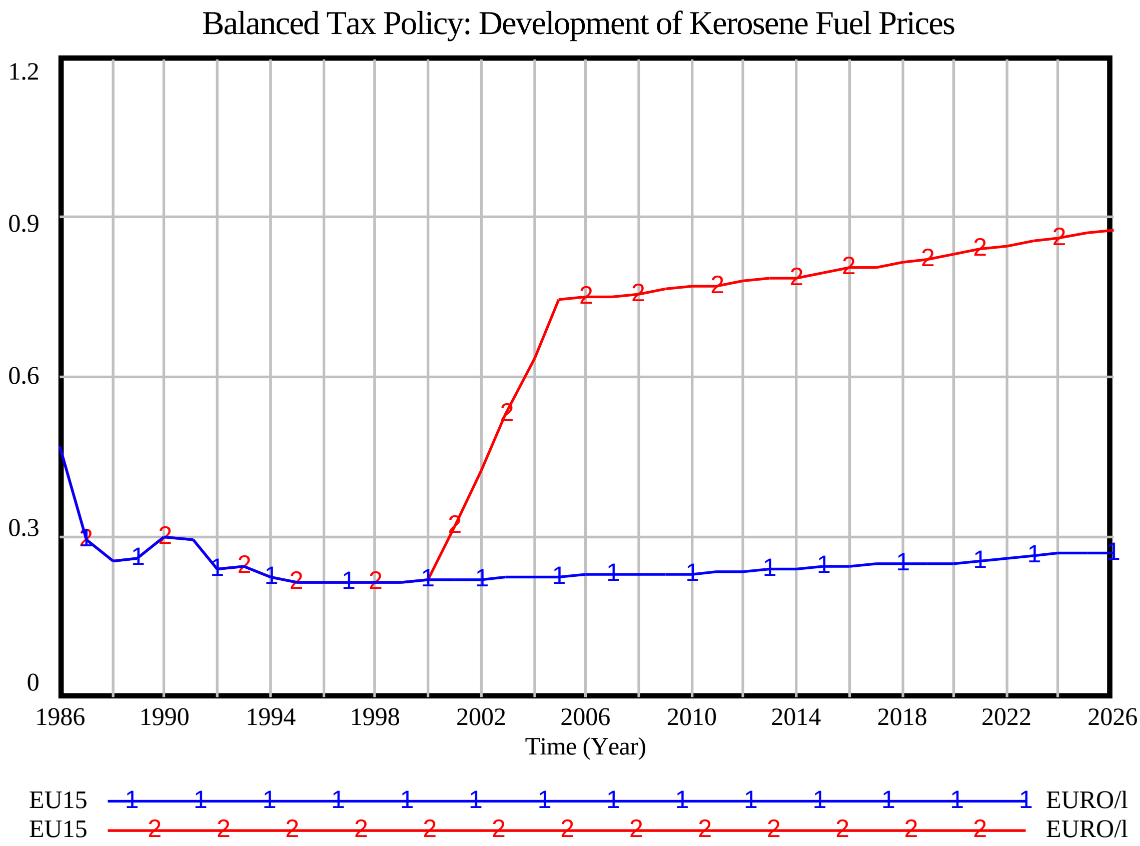

Figure 35: Development of kerosene fuel prices with balanced fuel tax policy

The next figure 36 presents the resulting additional tax revenues generated by the above described increase of fuel price respectively fuel tax.

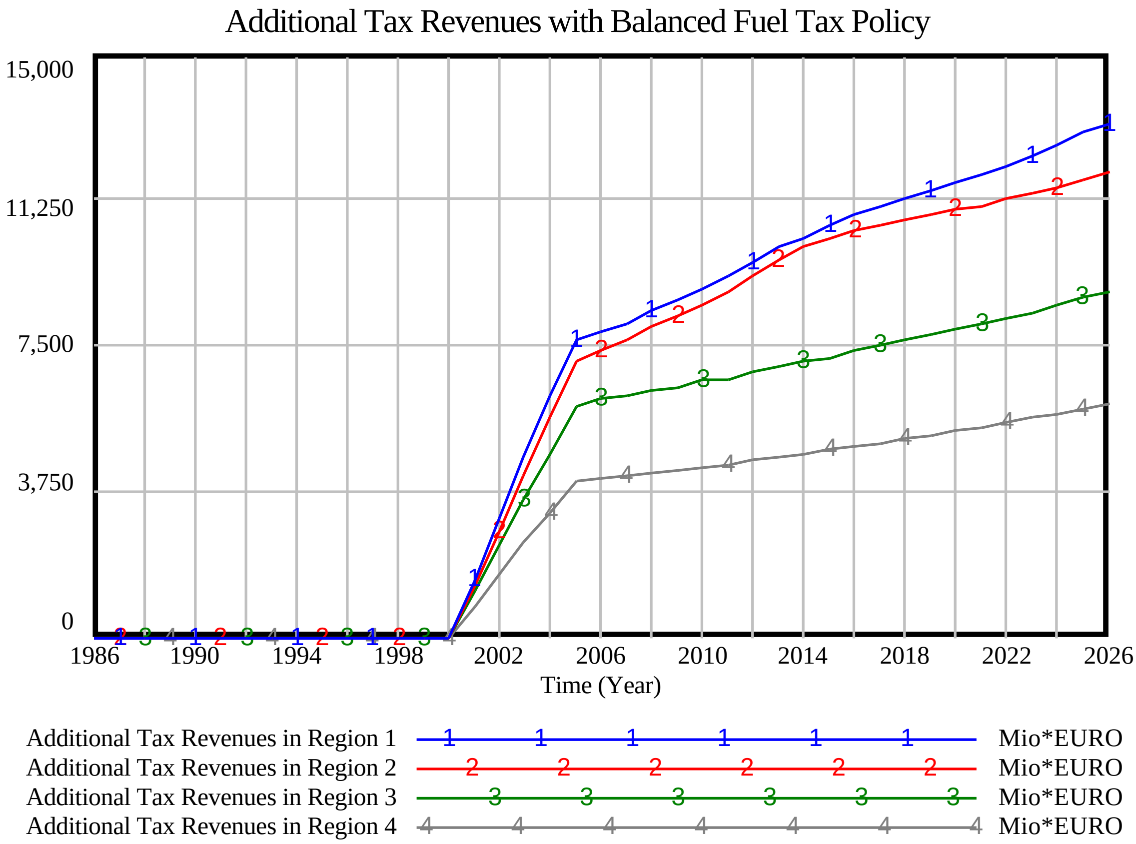

Figure 36: Additional tax revenues generated by the fuel tax increases for kerosene and diesel

These additional revenues are used to reduce the labour cost and produce additional sectoral GVA, which is shown in table 135. The sectors in the table are explained in more detail in table 1.

Table 135: Sectoral additional GVA caused by the reduction of labour cost

Region [Mio*EURO]	Economic Sector	2000	2004	2008	2010	2020
E1: A,D	Agriculture	0	16.58	21.83	23.02	26.59
	Energy&Resources	0	40.57	55.85	60.31	80.58
	Chemical Products	0	128.94	173.46	185.07	233.63
	Ores, Metals	0	24.94	32.89	34.61	41.65
	Machinery	0	185.65	243.53	252.1	328.56
	Electrical Goods	0	70.94	94.98	101.23	128.12
	Textiles	0	64.82	87.91	94.25	121.44
	Food	0	67.95	96.1	105.8	154.76
	Construction	0	89.14	118.91	126.31	155.67
	Service Sales	0	254.94	343.42	367.45	473.26
	Service Financial	0	25.79	42.28	49.45	89.1
	Non-market Services	0	258.13	351.05	376.77	495.96
E2: B,F,L,NL	Agriculture	0	33.44	46.31	49.58	59.09
	Energy&Resources	0	41.25	59.41	64.76	85.67
	Chemical Products	0	110.55	154.84	166.3	206.66
	Ores, Metals	0	22.64	30.77	32.16	38.26
	Machinery	0	96.75	127.14	126.07	149.28
	Electrical Goods	0	41.72	58.19	62.35	77.85
	Textiles	0	56.26	78.98	85.12	105.86
	Food	0	76.06	114	127.15	185.44
	Construction	0	86.02	117.44	125	144.53
	Service Sales	0	269.64	384.03	416.44	539.21
	Service Financial	0	59.65	87.24	95.94	135.13
	Non-market Services	0	222.71	319.68	348.92	462.75
E3: E,GR,I,P	Agriculture	0	26.25	34.59	36.05	40.53
	Energy&Resources	0	33.79	46.85	49.51	62.17
	Chemical Products	0	85.29	112.63	116.69	133.51
	Ores, Metals	0	15.79	20.37	19.93	20.93
	Machinery	0	77.67	97.11	89.25	97.13
	Electrical Goods	0	34.7	46.48	48.69	58.62
	Textiles	0	63.38	83.95	87.74	102.84
	Food	0	54.88	76.84	82.41	109.05
	Construction	0	62.91	83.04	87	100.37
	Service Sales	0	219.55	296.93	312.23	382.51
	Service Financial	0	61.76	89.36	96.69	135.33
	Non-market Services	0	200.9	267.24	280.51	330.55
E4: DK,FIN,IRL,S,UK	Agriculture	0	15.37	19.91	20.67	22.89
	Energy&Resources	0	20.08	27.83	29.81	39.72
	Chemical Products	0	54.25	69.01	71.07	79.37
	Ores, Metals	0	6.107	7.604	7.682	8.307
	Machinery	0	74.11	91.1	88.45	97.85
	Electrical Goods	0	23.9	30.82	32.01	37.31
	Textiles	0	37.05	48.06	49.96	57.76
	Food	0	38.6	53.79	58.31	82.41
	Construction	0	43.44	54.88	56.3	60.19
	Service Sales	0	138.71	184.74	195.1	245.9
	Service Financial	0	26.68	38.77	42.68	63.56
	Non-market Services	0	157.26	205.69	215.16	260.81

