



ASTRA

ASSESSMENT OF TRANSPORT STRATEGIES

Project No: ST-97-SC.1049

Deliverable D4

ASTRA METHODOLOGY

October 2000

Project co-ordinator:

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

Partners:

TRT, Trasporti e Territorio Srl, Milano (I)

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

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

ASTRA - ASSESSMENT OF TRANSPORT STRATEGIES

Work Package: **3**
Deliverable: **4**
Title: ASTRA Methodology

Date: 30.10.2000
Version No: 1
Availability: **Public**

Partner responsible: Wolfgang Schade (IWW)

Authors: Werner Rothengatter, Wolfgang Schade (all IWW), Angelo Martino, Michele Roda (all TRT), Andrew Davies, Lynn Devereux , Ian Williams (all ME&P).

Additional authors of the annex to deliverable 4: Paul Bryant, Douglas McWilliams (all CEBR).

ASTRA - ASSESSMENT OF TRANSPORT STRATEGIES

Project No: ST-97-SC.1049

Commissioned by: European Commission - Fourth Research Framework - DG VII

Project co-ordinator:

IWW, Institut für Wirtschaftspolitik und Wirtschaftsforschung, Universität Karlsruhe,
Karlsruhe, Germany

Partners:

TRT, Trasporti e Territorio Srl, Milano, Italy

ME&P, Marcial Echenique & Partners Ltd, Cambridge, United Kingdom

CEBR, Centre for Economics and Business Research Ltd, London, United Kingdom.

Summary Table of Contents

1	INTRODUCTION	1
2	EXECUTIVE SUMMARY	2
3	DEMARCATON OF ASTRA METHODOLOGY	7
3.1	LONG-TERM ASSESSMENT	7
3.1	MODELLING THE COMPLEXITY OF THE TRANSPORT SYSTEM	10
3.2	EQUILIBRIUM OR “DISEQUILIBRIUM” MODELS	12
4	ASTRA SYSTEM DYNAMICS MODEL PLATFORM (ASP)	13
4.1	GLANCE ON THE VENSIM MODEL	16
5	GENERAL FEATURES OF THE ASTRA MODEL	19
5.1	INTRODUCTION	19
5.2	SPATIAL STRUCTURE	20
5.3	TRANSPORT FLOWS REPRESENTATION	24
5.4	SPATIAL REPRESENTATION	25
6	DESCRIPTION OF THE FOUR ASTRA SUB-MODULES	28
6.1	MACROECONOMICS SUB-MODULE (MAC)	28
6.2	REGIONAL ECONOMICS AND LAND USE SUB-MODULE (REM)	42
6.3	TRANSPORT SUB-MODULE (TRA)	85
6.4	ENVIRONMENT SUB-MODULE (ENV)	105
7	ASTRA DEMONSTRATION EXAMPLES	143
7.1	THE ASTRA POLICY ASSESSMENT FRAMEWORK	143
7.2	ADVANTAGES OF POLICY TESTING WITH ASTRA	147
7.3	ASTRA SCENARIOS, SIMULATION RUNS AND POLICIES	150
8	ASTRA-TIP	244
9	OUTLOOK	251
10	CONCLUSIONS	252
11	REFERENCES	257

Detailed Table of Contents

1	INTRODUCTION	1
2	EXECUTIVE SUMMARY	2
3	DEMARCATIION OF ASTRA METHODOLOGY	7
3.1	LONG-TERM ASSESSMENT	7
3.1	MODELLING THE COMPLEXITY OF THE TRANSPORT SYSTEM	10
3.2	EQUILIBRIUM OR “DISEQUILIBRIUM” MODELS	12
4	ASTRA SYSTEM DYNAMICS MODEL PLATFORM (ASP)	13
4.1	GLANCE ON THE VENSIM MODEL	16
5	GENERAL FEATURES OF THE ASTRA MODEL	19
5.1	INTRODUCTION	19
5.2	SPATIAL STRUCTURE	20
5.2.1	MACROECONOMIC REGIONS	21
5.2.2	FUNCTIONAL ZONES	22
5.3	TRANSPORT FLOWS REPRESENTATION	24
5.3.1	TRIP PURPOSES	24
5.3.2	FREIGHT CATEGORIES	25
5.4	SPATIAL REPRESENTATION	25
5.4.1	PASSENGER DISTANCE BANDS	26
5.4.2	FREIGHT DISTANCE BANDS	27
6	DESCRIPTION OF THE FOUR ASTRA SUB-MODULES	28
6.1	MACROECONOMICS SUB-MODULE (MAC)	28
6.1.1	AIM OF THE MAC SUB-MODULE	28
6.1.2	BASIC STRUCTURE AND FUTURE EXPECTATIONS	28
6.1.2.1	Supply side model	29
6.1.2.2	Demand side model	29
6.1.2.3	Sectoral interchange model	30
6.1.3	IMPLEMENTATION OF THE MACROECONOMICS SUB-MODULE (MAC)	30
6.1.3.1	Potential Output Model	31
6.1.3.2	Final Demand Model and GDP	32
6.1.3.3	Input-Output-Model	32
6.1.3.4	Consumption Model	34
6.1.3.5	Investment Model	35
6.1.3.6	Employment Model	36
6.1.3.7	Model of the Capital Stock	37
6.1.3.8	Model of National Income and Personal Income	38
6.1.3.9	Tax Model	39
6.1.4	CALIBRATION OF THE MAC	40
6.1.5	INTERFACES TO OTHER SUB-MODULES	41
6.1.5.1	Interface MAC => REM	41
6.1.5.2	Interface MAC => TRA	41
6.1.5.3	Interface MAC => ENV	41

6.2	REGIONAL ECONOMICS AND LAND USE SUB-MODULE (REM)	42
6.2.1	AIM OF THE REM SUB-MODULE	42
6.2.1.1	Trends in passenger and freight travel demand	44
6.2.1.2	Model structure	45
6.2.2	BASIC STRUCTURE OF THE REM	46
6.2.2.1	Overview	47
6.2.2.2	Demand Segmentation	51
6.2.2.3	Passenger and freight generation	54
6.2.2.4	Passenger and freight distribution	58
6.2.3	FUTURE DEVELOPMENT	65
6.2.3.1	Demographic	66
6.2.3.2	Labour force	66
6.2.3.3	Car ownership	67
6.2.3.4	Industrial production	67
6.2.3.5	Trends in passenger transport	67
6.2.3.6	Trends in freight transport	68
6.2.4	IMPLEMENTATION	68
6.2.4.1	Passenger model	68
6.2.4.2	Freight model	76
6.2.5	CALIBRATION OF THE REM SUB-MODULE	81
6.2.5.1	Passenger model	82
6.2.5.2	Freight model	82
6.2.6	INTERFACES TO OTHER SUB-MODULES	82
6.2.6.1	Macro-Economic sub-module (MAC)	83
6.2.6.2	Transport sub-module (TRA)	84
6.2.6.3	Environmental sub-module (ENV)	84
6.3	TRANSPORT SUB-MODULE (TRA)	85
6.3.1	AIM OF THE TRA SUB-MODULE	85
6.3.2	BASIC STRUCTURE OF THE TRA	85
6.3.3	IMPLEMENTATION	87
6.3.3.1	Passenger component	88
6.3.3.2	Freight component	89
6.3.3.3	Modal choice	90
6.3.3.4	The road traffic assignment	91
6.3.3.5	The road capacity sector	93
6.3.3.6	The local network sector	96
6.3.3.7	The inter-regional distance network sector	97
6.3.4	THE CALIBRATION PROCESS	97
6.3.4.1	The STREAMS benchmark model	98
6.3.4.2	Elasticity tests	99
6.3.4.3	The validation data	100
6.3.5	INTERACTION WITH OTHER SUB-MODULES	102
6.3.5.1	Interface TRA MAC	103
6.3.5.2	Interface TRA REM	103
6.3.5.3	Interface TRA ENV	104
6.4	ENVIRONMENT SUB-MODULE (ENV)	105
6.4.1	AIM OF THE ENV SUB-MODULE	105
6.4.2	BASIC STRUCTURE AND FUTURE EXPECTATIONS	105
6.4.2.1	Global Impacts	106
6.4.2.2	Impacts on Human Health	106
6.4.2.3	Ecological Impacts	107
6.4.2.4	Impact Assessment	108
6.4.3	IMPLEMENTATION OF THE ENVIRONMENT SUB-MODULE (ENV)	108
6.4.3.1	Modelling Gaseous Emissions of Road Transport	109
6.4.3.2	Modelling Emissions of other Transport Modes	118
6.4.3.3	Modelling Potential Risk Indicators for Soot Particles	122
6.4.3.4	Modelling Traffic Accidents	127
6.4.3.5	Modelling Fuel Prices and Taxes	136
6.4.3.6	Modelling Impact Assessment: Welfare Indicators	136