13.5.4 Policy Package 4: Rail-TEN policy

For the Rail-TEN policy gasoline and diesel taxation are increased in the period from 2000 to 2015 to an extent that the additional revenues are sufficient to completely finance the construction of the priority rail TENs. The following figure 37 and figure 38 present the development of gasoline and diesel fuel price in this policy.

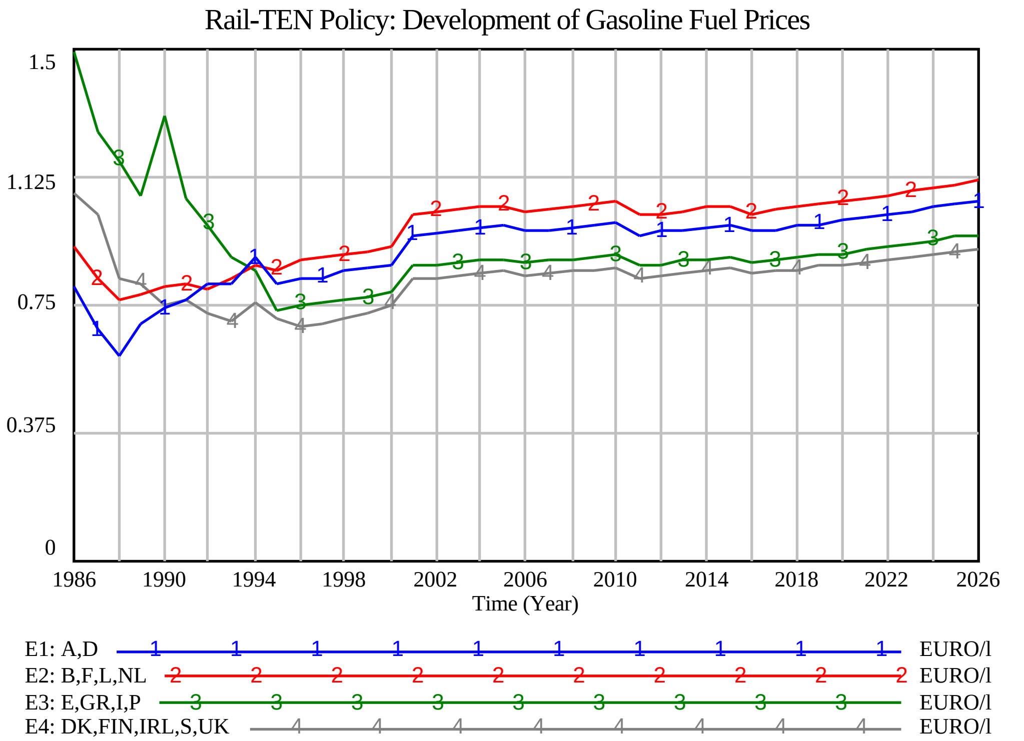

Figure 37: Development of gasoline fuel prices in Rail-TEN policy for the 4 regions

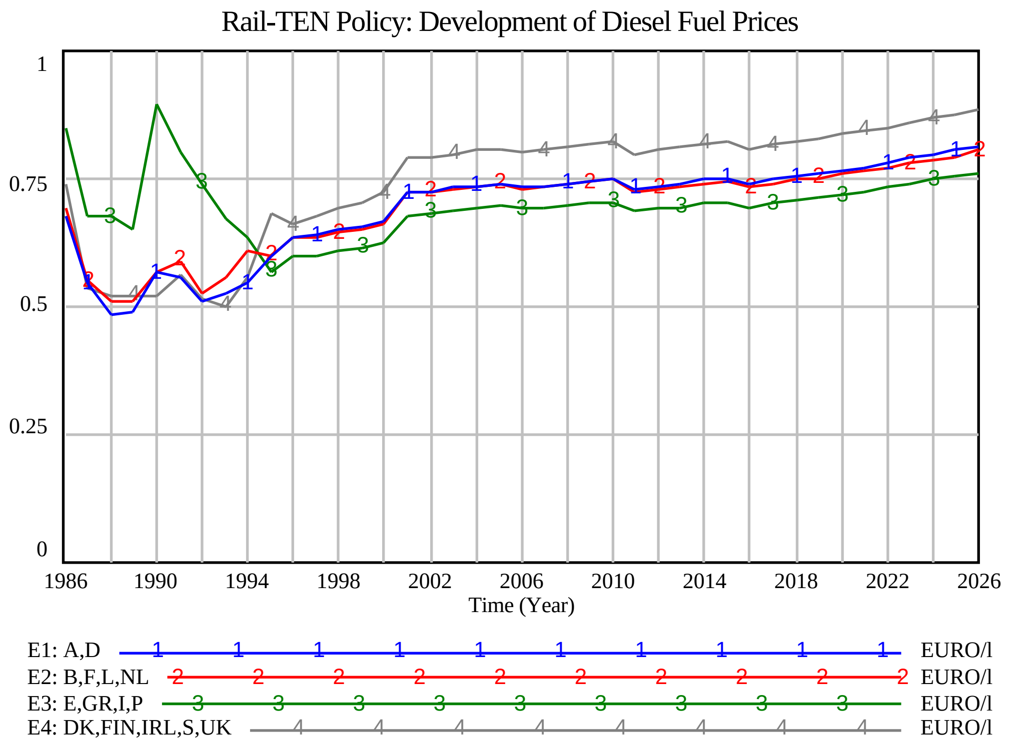

Figure 38: Development of diesel fuel prices in Rail-TEN policy for the 4 regions

The additional tax revenues of all four regions are collected and are spent for the construction of the rail priority TEN according to the current plans. This leads to the regional investments presented in figure 39.