6.4.4	CALIBRATION APPROACH FOR THE ENV	138
6.4.4.1	Validation results with the stand-alone model for Germany	139
6.4.4.2	Calibration of the ENV within the ASP	140
6.4.5	INTERFACES TO OTHER SUB-MODULES	141
7	ASTRA DEMONSTRATION EXAMPLES	143
7.1	THE ASTRA POLICY ASSESSMENT FRAMEWORK	143
7.1.1	OBJECTIVES OF THE COMMON TRANSPORT POLICY	143
7.1.2	COMPONENTS OF EUROPEAN TRANSPORT POLICY	145
7.2	ADVANTAGES OF POLICY TESTING WITH ASTRA	147
7.2.1	CONSISTENCY OF POLICY RESULTS	147
7.2.2	VERIFIABILITY OF SD MODELS	147
7.2.3	STEPWISE POLICY IMPLEMENTATION	148
7.2.4	MULTIPLE POLICY IMPLEMENTATION	148
7.2.5	TIME-PATH INDICATORS	149
7.2.6	INTENSITY INDICATORS	149
7.2.7	LINKING BACKCASTING AND FORECASTING	149
7.3	ASTRA SCENARIOS, SIMULATION RUNS AND POLICIES	150
7.3.1	ASTRA REFERENCE SCENARIO	151
7.3.2	STRUCTURE OF THE ASTRA DEMONSTRATION EXAMPLES	174
7.3.2	POLICY PACKAGE 1: IMPROVING SAFETY AND EMISSIONS SITUATION (ISE)	175
7.3.2.1	Implementation in the Model	175
7.3.2.2	Results of Emission & Safety Policy (ISE)	176
7.3.3	POLICY PACKAGE 2: INCREASED FUEL TAX PLUS REDUCTION OF LABOUR COSTS (IFT)	184
7.3.3.1	Implementation in the Model	185
7.3.3.2	Results of the Increased Fuel Tax Policy (IFT)	186
7.3.4	POLICY PACKAGE 3: BALANCE FUEL TAX PLUS REDUCTION OF LABOUR COSTS (BFT)	196
7.3.4.1	Implementation in the Model	197
7.3.4.2	Results of Balanced Fuel Tax Policy (BFT)	198
7.3.5	POLICY PACKAGE 4: FUEL TAXATION AND INVESTMENT IN TEN (RAIL-TEN, ALL-TEN)	209
7.3.5.1	Implementation in the Model	210
7.3.5.2	Results of Rail-TEN policy and All-TEN policy	211
7.3.6	INTEGRATED POLICY PROGRAMME (IPP)	218
7.3.7	COMPARISON OF THE POLICY PACKAGES	228
7.3.8	EXAMPLE FOR SENSITIVITY RESULTS	234
8	ASTRA-TIP	244
8.1	INTRODUCTION	244
8.2	BASIC USAGE	244
8.3	THE POLICY PACKAGES	247
8.4	MODEL STRUCTURE	248
8.5	TECHNICAL REQUIREMENTS	250
9	OUTLOOK	251
10	CONCLUSIONS	252
11	REFERENCES	257

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
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 4 th 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
PM2.5	=	Particulate Matter with Diameter of less than 2.5 µm
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

List of Tables

Table 1: Spatial units used by sub-modules in ASTRA Systems Dynamics Model Platform.....	20
Table 2: Trends in passenger and freight demand to be modelled in REM and TRA.....	46
Table 3: Key dimensions of the passenger and freight models in the REM sub-module.....	48
Table 4: Traveller type segments in passenger model.....	52
Table 5: Industrial sectors in the REM freight model.....	54
Table 6: Average number of journeys per person per week according to type of settlement.....	55
Table 7: Average journeys and kilometres travelled per person a year in Great Britain.....	56
Table 8: Correspondence of trip purpose and distance bands (Passenger model).....	60
Table 9: Correspondence of direction of movement and distance bands (Passenger model).....	60
Table 10: Correspondence of direction of movement and distance bands (Freight model).....	63
Table 11: Freight flows in the REM freight model.....	64
Table 12: Correspondence between "Industrial sectors" and "Freight transport flows".....	65
Table 13: Units in the REM sub-module.....	68
Table 14: Inputs to and outputs from REM demographic model.....	70
Table 15: Inputs to and outputs from REM car ownership model.....	72
Table 16: Inputs to and outputs from REM trip generation.....	73
Table 17: Inputs to and outputs from REM trip distribution.....	75
Table 18: Inputs to and outputs from REM industrial production model.....	78
Table 19: Inputs to and outputs from REM freight generation model.....	79
Table 20: Inputs to and outputs from REM freight distribution model.....	80
Table 21: Inputs to and outputs from REM freight aggregation model.....	81
Table 22: ASTRA road network km by macro-regions.....	94
Table 23: ASTRA - Growth in the length of roads (1992-1994).....	95
Table 24: ASTRA length of road network increase by macro-regions(1986-2026).....	95
Table 25: Distribution of the vehicles*km by macro-regions and type of road.....	96
Table 26: Weights matrix.....	96
Table 27: Passenger Time and Cost Elasticity.....	99
Table 28: Freight Time and Cost Elasticity.....	99
Table 29: Passenger*km by mode (1000 millions, year).....	100
Table 30: Passenger modal split.....	101
Table 31: Tons*km by mode (1000 millions, year).....	101
Table 32: Tons by mode (millions, year).....	101
Table 33: Freight modal split.....	101
Table 34: Passenger*km trend 1990-1997 (1000 millions, year).....	102
Table 35: Tons*km trend 1990-1997 (1000 millions, year).....	102
Table 36: Fuel Consumption and Emission Factors for Air Transport.....	121
Table 37: ASTRA Ship Emission Factors.....	122
Table 38: Traffic situations and corresponding urban road types.....	124