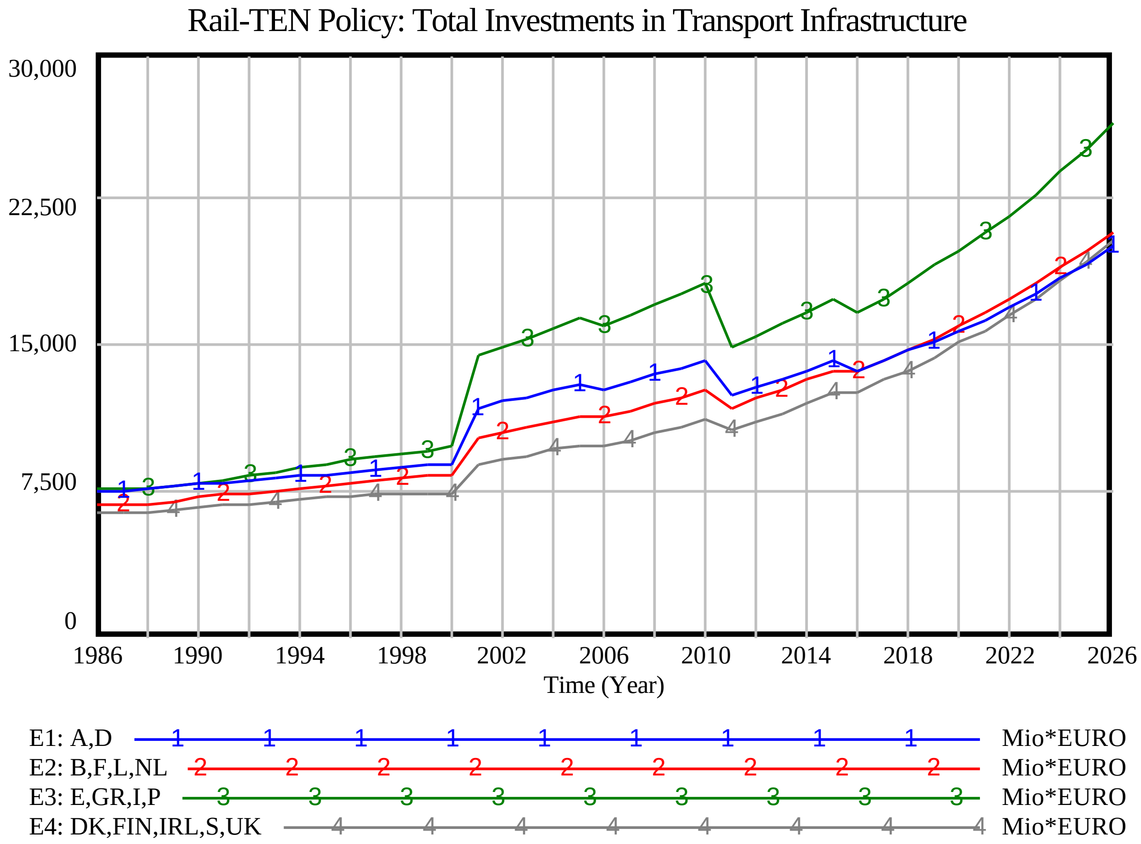

Figure 39: Total investments in transport infrastructure with Rail-TEN policy in the four regions

13.5.5 Integrated Policy Programme (IPP)

For the implementation of the integrated policy programme (IPP) the effects described in section 13.5.1 are in the same way implemented and the fuel taxes are increased to reflect the integration of the tax increases taken in the IFT, the BFT and the Rail-TEN policy. This leads to the fuel prices shown in figure 40 and figure 41.

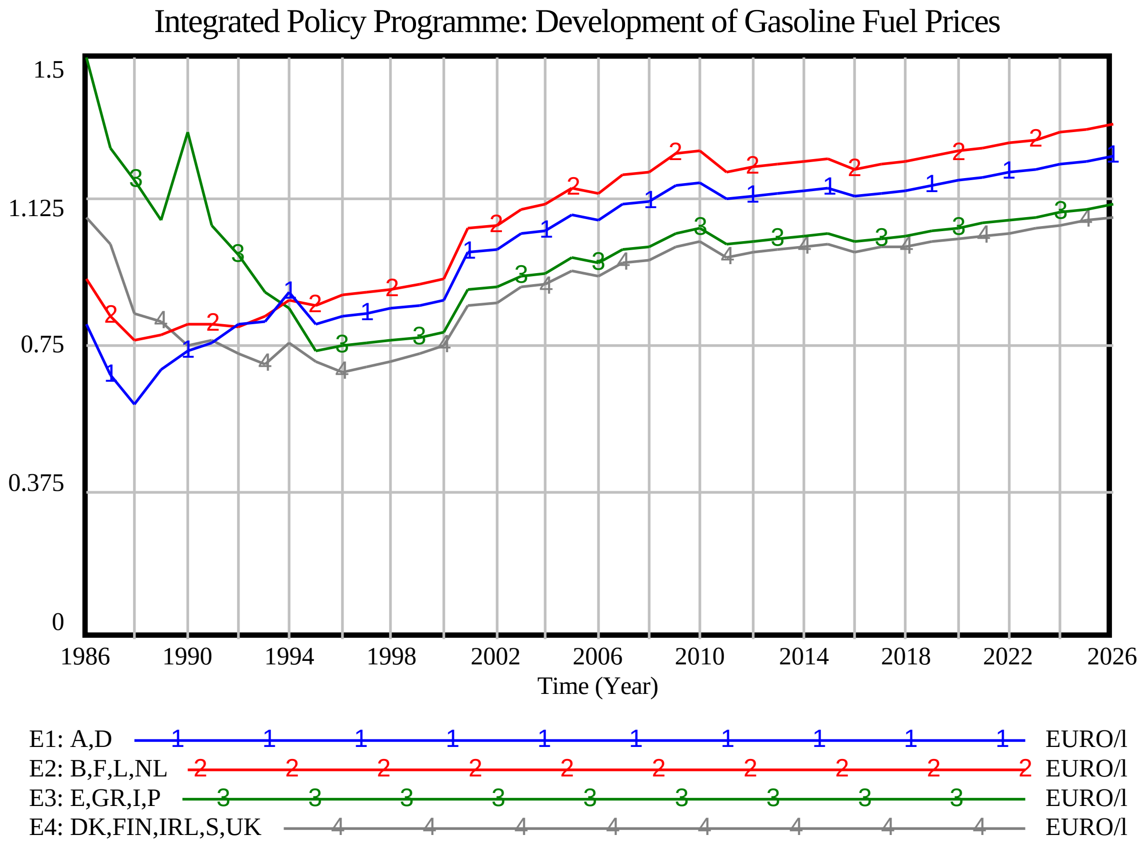

Figure 40: Development of gasoline fuel prices in integrated policy programme for the 4 regions

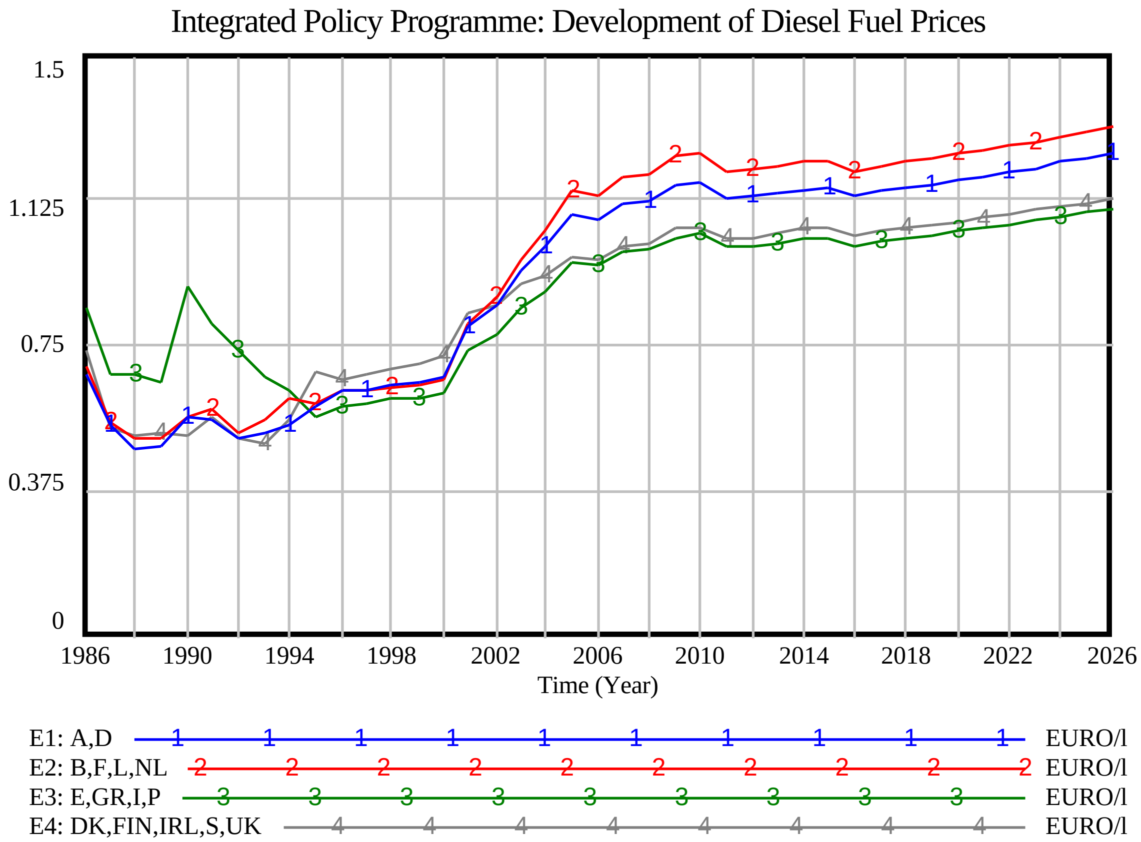

Figure 41: Development of diesel fuel prices in integrated policy programme for the 4 regions

13.5.6 Overview on the Development of Diesel Fuel Prices in the Policies

This section is closed with a cross-policy comparison of the development of the diesel fuel prices in the four regions. The development in the regions is presented in one of the following figures each.

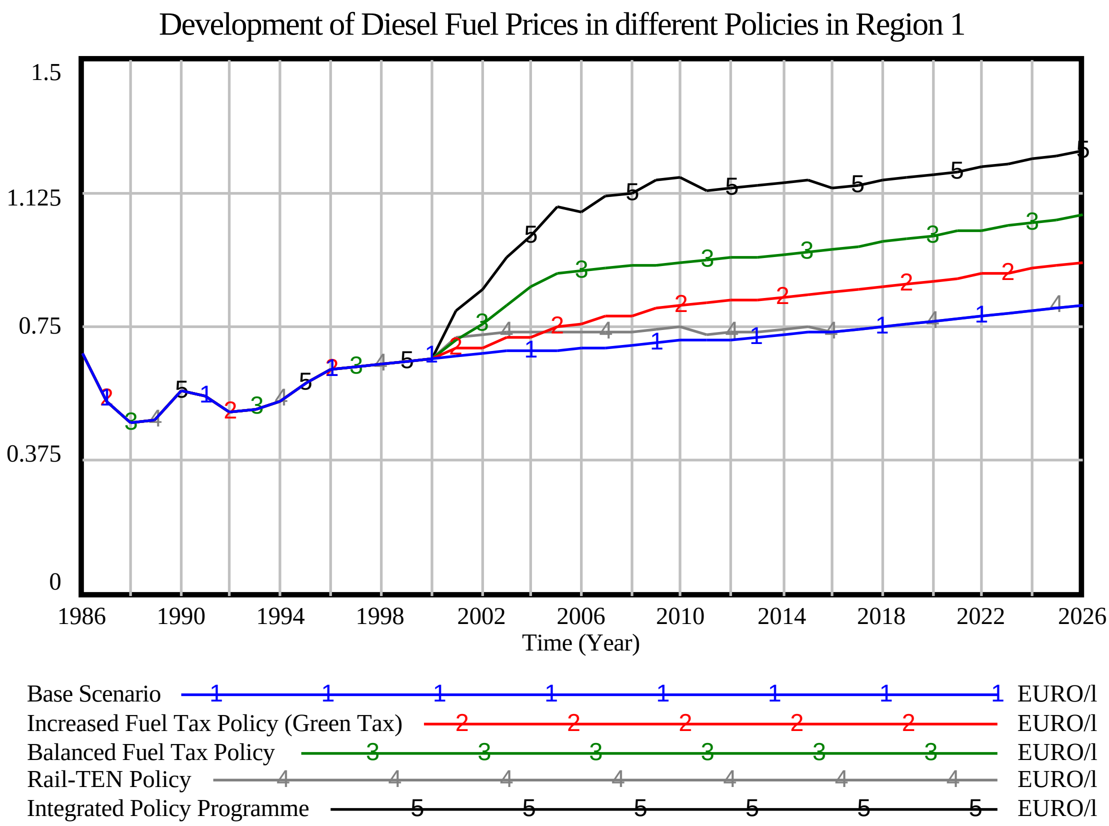

Figure 42: Cross-policy comparison of development of diesel fuel prices in region 1

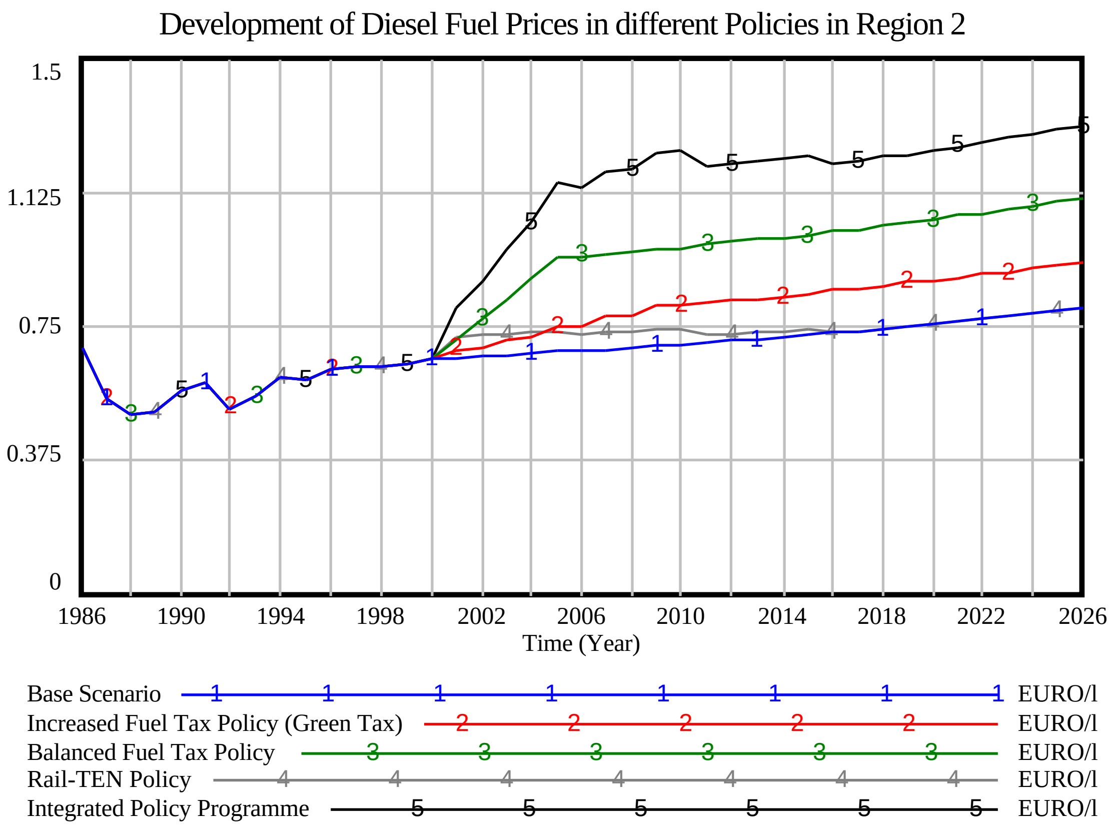

Figure 43: Cross-policy comparison of development of diesel fuel prices in region 2