Table 39: Background concentrations for soot particles.....	125
Table 40: Applied standardised concentrations and ADTs.....	126
Table 41: Examples of Different Accident Risks.....	128
Table 42: Influences on Car Passenger Risks.....	133
Table 43: Results of Comparison between Real Indicators and not calibrated SASDyG Model indicators	139
Table 44: Development of Population in ASTRA Reference Scenario.....	152
Table 45: Summary of Trends in REM Sub-module for Reference Scenario (1996-2026).....	154
Table 46: Comparison of long-term growth rates for GDP between ASTRA and SCENES.....	156
Table 47: Changes of weighted speed limit for emission & safety policy.....	175
Table 48: Share of fuel costs on total transport costs per km.....	185
Table 49: Development of employment in all regions at certain points of time.....	195
Table 50: Overall increase of diesel tax to reach the level of gasoline taxation after 2004.....	197
Table 51: Investment plan for Rail-TEN and All-TEN policy package.....	210
Table 52: Yearly improvements of rail travel times by new rail-TEN infrastructure.....	211
Table 53: Investment multipliers for Rail-TEN and All-TEN policy at 2016 and 2026.....	218
Table 54: Ranking of policies for the different regions.....	234

List of Figures

Figure 1: Structure of the ASTRA System Dynamics Model Platform (ASP).....	2
Figure 2: Development of CO ₂ -concentrations from 1958 to 1997.....	8
Figure 3: Transport and its Interlinkages to other Complex Systems.....	10
Figure 4: Structure of the ASTRA System Dynamics Model Platform (ASP).....	13
Figure 5: Output data forming the major feedback loops between the ASP sub-modules.....	14
Figure 6: Aggregated Relationships of the Passenger Model.....	15
Figure 7: Aggregated Relationships of the Freight Model.....	16
Figure 8: Comparison of development of GDP with CO ₂ emissions from transport.....	17
Figure 9: Zoning scheme for ASTRA System Dynamics Model Platform (ASP).....	23
Figure 10: Schematic Representation of Spatial Dimensions of EU15 countries in ASTRA.....	24
Figure 11: Relationships between the Models of the MAC.....	31
Figure 12: Structure of the Input-Output-Model.....	34
Figure 13: Structure of National Income and Consumption Model.....	35
Figure 14: Structure of the Employment Model.....	37
Figure 15: Structure of the Model of the Capital Stock.....	38
Figure 16: Passenger transport in billion passenger-kilometres by mode for EU15 countries.....	44
Figure 17: Freight transport in Billion tonne-kilometres by mode for EU15 countries.....	45
Figure 18: Structure of REM passenger model.....	49
Figure 19: Structure of REM freight model.....	50
Figure 20: Comparison of annual change in trip rates by demand segment.....	57
Figure 21: Comparison of proportion of journeys by distance band over time.....	59
Figure 22: Comparison of number of journeys by distance band over time.....	59
Figure 23: Trip distribution in REM passenger model.....	61
Figure 24: Freight distribution in REM freight model.....	63
Figure 25: Data flows in REM passenger model.....	69
Figure 26: Structure of demographic model in REM.....	71
Figure 27: Structure of trip generation stage of REM.....	74
Figure 28: Structure of trip distribution stage of REM.....	76
Figure 29: Data flows in REM freight model.....	77
Figure 30: Structure of Freight generation stage of REM freight model.....	79
Figure 31: Structure of Freight distribution and aggregation stages of REM freight model.....	81
Figure 32: Feedback loops between REM and other ASTRA SDM sub-modules.....	83
Figure 33: Impact chain in ASTRA.....	87
Figure 34: Transport sub-module structure - Passenger component.....	89
Figure 35: Transport sub-module structure - Freight component.....	90
Figure 36: Modal split and road assignment.....	91
Figure 37: Interaction of passenger and freight sectors with the road network sectors.....	92
Figure 38: Local road network sector.....	97

Figure 39: Interaction among the transport sub-module and the other sub-modules.....	103
Figure 40: Structure of the Environment Sub-module (ENV).....	109
Figure 41: Structure of the Model for Gaseous Emissions of Cars in the ENV.....	111
Figure 42: Conveyor for Bus Vehicle Fleet.....	113
Figure 43: Effect Diagram for Calculation of New Registration of Buses.....	114
Figure 44: Influences on Emissions from Rail Transport.....	119
Figure 45: Model Structure for Calculation of Concentrations of Soot Particles.....	123
Figure 46: Development of Urban Fatality Accident Risks in Germany.....	129
Figure 47: Effect Diagram of Road Accident Model.....	134
Figure 48: Example of Stepwise Policy Implementation.....	148
Figure 49: Different Results with Point-to-Point-Indicators and Time-path-Indicators.....	149
Figure 50: Connection between Reference and Policy Scenarios.....	150
Figure 51: Development of GDP in the Reference Scenario (SCENARIOS 1998).....	153
Figure 52: Development of Employment in the MAC in the Reference Scenario.....	153
Figure 53: Development of PC Vehicle Fleet (MEET D4, TRENDS-Project).....	155
Figure 54: GDP in Base Scenario.....	156
Figure 55: Employment in Base Scenario.....	157
Figure 56: Index for the Development of Labour Productivity in Base Scenario.....	158
Figure 57: Total Population per Functional Zone.....	159
Figure 58: European Demand for Passenger Trips.....	160
Figure 59: Split of Trip Demand between the five Distance Bands for Passenger Transport.....	161
Figure 60: Passenger Modal Split related to Transport Performance in EU15 Countries.....	162
Figure 61: Passenger Modal Split for Interurban Trips in EU15 based on Trip Volumes.....	162
Figure 62: Yearly Origin Passenger Kilometres per Mode for Metropolitan Areas plus Hinterland (MPH zone) in the long distance band (>700km).....	163
Figure 63: Freight Modal Split related to Transport Performance for Region 1 (A, D) and Region 4 (DK, FIN, IRL, S, UK).....	164
Figure 64: Transport Performance and Vehicle Kilometres for Trucks in Region 2 and Region 4	165
Figure 65: Cost per km for a set of passenger modes for business transport in local and long distance band.....	166
Figure 66: Hot NO _x -emissions for all modes per region.....	167
Figure 67: Hot NO _x -emission for EU15 countries per mode.....	167
Figure 68: Reference Development of NO _x Emission Factors in Local and Medium Distance Band.....	168
Figure 69: Hot CO ₂ -emissions for all modes per region.....	169
Figure 70: CO ₂ emissions from road vehicle production and fuel production.....	170
Figure 71: Yearly Externalities of Emissions and Accidents in Regions 1, 2 and 3.....	171
Figure 72: Development of Passenger Car Fleet per Region.....	172
Figure 73: Development of Expenditure for Private Fuel Consumption in Comparison with Total Fuel Tax Revenues in Regions 1,2 and 4.....	173
Figure 74: Structure and notion of the ASTRA demonstration examples.....	174

Figure 75: Comparison of different sources and policy results for NO _x emissions.....	177
Figure 76: Yearly Road Fatalities in Region E1 (A, D) and Region E3 (E, GR, I, P).....	178
Figure 77: Combined Environment and Welfare Indicators for Region 1 (A, D).....	179
Figure 78: Transport CO ₂ -, NO _x - emissions and Gasoline Consumption in the EU15 countries.....	180
Figure 79: Passenger Demand Split between Distance Bands.....	181
Figure 80: Trip Distance Split.....	182
Figure 81: Freight Modal Split for Medium Long Distance Band (150-700km) in Region 1 (A, D).....	182
Figure 82: Transport related Consumption in Region 3 (E, GR, I, P).....	183
Figure 83: Total Employment in Transport Service Sectors in Region 2 (B, F, NL, L), Region 3 (E, GR, I, P) and Region 4 (DK, FIN, IRL, S, UK).....	184
Figure 84: Development of Fuel Price and Fuel Taxes in Region 2 (B, F, L, NL).....	186
Figure 85: Cost structure for business road transport in short distance band in large stand-alone metropolitan zones (LSA).....	187
Figure 86: Passenger transport performance for base scenario and green tax policy.....	188
Figure 87: Passenger modal-split for EU15 in terms of transport performance.....	188
Figure 88: Changes in demand split by the IFT policy for the five passenger distance bands.....	189
Figure 89: Freight transport volume for EU15 countries.....	190
Figure 90: Passenger demand changes by increased fuel tax policy (yearly).....	191
Figure 91: Share of diesel cars in European fleet and in the car fleet of region 2 and region 3.....	192
Figure 92: Additional fuel tax revenues generated by the increased fuel tax policy.....	193
Figure 93: Employment effects of green tax policy in region 1.....	194
Figure 94: Development of transport CO ₂ emissions in base scenario and with IFT policy.....	196
Figure 95: Development of fuel prices and diesel fuel consumption in region 1 with BFT policy.....	199
Figure 96: Additional fuel tax revenues of BFT policy.....	199
Figure 97: Examples of policy influences on specific transport costs for different relations and purposes.....	200
Figure 98: Comparison of passenger transport performance between base scenario and BFT policy.....	201
Figure 99: Freight modal split in region 2 (B, F, L, NL).....	202
Figure 100: Effects of balanced tax policy on air transport.....	203
Figure 101: Influence of balance tax policy(BFT) on share of passenger diesel cars in EU15, region 2 (B, F, L, NL) and region 3 (E, GR, I, P).....	205
Figure 102: For comparison development of share of diesel cars with IFT policy.....	205
Figure 103: Concentrations of soot particles in LSA zones in region 2 (B, F, L, NL).....	207
Figure 104: Comparison of freight transport performance between increased tax policy and balanced tax policy.....	208
Figure 105: Results for vehicle kilometres travelled in Base scenario and Rail-TEN policy.....	212
Figure 106: Modal-split in EU15 based on transport performance for Rail-TEN policy compared with base scenario.....	213
Figure 107: Freight modal-split with rail-TEN policy in region 3 (E, GR, I, P) based on transport performance (tkm).....	214

Figure 108: Development of macroeconomic indicators in region 3 (E, GR, I, P) with Rail-TEN policy.....	215
Figure 109: Yearly hot CO ₂ -emissions from transport in region 1(A, D) and region 2 (B, F, L, NL) and specific CO ₂ emissions in region 1.....	216
Figure 110: Development of yearly NO _x emissions in EU15 countries with Rail-TEN policies.....	217
Figure 111: Additional tax revenues in region 2 and 4 that are used to reduce labour costs.....	219
Figure 112: Consumption of different type of fuels in the EU15 countries with IPP.....	220
Figure 113: Passenger modal-split in EU15 countries based on transport performance (pkm).....	222
Figure 114: Comparison of car and air mode transport performance in base scenario, Rail-TEN policy and integrated policy.....	222
Figure 115: Freight transport performance in the EU15 countries with IPP.....	223
Figure 116: Change of consumption structure with IPP policy in region 3 (E, GR, I, P).....	224
Figure 117: Employment in region 4 (DK, FIN, IRL, S, UK) with IPP.....	225
Figure 118: Development of EU15 fatality accidents with integrated policy programme.....	226
Figure 119: CO ₂ emissions from transport in region 3 (E, GR, I, P) with IPP.....	227
Figure 120: Development of GDP in EU15 countries between 2020 and 2026.....	228
Figure 121: Passenger transport performance in EU15 countries.....	229
Figure 122: Freight transport performnace in EU15 countries.....	230
Figure 123: Average fuel consumption of gasoline cars in region 1 (A, D).....	231
Figure 124: Yearly transport CO ₂ emissions in EU15 countries.....	232
Figure 125: Percentage of transport externalities on GDP for region 1 (A, D).....	233
Figure 126: Fuel tax revenues in region 1 (A, D) with sensitivity testing.....	235
Figure 127: Reaction of GDP in region 1 and region 2 to fuel price variation.....	236
Figure 128: Histogram of sensitivity tests for GDP in region 1.....	237
Figure 129: Sensitivity results for employment in region 3.....	238
Figure 130: Modal-split of non-local passenger transport based on trip volumes.....	239
Figure 131: Sensitivity results for total CO ₂ emissions of transport in region 3.....	240
Figure 132: Results for passenger car fleet in region 4 with sensitivity testing.....	241
Figure 133: Long-distance modal-split (>160km) for car and air transport based on trip volumes (results of sensitivity test).....	242
Figure 134: Long-distance (>160km) transport performance of passenger modes in metropolitan areas plus hinterland (MPH) with growth rate for value of time of 10%.....	243
Figure 135: Welcome screen of ASTRA-TIP.....	244
Figure 136: General structure of result screens.....	245
Figure 137: Selection dialog for spatial selection of Euro Region type indicators.....	246
Figure 138: Pre-defined graph for consumption in region 4.....	247
Figure 139: Display of information for different runs simultaneously.....	248
Figure 140: Example of a model structure screen.....	249
Figure 141: Dialog to choose a view presenting a part of the model structure.....	249

1 Introduction

The aim of ASTRA is to develop a tool for analysing the impacts of the Common Transport Policy (CTP) including secondary and long-term effects. For this purpose the System Dynamics modelling method is applied. By using the commercial system dynamics software package Vensim the ASTRA System Dynamics Platform (**ASP**) is developed. The ASP integrates key relationships of state-of-the-art models in the fields of macroeconomics, regional economics and land use, transport and environment. It is composed of the four sub-modules: macroeconomics sub-module (**MAC**), regional economics and land use sub-module (**REM**), transport sub-module (**TRA**) and environment sub-module (**ENV**). Results of the conventional¹ models are used for calibration of the ASP sub-modules.

The first approach using the ithink system dynamics software package could not successfully be completed with an integration of all sub-modules as the size of the ASP exceeded the size limit of ithink. Therefore the ithink version of the ASP is limited to a core model consisting of MAC, REM, TRA and the car vehicle fleet model of the ENV.

In sciences real systems usually are split up and allocated to different disciplines. This way of scientific division of research - often referred to as the Descartes-type of structuring scientific analysis - abstracts from the interrelationships between the elements of the system and the dynamics, which are induced by feedback mechanisms. E.g. this concerns many of the available tools and models for assessment of different types of impacts from transport policies and investments. These conventional models are constantly up-graded to support assessments in terms of analysing and forecasting impacts that are internal in the transport sector - such as on transport demand and modal choices, modal capacity and traffic level and patterns. Also, in an increasingly number of applications transport models are being used to assess transport related impacts on environment as well as on location choices of both families and firms. But other interrelationships e.g. between transport and macroeconomics or between location choices and the transport system (vice versa then mentioned before) are often treated as exogenous or not existing. Here lies the field of application of system dynamics because it is one of the few tools, which are able to re-establish these interrelationships and to tie together the elements of reality in one model again.

For instance the development of GDP will usually be taken exogenous for all conventional models except the macroeconomic models. But in ASTRA GDP is modelled endogenous within the macroeconomics sub-module and results are passed onto the regional economics sub-module. This may influence transport demand, while the changes in transport may change GDP. This is only one example of an interface between the four ASTRA sub-modules. These interfaces form an added value of the project besides the application of a system dynamics approach and the long-term perspective of the assessment.