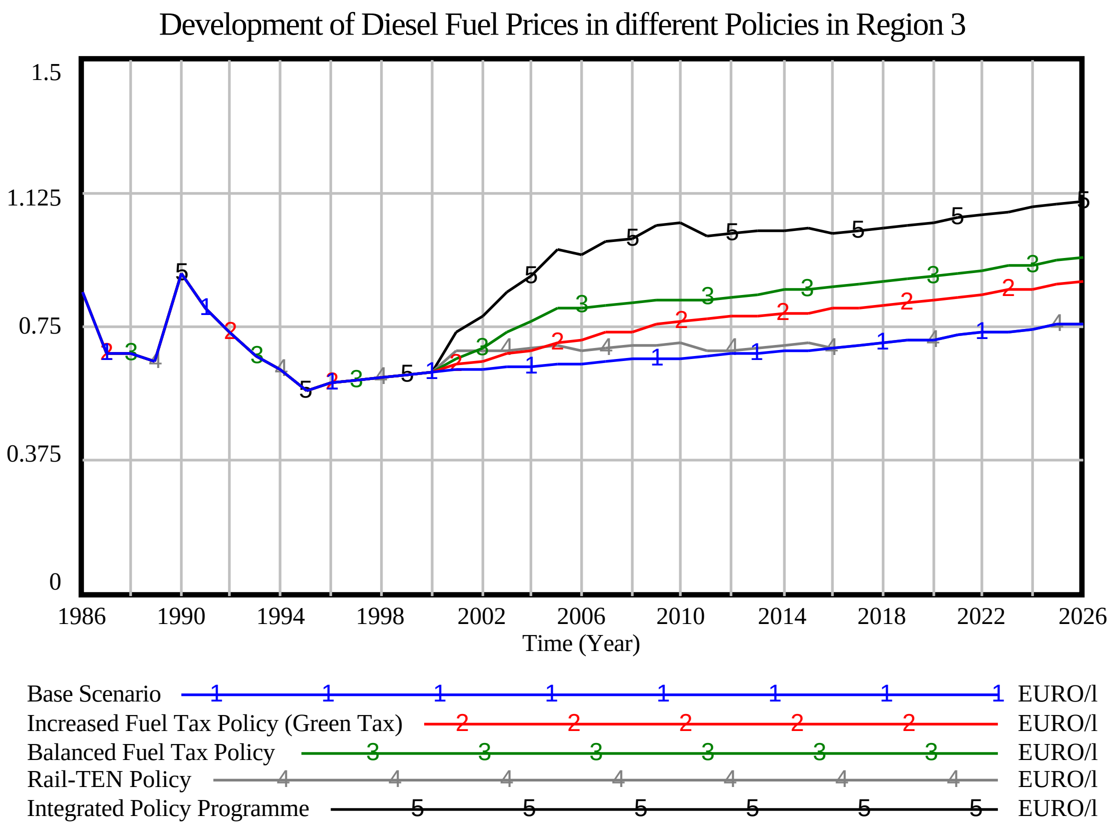

Figure 44: Cross-policy comparison of development of diesel fuel prices in region 3

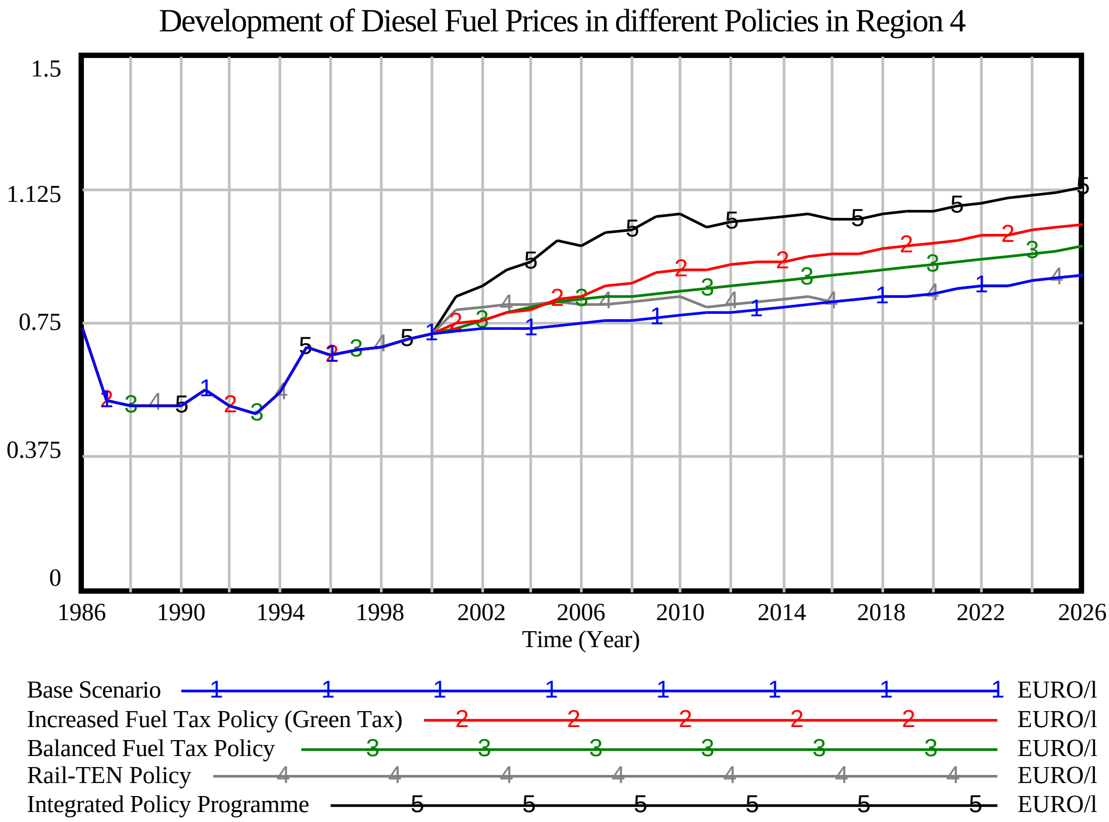

Figure 45: Cross-policy comparison of development of diesel fuel prices in region 4

14 Annex C: Description of the ASTRA model in ithink

The development of the ASTRA model is initially commenced based on the ithink system dynamics software package. This section of the annex briefly describes special features of the ithink approach. It starts with an overview on the model structure, then provides a glance on the potentials of the ithink user interface, continues with an explanation of the transfer from ithink to Vensim and concludes with a description of the MAC sub-modules in ithink, which is quite different from the approach chosen in the Vensim ASP.

14.1 Structure of the ithink ASTRA model (iAM)

The ithink ASTRA model (iAM) integrates key relationships of state-of-the-art models in the fields of macroeconomics, regional economics and land use, transport and a model of the car vehicle fleet. It is composed of the three sub-modules: macroeconomics sub-module (**MAC**), regional economics and land use sub-module (**REM**), transport sub-module (**TRA**) and a vehicle fleet model (**VFM**). Results of the underlying conventional models are used for calibration of the iAM sub-modules.

In the following the global structure and interrelationships of the model are presented in comprehensive diagrams. The first diagram (figure 46) presents the structure of the models that superimpose each other in the iAM. The structure consists of the three sub-modules MAC, REM, TRA, the car vehicle fleet model (VFM) and the passenger and the freight model that are formed by parts of REM and TRA. Also the conventional models underlying the four sub-modules are shown. They provide key-relationship and calibration data for the implementation of the sub-modules.

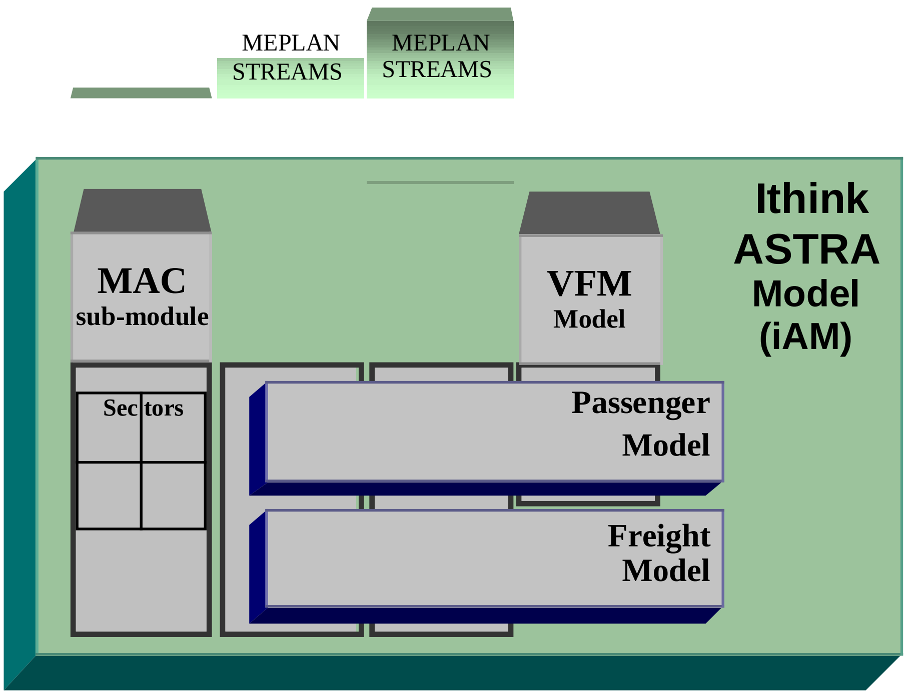

Figure 46: Structure of the ithink ASTRA model platform (iAM)

The second diagram (figure 47) presents a global overview on the implemented interrelationships between the different sub-modules. All data that is transferred between two sub-modules is produced endogenously and is provided by the distributing sub-module for every integration period DT to the receiving sub-module. Here, it should be noted that the results of the TRA and parts of the REM concerning transport variables are calculated on a daily basis while MAC is working on a yearly basis. So, interfaces between the former and the latter have to consider an annualisation of the data. In figure 47 an interface can be identified at all positions where an arrow is shown.