¹ The state-of-the-art models are referred to as *conventional models* in contrast to the denotation *system dynamics models*.

2 Executive Summary

The purpose of deliverable 4 is to present the ASTRA methodology. A description of methodology includes a representation of the model, called the ASTRA system dynamics model platform (ASP), as well as a portrayal of the usage of the model for demonstration examples. The ASP can be categorised as system dynamics model for integrated long-term assessment of the European transport policy with a spatial representation on a functional basis.

The ASP integrates the macroeconomics sub-module (MAC), regional economics and land use sub-module (REM), the transport sub-module (TRA) and the environment sub-module (ENV) into one model. The passenger model and the freight model are implemented such that they are formed by parts of REM, TRA and ENV. Each sub-module is subdivided into several sectors. This structure of the ASP is shown in figure 1.

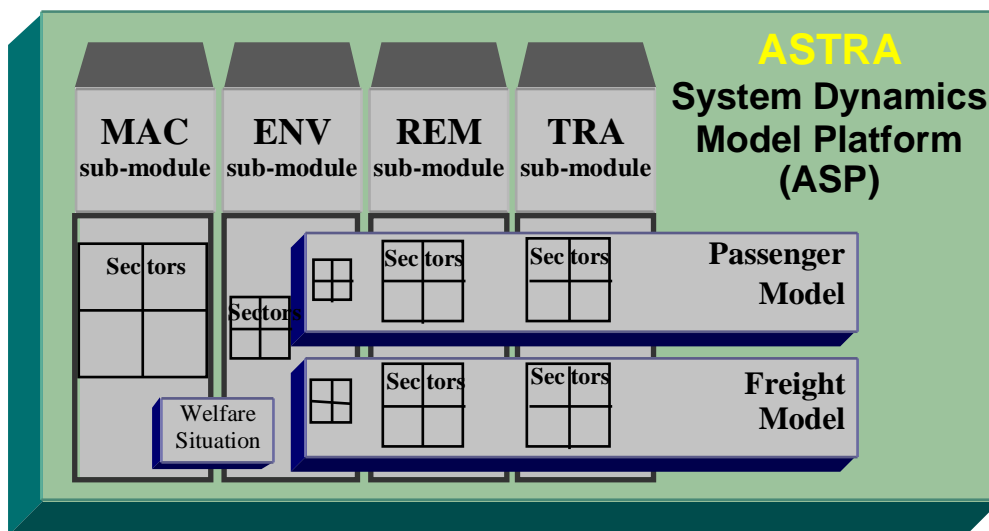


Figure 1: Structure of the ASTRA System Dynamics Model Platform (ASP)

The ASP is implemented in two versions: a full Vensim version and a core ithink version. This was necessary to overcome size limits of the ithink software. The full Vensim ASP integrates all four sub-modules and the welfare situation. It is the final outcome of the ASTRA project and as such the main object described in this deliverable. The core ithink ASP comprises the complete MAC, REM, TRA sub-modules and the car vehicle fleet model from the ENV. Considering policy simulations the capability of the core ASP are restricted to the explanation of transport and economic consequences. Environmental effects, technological improvements and changes in the welfare situation can only be observed with the full ASP.

Creating the ASP a very important task of the modelling process is to define the spatial representation within the model. For the MAC a clustering with 4 *Macro Regions* is applied that is based on the geography of 15 NUTS 0 zones. For the passenger model within REM, TRA and ENV a clustering with 6 *Functional Zones* is applied that is based on the settlement patterns of the 201 NUTS II zones. The transport system is represented by five *Distance Bands*, which consider different modal choice alternatives and different driving patterns in dependency of the trip length. For the freight model within REM, TRA and ENV a clustering with 4 functional zones is aspired. The freight clustering scheme is also based on the macro regions. The freight transport system is represented by four distance bands that consider the different modal choice alternatives for freight transport. The road transport network is divided into an urban-network and a non-urban-network on which passenger and freight transport are competing.

In general, the ASTRA System Dynamics Model Platform (ASP) is working as follows. The macroeconomics sub-module (MAC) estimates the economic framework data of the EU respectively the member countries. The results of the MAC key indicators (e.g. GDP, employment) are transferred to the regional economics and land use sub-module (REM). Within the REM basic data for transport demand modelling (e.g. population, car-ownership) is calculated. Both data forms the input of the first two steps of the classical 4-stage transport model: trip generation and trip distribution on the basis of the previously described spatial representation. The resulting transport demand is transferred to the transport sub-module (TRA), which includes the final two stages of the transport model: modal split and a simplified assignment. The environmental sub-module (ENV) is mainly fed by data from the TRA (e.g. traffic volumes). It includes the vehicle fleet models and models for description of changes in technology. Environmental indicators (e.g. CO₂ emissions) are calculated and the welfare consequences performed by the environmental impacts are estimated in the ENV. Finally the aggregated welfare situation based on economic, social and employment indicators is presented. All model variables (e.g. GDP, transport performances, emissions) are calculated as time series from 1986 to 2026, where the first ten years are used for initialisation and calibration of the ASP and the forecasting period lasts from 1996 to 2026.

It has to be emphasised that the data between the sub-modules is not transferred as a complete time series over the whole simulation period. Instead data calculated at a certain point of time - called integration period DT - is transferred between the sub-modules. The data can be used in the other sub-modules for the calculation of variables within the same integration period, of variables in the next integration period or, if there are time lags included in the model, of subsequent integration periods. That means, the MAC does not calculate all GDP values between 1986 and 2026 in one time series before the transfer to the REM. Instead it calculates the GDP, for instance, for the third quarter of the year 1987. This value is transferred to the REM and the TRA, which calculate the transport demand and the transport cost in the third quarter of 1987. Assuming that there is no longer time lag included in this feedback structure the transport cost of the third quarter are transferred to the MAC. Within the MAC they form an input of the calculation of GDP of the fourth quarter of 1987.

The use of the model is explained with the Vensim ASP by undertaking and presenting demonstration examples. The ASTRA demonstration examples cover a reference scenario, five policy packages consisting of sets of policy measures and an integrated policy programme comprising most of the policy packages. The five policy packages can be described as:

- Improved emission and safety policy package,
- Increased fuel tax policy package,
- Balanced fuel tax policy package,
- Rail-TEN policy package and
- All-TEN policy package.

The policy packages are designed such that they fit to the general framework of European transport policy. With the chosen packages it is aspired to take advantage of the special capabilities of the system dynamics methodology. The scenarios address policy decisions in the field of taxation, construction of the TEN, mitigation of air pollution and increase of safety of transport. Briefly summarising the results the integrated policy programme (IPP) produces the best results considering the whole range of economic, environmental and (un-)employment indicators. But it seems that also with the IPP environmental sustainability is not reached.

The deliverable is structured into five parts. The first part introduces the ASTRA project and summarises this deliverable. In the second part the ASTRA methodology is demarcated from and compared to other approaches. In the third part an overview on the model is presented and the features of the model that are used in more than one sub-module are described. In the fourth part a description of the modelling approaches of the four sub-modules, the output of the sub-modules and the calibration approach for each sub-module are given. The fifth part presents the policy framework for the demonstration examples, the results for the base scenario, approach and results for the five policy packages and the integrated policy programme as well as results for some sensitivity tests. In a sixth part the ASTRA-TIP an easy-to-use tool for presentation of the results is described. The deliverable concludes with an outlook on planned work and improvements followed by the conclusion. Additionally to this deliverable detailed information about the sub-modules, the scenario implementation and the ithink core ASP is integrated in one separate appendix with three parts: in the first part additional explanations and input data on the implementation of the four sub-modules is given, in the second part further data for the scenario and policy description is included and in the third part structure and difference of the ithink core ASP are explained.