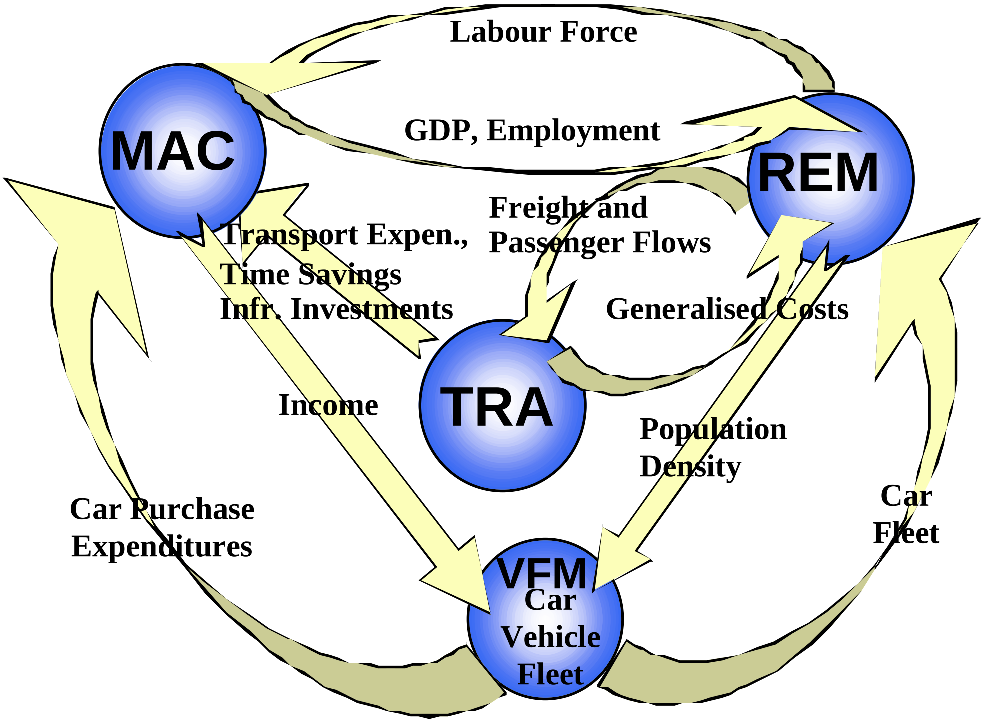

Figure 47: iAM interelationships

The third diagram (figure 48) presents the main relationships that drive the passenger model. Mainly the development of disposable income influences the car vehicle fleet. Population density and fuel prices are considered to be further influences on the fleet. The actual stock of the cars then provides an input for the car-ownership calculation. Together with the population development (distinguished into age classes) and the trip rates (dependent on household types) the car-ownership drives the trip demand. The demand is transferred to the TRA where the modal-split (dependent on times and costs) and assignment is determined. The TRA calculates the number of trips and the traffic volume for the different passenger modes. Based on this output transport expenditures, business and leisure time savings are calculated and transferred to the MAC. Within the MAC the time savings form an input for the calculation of potential output and wages. The transport expenditures, which cover only perceived cost, are part of consumption. Trips and traffic volume are also transferred to the ENV where indicators for fuel consumption, emissions and accidents are calculated. Based on the fuel consumption the fuel tax is calculated and transferred to the MAC where it performs an influence on consumption for certain policies. Based on vehicle purchase the fixed costs for car purchase are calculated and added to transport expenditures such that they also influence consumption.

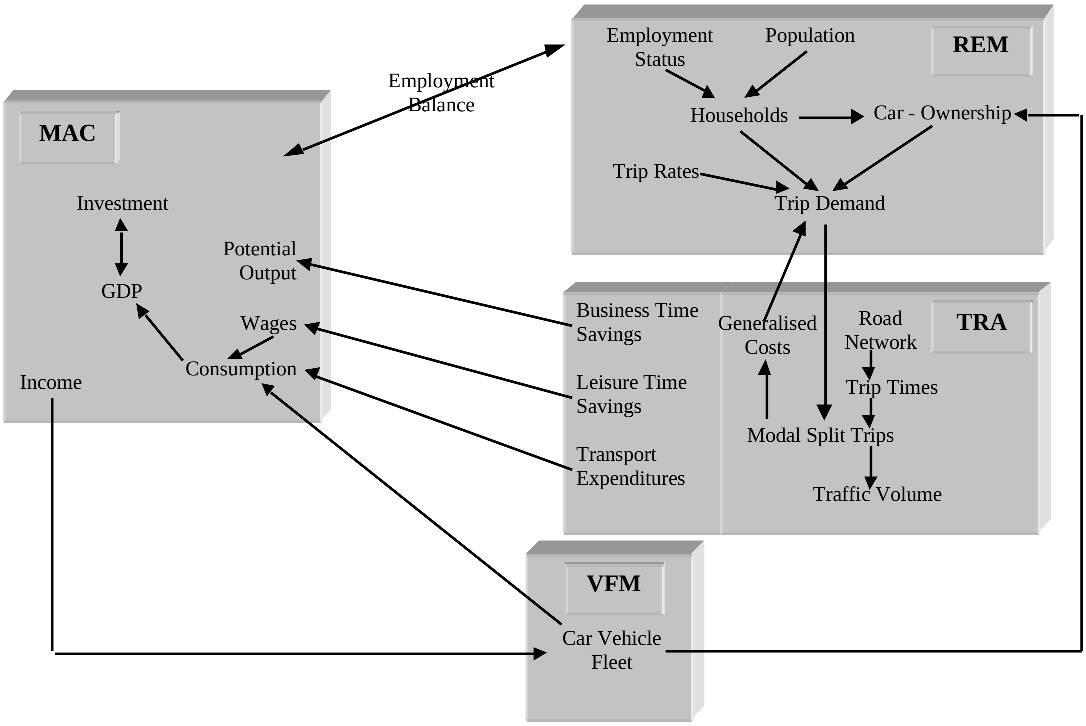

Figure 48: Aggregated Relationships of the Passenger Model

The fourth diagram (figure 49) presents the main relationships that drive the freight model. In the freight model there is a strong relationship between the MAC and the REM. GDP and imports/exports are transferred from MAC to REM where they form an input to generate the transport flows. The resulting transport demand is transferred to the TRA where the modal-split is performed and the traffic volume for the freight modes is calculated. Based on the traffic volume freight time savings are calculated and transferred to the MAC, where they are recapitalised and therefore influence the capital stock. The traffic volume is transferred to the ENV to calculate the environmental indicators. Also the demand for freight transport expressed by the traffic volume together with the average truck life time steers the purchase of LDV and HDV and therefore influences the fleet. The output relationships of the ENV are similar to the ones in the passenger model.

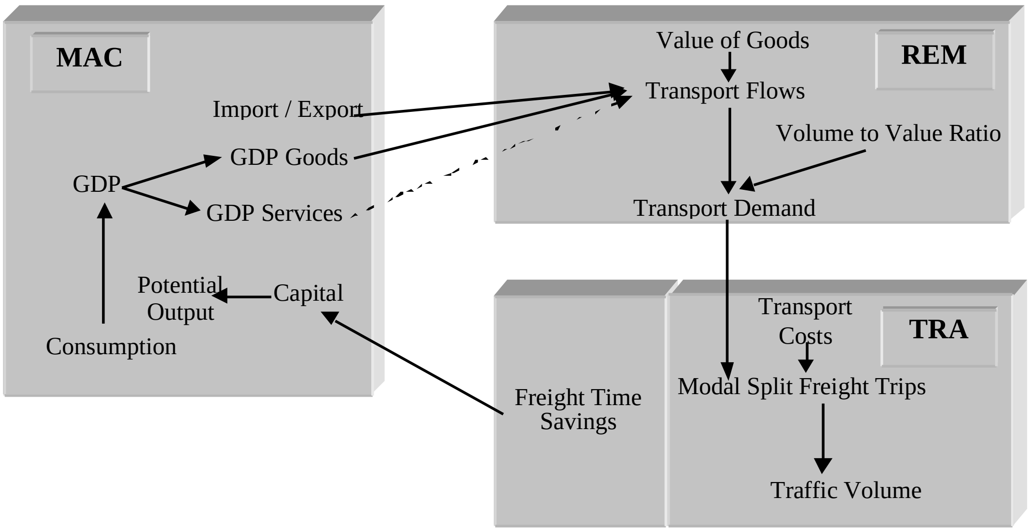

Figure 49: Aggregated Relationships of the Freight Model

14.2 Glance on the ithink model interfaces

Ithink[35] provides three levels for model development. On the top level it is possible to create a user-interface with a user-friendly handling to test different policies. Also, aggregated maps of the model structure can be designed, which display the ithink model sectors. On the middle level the structure of the model (e.g. stocks, flows) is designed and the relationships given by the equations can be implemented. The bottom level contains the whole list of equations. It can be used to insert equations, too.

The top and the middle level can be used to analyse the logical structure of the ***iAM***. On the top level the map of all ASTRA ithink model sectors is displayed. This map includes also the links between the different sectors. By double clicking a link a dialog box is displayed that presents the information, which variables of the linked sectors are building the interface between the sectors. Because of the size of this map it can not be presented in the form of a deliverable. Second, the detailed structure of the model can be viewed on the middle level of the ***iAM***. The model structure covers already about 100 pages and therefore it is also not possible to present it here.

For the assessment of policies a control panel is in parts developed on the top level of the ***iAM***. The control panel consist of a steering panel, a display panel and a parameter panel. With the *steering panel* model simulation runs are started and controlled. Also the principles are shown how policies can be varied on this panel. The results of model simulation runs are presented on the ASTRA *display panel*, which is placed besides the steering panel. On this panel different types of graphs and tables presenting the model results can be shown. The ASTRA ithink panels can especially be designed for the needs of decision makers such that they can easily create their own policy packages, immediately can test these packages and reveal results for the most important indicators. Experts in the use of the ithink software tool might in addition work on the middle level of ithink, which contains the detailed structural presentation of an ithink model, and by this create new policies or new output graphs. The version of the steering panel that is shown in figure 50 consists of the main simulation control box, the environmental policy box, the transport policy box and the regional and distance band assessment boxes. The simulation control box is used to start, pause and stop simulation runs. The other boxes are used to set model parameters or policy parameters. For instance the distance band assessment box consists of five switches to set the model parameters such that relevant indicators are only calculated for the distance bands that are switched on. The regional assessment box behaves similar. Other boxes e.g. the transport policy box are used to vary policy parameters like cost or tax variables.

35 Details about the ithink software can be obtained from the ithink documentation distributed by High Performance Systems (HPS 1997a, 1997b)

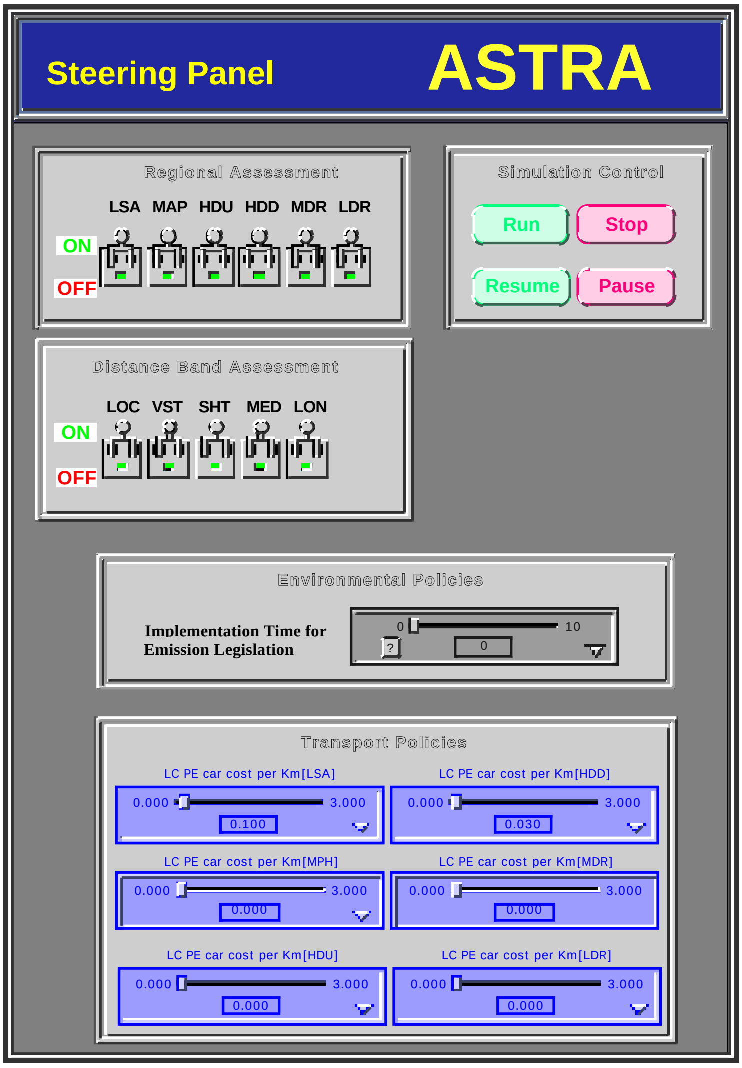

Figure 50: Screen shot of iAM steering panel in core model

14.3 ithink to Vensim transfer

When the modelling process of the ASP achieved a stage at which new and updated freight model components should be integrated the joint model reached the software size limit of ithink. Discussions with the hotline support for the ithink software revealed that the software is only able to handle 32767 entities. Roughly spoken one entity corresponds to one equation for a model variable. The meaning of equation varies from a constant value to a complex non-linear equation or graph. Obviously the updated ASTRA model would consist of a number of variables and corresponding equations that is higher than 32767, which can not be implemented with ithink. For the final ASP structure in Vensim a number of about 100.000 entities is counted.

After an intensive discussion of this issue the decision is taken to keep a core version of the model in the ithink world and develop the full version with the Vensim software. So, three sub-modules (MAC, REM and TRA) are furthermore developed with ithink, while the ENV is developed in Vensim. So, the core ***iAM*** consists of MAC, REM and TRA and the car vehicle fleet model (VFM) from the ENV. It is planned to transfer a calibrated version of this iAM into the Vensim syntax and subsequently link it with the calibrated ENV such that finally the full system dynamics model in Vensim comprises all sub-modules. For the transfer from ithink to Vensim a translation tool is developed, which provides a semi-automatic translation from ithink syntax to Vensim syntax. However, for every transfer process also some manual work is required. As test runs with the MAC approach in the iAM revealed a set of implausible results and only weak opportunities to implement policies and measure policy sensitivity it is decided to use an alternative approach for the MAC in the Vensim ASP. That also implied to modify the approach for calibration of REM and TRA such that both first are calibrated in their stand-alone versions in ithink. A second calibration phase is then undertaken with the integrated REM and TRA sub-modules in the full Vensim ASP.

Considering policy simulations the capabilities of the iAM are restricted to the explanation of reactions of the single stand-alone sub-modules. Also, environmental impacts and changes in the welfare situation can only be observed with the full Vensim ASP. Therefore it is recommended only to use the full Vensim ASP for policy tests.

14.4 Macroeconomics Sub-module (MAC) in the ithink Model

This paper outlines the CEBR's proposed macro-modelling methodology for the MAC, the model of the EU macro economy.

First, it provides a brief description of the proposed model structure. Second, it discusses the potential linkages with the other components of the ASTRA modelling structure.

14.4.1 Introduction

The sub-module is based upon the familiar macroeconomic national accounting framework. It uses national data on the European System of Accounts 1979 basis.[36] The sub-module is formulated on the basis of 5 *macro regions*:

- Germany and Austria
- France, Belgium, Netherlands and Luxemboug
- Italy, Spain, Portugal and Greece
- UK, Ireland, Sweden, Denmark and Finland
- Rest of the World.

Each of the first 4 macro regions, which include all EU member states, has the equation structure set out in the equations described in chapter 14.4.2.

[36] SOEC (1995)

14.4.2 Internal Structure of the MAC in the ithink model

The core identity for the model is real gross domestic product for each region (GDP):

$$\mathbf{GDP \equiv C + I + G + X - M} \qquad \text{(eq. 24)}$$

Where: C = government and household consumption

I = fixed investment plus inventories

X = Exports

M = Imports

This identity therefore gives the aggregate Regional demand for goods and services. The supply of goods and services in a particular Region is represented by the Potential Output, modelled by equation 25 below.

$$\mathbf{YP = YP_{t-1} * (K/K_{t-1})^{\alpha} * (E*BTS/(E_{t-1}*BTS_{t-1}))^{\beta} * \gamma} \qquad \text{(eq. 25)}$$

Where: YP = potential output

K = Capital stock

E = Employment

BTS = Business & commuter time savings as a percentage of total time worked

α, β, γ = fixed coefficients

Potential output depends on the capital stock and the size of the current labour force taking into account any changes in productivity over time. One such change is due to business and commuting time savings through improvements in transport. This is treated as increasing labour productivity.