ASTRA

Methodology

3 Demarcation of ASTRA Methodology

The ASTRA approach can be demarcated from other approaches with four significant criteria. Models can be distinguished at least in two groups: partial or specialised models and global or integrated models. The ASTRA model belongs to the latter group of models, as the model integrates transport with three other research fields (macroeconomics, regional economics and environment) that influence or that are influenced by the transport system.

The second criteria is the time scale. Models can be designed to work on a short-term, a mid-term and a long-term time horizon. ASTRA is constructed such that it can be applied for the long-term time horizon with a forecasting period from 1996 to 2026. With minor completions even longer time horizons might be applied at least for sensitivity testing of policies.

The third criteria is given by the level of spatial detail that is reflected by a model. Herewith disaggregated GIS-based models and models with different levels of aggregation can be distinguished. ASTRA is based on a meso-level of spatial aggregation. So, for spatial representation the whole EU15 is divided into different types of functional zones.

Finally the modelling methodology can be used as demarcation criteria. In this case the group of statistic or econometric models and the group of functional or cause-and-effect based models can be differentiated. With the use of the system dynamics methodology to reflect the complex causal interrelationships of the investigated socioeconomic and environmental systems ASTRA belongs to the latter category. Summarising, the ASTRA model can be categorised as system dynamics model for integrated long-term assessment of the European transport policy with a spatial representation on a functional basis.²

3.1 Long-term Assessment

Why is long-term assessment of the consequences of transport policies necessary ? This question arises as one might argue that assessments with a time horizon of more then 5 to 10 years are tainted with high uncertainty or even are speculative. This might be right for some systems for which the framework of the system can be changed completely within short-terms e.g. in financial markets where varying money flows can change the whole system within hours or days. However the framework in which the transport system is embedded behaves different. Major driving forces of the transport system can be changed only in the long-term. For instance the construction and planning of transport infrastructure might take up to 10 years and the usage duration is often longer then 40 years. Human habits that increase the need for transport like the preference to live in green suburban areas instead of the city centers also develop over a long time such that they contribute to the self-image of a generation of people. To change these human habits needs also longer time periods.

² ASTRA D2 presents the basics of system dynamics modelling and a categorisation of models according to a set of formal mathematical criteria. ASTRA can be classified with these criteria as formal, abstract, non-linear dynamic model (ASTRA 1998)

Additionally, on the supply side of the transport system huge industrial structures (e.g. fuel producing industries, car manufacturers) have been built. To change these requires changes of the production structures with an enormous scope and therefore also with a long-term time horizon.

Finally, environmental consequences performed by the transport system like the carcinogenic risk caused by particulate matter or the contributions to the greenhouse effect caused by CO₂ emissions from transport have an effect after an activity period of several decades or might even last for decades or hundreds of years. This can be seen at the development of CO₂ concentrations observed at the Mauna Loa observatory, which have been increased from 1958 to 1997 by about 17 % (figure 2). Currently scientists are sure that this increase of greenhouse gases that can be observed worldwide will effect the global climate. But discussions are ongoing if today we can already notice these changes e.g. by the increase of the number of heavy storms during the last years.

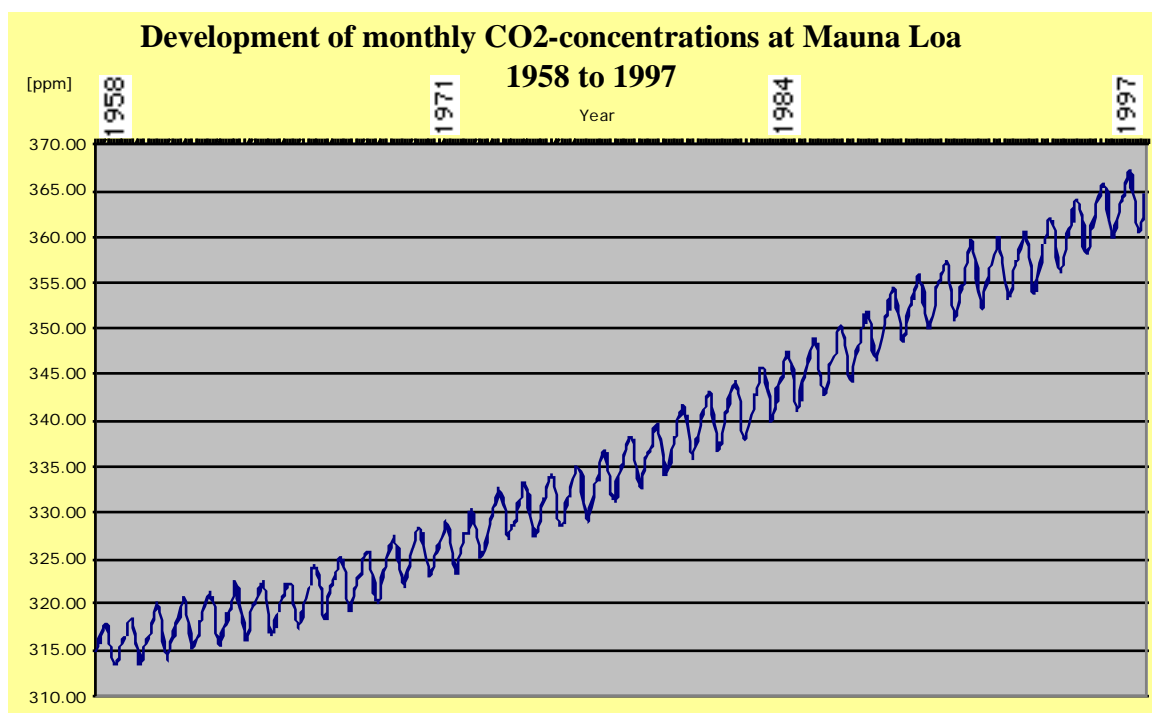


Figure 2: Development of CO₂-concentrations from 1958 to 1997³

Coming back to the problem of increasing uncertainty. When the forecasting time horizon is moved further into the future it is important to choose a modelling methodology that diminishes the influence of uncertainty. It is obvious that for methodologies relying strongly on data from the past like econometric or other modelling based mainly on statistical analysis results become less reliable the further into the future these models are applied. Therefore the decision is taken to focus the ASTRA approach on the investigation of functional cause-and-

³ Graphic based on KEELING/WHORF (1998)

effect relationships between the transport system and the other three connected systems. To implement these relationships, which often are existing in the form of feedback loops, the system dynamics (SD) methodology is applied, because it is especially created to represent systems consisting of several feedback loops. A second advantage of the SD methodology is that all applied model variables have to be quantified and thus may be reviewed and checked by users for validity and consistency. This provides a major difference to other reasonable methodologies for long-term assessment, which can be found in the group of qualitative approaches.

The basic feature of qualitative approaches is the use of expert judgements about future developments. This approach can be formalised in so-called Delphi studies where a panel of experts is requested to make judgements on long-term developments (“Megatrends”). The composition of the expert panel should be multidisciplinary to overcome inherent bias of the judgements that is given by the focus of the experts on their scientific disciplines. Also the experts should stem from different professions like universities, state administration and business. This approach is e.g. presented by a study on global trends in science and technology with a panel of 2300 experts.⁴ With the panel it was able to identify several Megatrends for the next three decades, though the expert assessments are not homogenous. This approach is advantageous in a sense that interrelationships of the different real systems are considered implicitly by the knowledge and experience of the experts. Problems might arise with inhomogeneity of the judgements and the qualitative character of results, which makes it difficult to review and check the findings of the experts.