By comparing the supply of goods and services in the form of Potential Output with the demand for goods and services in the form of GDP expenditure, the rate of inflation in the Region's economy can be modelled.

The rate of inflation is therefore directly dependent upon Potential Output, GDP and the rate of inflation in the previous period.

$$\mathbf{\Delta P = f\ (YP, \Delta P_{t-1})} \qquad \text{(eq. 26)}$$

where: ΔP = change in prices

YP = potential output

ΔP_{t-1} = changes in prices in the previous period

If demand is outstripping supply then price increases will gradually filter into the economy and vice-versa.

Inflation is calculated separately for each Region. However in order to take into account the effects of European Monetary Union a single interest rate is used for the entire EU area. This reasonably assumes convergence amongst countries outside of the Euro-Zone. The interest rate is dependent upon the change in inflation, the interest rate in the previous period and the target rate of inflation.

$$\mathbf{Int = f(\Delta P_{t-1}, Int_{t-1}, T)} \qquad \text{(eq. 27)}$$

Where Int = rate of interest

ΔP_{t-1} = changes in prices in the previous period

T = target rate of inflation

Components of GDP:

Imports grow as a proportion of GDP growth. In other words spending on foreign goods and services is in line with the general domestic spending trend. The total value of imports is then split according the source Region using fixed coefficients.

$$\mathbf{M = f(\Delta GDP_{t-4}, M_{t-1})} \qquad \text{(eq. 28)}$$

$$\mathbf{M_i = K_i \times M}$$

Where M = Imports

M_i = the imports by region i from the region under consideration.

K = a constant

The total value of a Region’s exports can then be derived from the import figures. For example Region 1’s exports are the sum of Region 2,3,4 and 5 s’ imports from Region 1.

$$\mathbf{X \equiv \Sigma M_I} \qquad \text{(eq. 29)}$$

Where X= exports

M_i = the imports by region (i) from the region under consideration.

Investment is a function of the lagged change in GDP. It is also sensitive to the level and rate of change of interest rates. This reflects the investment decisions of firms based upon the level of demand and the rate of return.

$$\mathbf{Inv = f(Inv_{t-1}, \Delta GDP_{t-4}, Int, \Delta Int_{t-1})} \qquad \text{(eq. 30)}$$

Consumption is dependent upon the growth in personal disposable incomes, interest rate and inflation. Higher interest rates will encourage saving and higher prices will discourage consumption. The level of current expenditure on transport is also accounted for through a linkage with the transport module. Government consumption is aggregated into the consumption variable. This takes account of transport taxes which are calculated through the environmental submodule.

$$\mathbf{C = f(\Delta PI, Int, \Delta Int, P, \Delta P)} \qquad \text{(eq. 31)}$$

Aggregate personal disposable income grows according to growth in employment and wage levels.

$$\mathbf{PDI = f(PDI_{t-1}, \Delta Emp, \Delta W)} \qquad \text{(eq. 32)}$$

Where Emp = Employment

W = Wage level

Changes in the wage level depend on changes in prices in the previous period, unemployment and changes in unemployment levels. A link with the transport module is also established using leisure time savings. This affects wage levels since, in part, payment is compensation for loss of leisure time.

$$\mathbf{\Delta W_i = f(\Delta P_{t-1}, U, \Delta U, LTS)} \qquad \text{(eq. 33)}$$

where: ΔW_i = change in wages

ΔP_{t-1} = changes in prices in the previous period

U = unemployment

ΔU = changes in unemployment

LTS = Leisure time savings

Employment grows relative to the growth in spending in the Region's economy. It increases as a proportion of GDP growth and a productivity trend. The model assumes a 2% annual increase in labour productivity.

$$\mathbf{E = f\,(\Delta GDP_{t-1},\ Prod)} \qquad \text{(eq. 34)}$$

Where: E= Employment

Prod = Productivity trend

The unemployment level used in the calculation of the wage level is determined by size of the labour force – supplied by the REM – minus the employment figure.

Components of Potential Output:

Potential Output is determined by the employment level and capital stock through a production function. The calculation of Employment has been covered above. The capital stock grows according to the level of investment taking into account depreciation. It also takes into account savings in freight costs that are recapitalised and added back into the capital stock.

$$\mathbf{K = f\,(K_{t-1},\ Inv_{t},\ FCS)} \qquad \text{(eq. 35)}$$

Where K_{t-1} = Capital stock in the previous period

Inv_t = Investment

FCS = Freight cost savings

Region 5 – the rest of the world

Region 5 exists purely in terms of exports and imports. These are derived using the system of import/export equations described earlier.

14.4.3 ASTRA Model Links for the MAC in ithink model

For the ASTRA model the Macroeconomic sub-module (MAC) needs to have the following interfaces with the other sub-modules:

- Transport inputs for the MAC are required from the transport sub-module;
- Transport tax inputs for the MAC are required from the environmental sub-module; and
- Macroeconomic outputs from the MAC are required for the regional economics sub-module while labour force inputs are required for the MAC from the regional economics sub-module.

14.4.3.1 Links with the Transport Sub-module

The transport sub-module produces as output transport benefits measured in terms of generalised costs.

As input to the MAC annual streams of costs and benefits split by MAC region[37] are required.

The transport benefits or costs should be expressed as:

- Generalised business and commuting time savings (millions of minutes per year for each year in each region)
- Generalised leisure time savings (millions of minutes per year for each year in each region)
- Generalised freight cost savings (millions of 1995 price euros per year for each year in each region).

They will of course need to take account of both the consumer and producer surplus.

The investment and other expenditure streams should be expressed as:

- All private current expenditure per year that is not in effect netted off in the calculations of generalised time savings (millions of 1995 price euros per year for each year in each region)
- Transport taxes and revenues (millions of 1995 price euros per year for each year in each region).

14.4.3.2 Outputs of the MAC required for Regional Economics Sub-module

The output required from the MAC for the regional economics sub-module is as follows:

- GDP by REM functional zone
- Industrial Output by REM functional zone
- Employment by REM functional zone
- Trade in goods between each MAC region
- Investment by REM functional zone
- Personal disposable income by REM functional zone

[37] The 5 MAC regions are: Region 1 – Germany and Austria
Region 2 – Belgium, the Netherlands, Luxembourg and France
Region 3 – Spain, Greece, Italy and Portugal
Region 4 – Ireland, Sweden, Denmark, Finland and the UK
Region 5 – The rest of the world

These are to be provided in millions of 1995 price euros for each year.

The GDP output and main indicators will be divided between two sectors - GOODS and SERVICES It was agreed at the November meeting that goods would include industrial production and agriculture, services making up the balance.

The translation of this output in the standard MAC regions to the input in REM functional zones is as follows:

The MAC output in each of the MAC regions other than the trade output will be split into REM functional zones using fixed coefficients provided to CEBR by ME&P. This, therefore splits each of the MAC regions into 6 zones per region, generating a total of 24 region/zones. These 24 region/zones are then combined into 6 zones using the identity:

- Zone 1 ≡ $\Sigma(\text{Region}_1\text{zone}_1, \text{Region}_2\ \text{zone}_1, \text{Region}_3\ \text{zone}_1, \text{Region}_4\ \text{zone}_1)$
- Zone 2 ≡ $\Sigma(\text{Region}_1\text{zone}_2, \text{Region}_2\ \text{zone}_2, \text{Region}_3\ \text{zone}_2, \text{Region}_4\ \text{zone}_2)$
- Etc.

14.4.4 Calibration of the MAC in ithink

The MAC will be calibrated over the period 1990 to 1995 with historical data from the OECD. The process will focus on the variables listed below and will aim for a maximum forecasting error of 3%. This is the maximum forecasting error used by the UK Government's Treasury Department in its model of the UK economy. The values of the main model variables will therefore be within 3% of the historical OECD values for the stated period.

Model variables to be calibrated:

- GDP
- Potential Output
- Consumption
- Investment
- Imports
- Personal Disposable Income
- Employment
- Capital Stock

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