A second group of qualitative approaches for long-term assessment are based on backcasting techniques in the form, which is presented by the POSSUM project.⁵ In this project, first different images of the future for the final year of the forecasting period are designed and then possible paths, which lead from the present situation to this future, are investigated. For this investigation lists of policy measures are developed and then grouped to policy packages in which the different measures of one package are expected to cause synergies. The validation of images, paths and corresponding policy packages is then carried out by expert judgements during several expert workshops. However, because of the throughout qualitative nature of this approach difficulties to review and check results in terms of consistency or of adequacy of causal relationships occur.

Therefore an improvement of the backcasting approach can be achieved, when the development paths that lead to the different images of the future at the endpoints of the paths are quantified and modelled such that at least consistency of variables of the images can be demonstrated. This approach is followed in the Sustainable Society Project in Canada where the SERF model (socio-economic resource framework) is used to find paths towards a sustainable future scenario. The authors argue that *“Forecasting takes the trends of yesterday and today and projects mechanistically forward as if humankind were not an intelligent species with the capacity for individual and societal choice. Backcasting sets itself against such*

⁴ CUHLS ET AL. (1998)

⁵ POSSUM (1998)

predestination and insists on free will, dreaming what tomorrow might be and determining how to get there from today.”⁶

3.1 Modelling the Complexity of the Transport System

The transport system forms a complex system with determinants that are changing over different time scales. As shown above some of the determinants are very stable in the short run while others like fuel prices can vary significant in the short-term and mid-term time horizon.

Also the transport system is connected with other complex systems like the society, economy and environment. Improvements of the transport system was in history often a major source of growing welfare of societies. In 1995 in the EU15 countries transport services generated 4% of the GDP and 6.2 million employees - that is 4.2% of all employees - are working in the transport sector. These figures do not include the production of infrastructure and vehicles. Also transport forms a part of the social life of society by providing the basis for personal mobility. This is reflected by the growing passenger transport demand that reached a value of 4500 billion pkm in the year 1995. On the other hand transport is a major source of environmental burdens that influences sustainability in the opposite direction than the positive welfare and the mobility effects of transport. In 1995 road transport caused 44.000 deaths by traffic accidents within the EU15 countries. The World Health Organization (WHO) estimates that additionally 80.000 people in EU15 are killed by hazardous gaseous emissions of transport per year. Also the contributions of transport to global effects like the greenhouse effect is considerable as the CO₂ emissions of transport contribute with a share of 26% to the man made CO₂ emissions.⁷ This situation is reflected in figure 3:

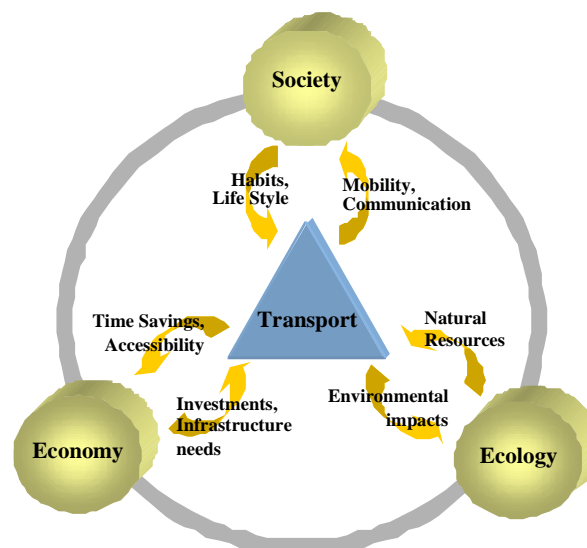


Figure 3: Transport and its Interlinkages to other Complex Systems⁸

⁶ ROBINSON (1996)

⁷ EUROSTAT (1997a)

⁸ SCHADE/ROTHENGATTER (1999)

Modelling approaches that are used for such a complex system should provide an explanatory component, such that users as well as modellers besides the mere results of the model can also get improved insights into the systems relationships from the modelling process and the model structure. Because the whole detailed system can not be captured with a model one main task is to identify the key relationships of the real system that is underlying the model. Subsequent these relationships are formalised and implemented according to the rules of the applied modelling methodology. In ASTRA the SD methodology is applied as well as in three other ongoing respectively just finalised transport research projects. However, the approach by which the key relationships are identified and quantified in functional relationships is different between the projects.

- **ASTRA:** the ASTRA baseline are existing state-of-the-art models from four research disciplines. From these models the key-relationships are extracted and adjusted such that they can be implemented into a SD model. In addition new interfaces between the four models have to be developed (spatial scope: Europe, time horizon: 2026, passenger and freight transport).
- **SIMTRANS:** in SIMTRANS the key relationships are mostly qualitative. They are designed based on expert knowledge of the involved transport experts and then transferred into the SD model by SD experts (spatial scope: France, time horizon: 2020, only freight transport).⁹
- **MODUM:** in MODUM the key relationships, which can be qualitative and quantitative, are derived from discussions on actors workshops. Actors involved the research team and transport companies, administrations and other concerned groups. These key-relationships are afterwards quantified by the project team and then implemented in the SD model (spatial scope: Switzerland, time horizon: 2030, passenger and freight transport).¹⁰
- **EST:** within the EST project of the OECD the ESCOT model is developed. In EST the key relationships are derived from existing models as well as from discussions with groups of economic, environmental and transport experts. The key-relationships are then modified and adjusted for the SD methodology and implemented in ESCOT. This project also shows the ability of SD models to provide a quantitative foundation for the backcasting approach. In EST scenarios for an environmentally sustainable transport system are designed and the path to reach these in the future is modelled and checked for consistency with the SD model ESCOT (spatial scope: Germany, time horizon: (2015) 2030, passenger and freight transport).¹¹

⁹ KARSKY/SALINI (1999)

¹⁰ KELLER ET AL. (1999)

¹¹ SCHADE ET AL. (1999)

3.2 Equilibrium or “Disequilibrium” Models

This point shall only be touched to highlight an important characteristic of system dynamics. Actually most of the models are based on equilibrium approaches. One major reason may be that for these equilibrium calculations sophisticated tools and rules are provided by mathematics. However, the equilibrium state is rarely existing in socio-economic systems or as Keynes said equilibrium is reached only “by accident or by design”. Nevertheless, it can be argued that the systems are not in an equilibrium state, but that they always tend to move towards an equilibrium state.

A different approach would be to look for alternative modelling methodologies for which the existence of an equilibrium state is not a prerequisite. One of these approaches is the System Dynamics methodology for which the development of the system over time is determined by the decision rules that define the transition of the system from one point of time to the subsequent point of time. In this case neither a current equilibrium state nor a future equilibrium state is required.

4 ASTRA System Dynamics Model Platform (ASP)

This section provides an overview on the ASTRA System Dynamics Model Platform (ASP). The ASP integrates key relationships of state-of-the-art models in the fields of macroeconomics, regional economics and land use, transport and environment. It is composed of the four sub-modules: macroeconomics sub-module (**MAC**), regional economics and land use sub-module (**REM**), transport sub-module (**TRA**) and environment sub-module (**ENV**) and a model sector that outlines the development of the welfare situation based on a selected set of key indicators. Results of the conventional models are used for calibration of the ASP sub-modules. Basically the ASP is operated on a yearly time basis with a time scale from 1986 to 2026 and a base year 1985. The applied time step DT for the integration period is 0.25, which implies that all model variables are calculated every three months.

In the following the global structure and interrelationships of the model are presented in comprehensive diagrams. The first diagram (figure 4) presents the structure of the models that superimpose each other in the ASP. The structure consists of the four sub-modules MAC, REM, TRA and ENV, the passenger and the freight model that are formed by parts of REM, TRA and ENV and the welfare situation sector that is created by indicators from MAC and ENV. 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.

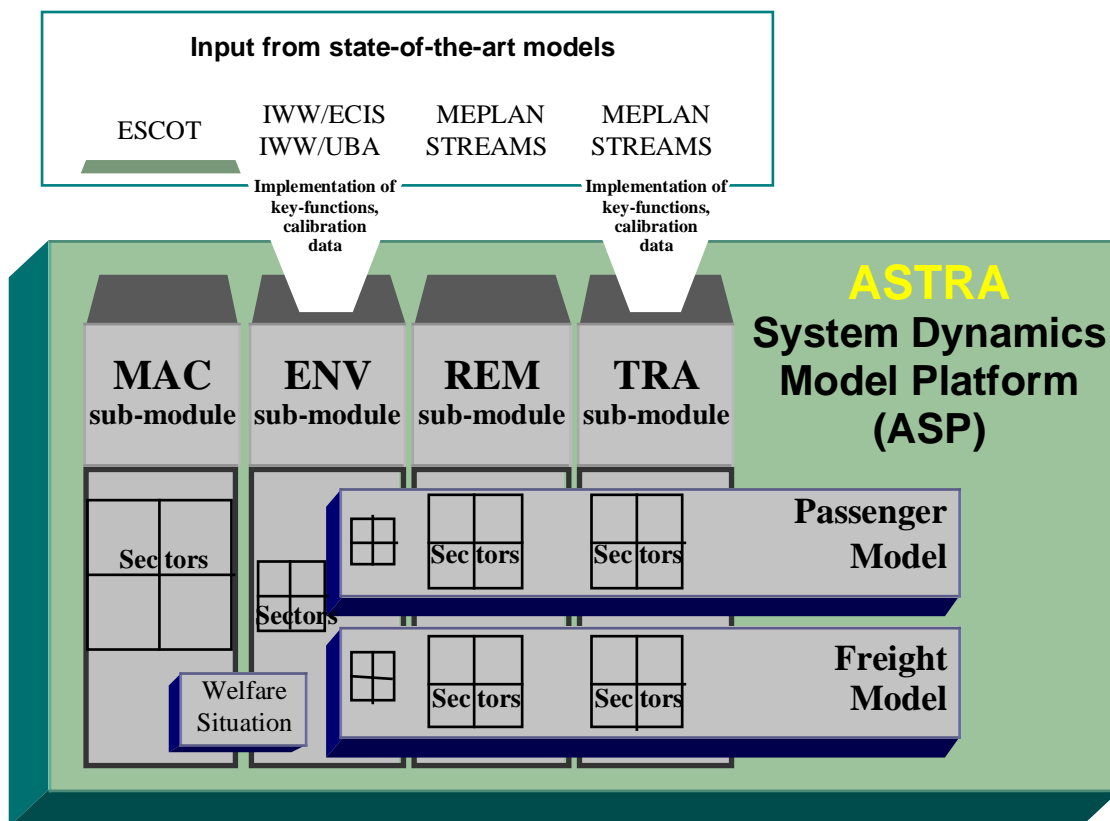


Figure 4: Structure of the ASTRA System Dynamics Model Platform (ASP)

The second diagram (figure 5) presents a global overview on the implemented feedbacks 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 part of the REM and the whole TRA concerning transport variables are calculated on a daily basis while MAC and ENV are working completely on a yearly basis. So, interfaces between the former and the latter group have to consider an annualisation of the data.

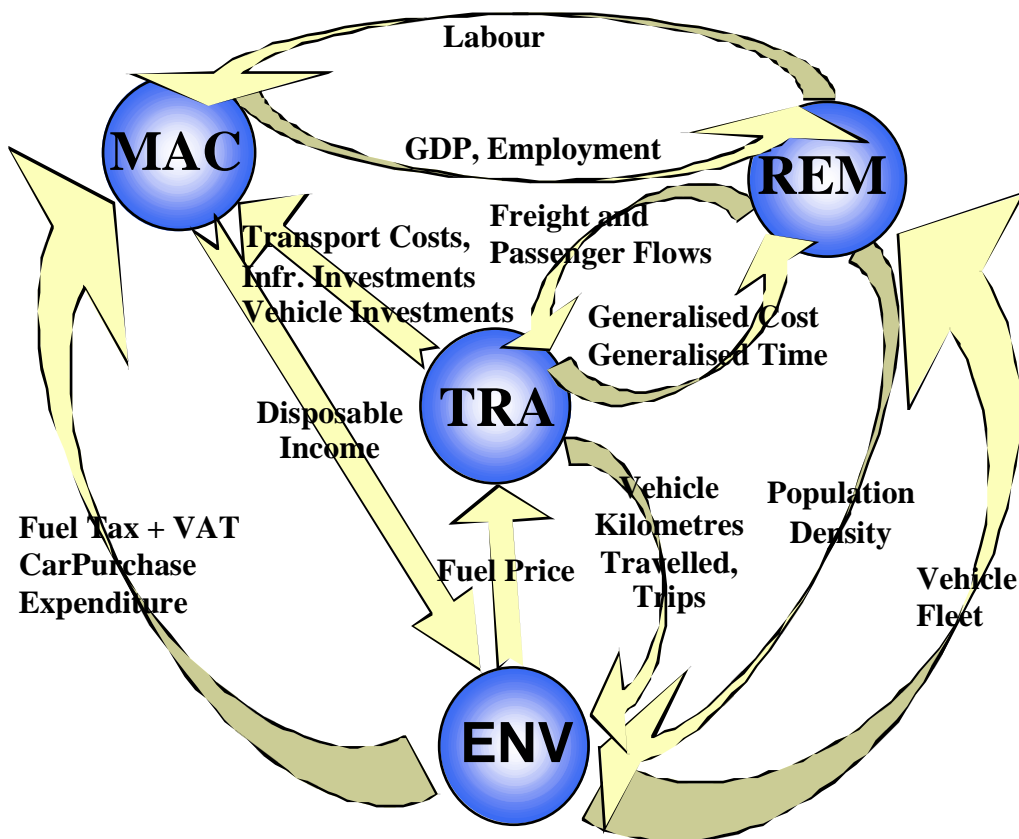


Figure 5: Output data forming the major feedback loops between the ASP sub-modules

The third diagram (figure 6) presents the main relationships that drive the passenger model. Based on potential output and final demand GDP is calculated considering also taxes and transfers. GDP determines the national income, which is used to calculate the level of disposable income. 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 that e.g. consider different employment situations) 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 are calculated and transferred to the MAC. Within the MAC the transport expenditures, which cover for road mode only perceived cost, are part of consumption and also drive employment in the transport service sectors. Trips and traffic volume are 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 forms a part of private consumption. Based on vehicle purchase the fixed costs for car purchase are calculated and added to transport expenditures such that they also influence private consumption. Additionally they have an effect on employment in the transport vehicle manufacturing sectors. Externalities and defensive costs of emissions and accidents are estimated and form a part of the welfare situation. Within the MAC the remaining indicators that describe the welfare situation are calculated.

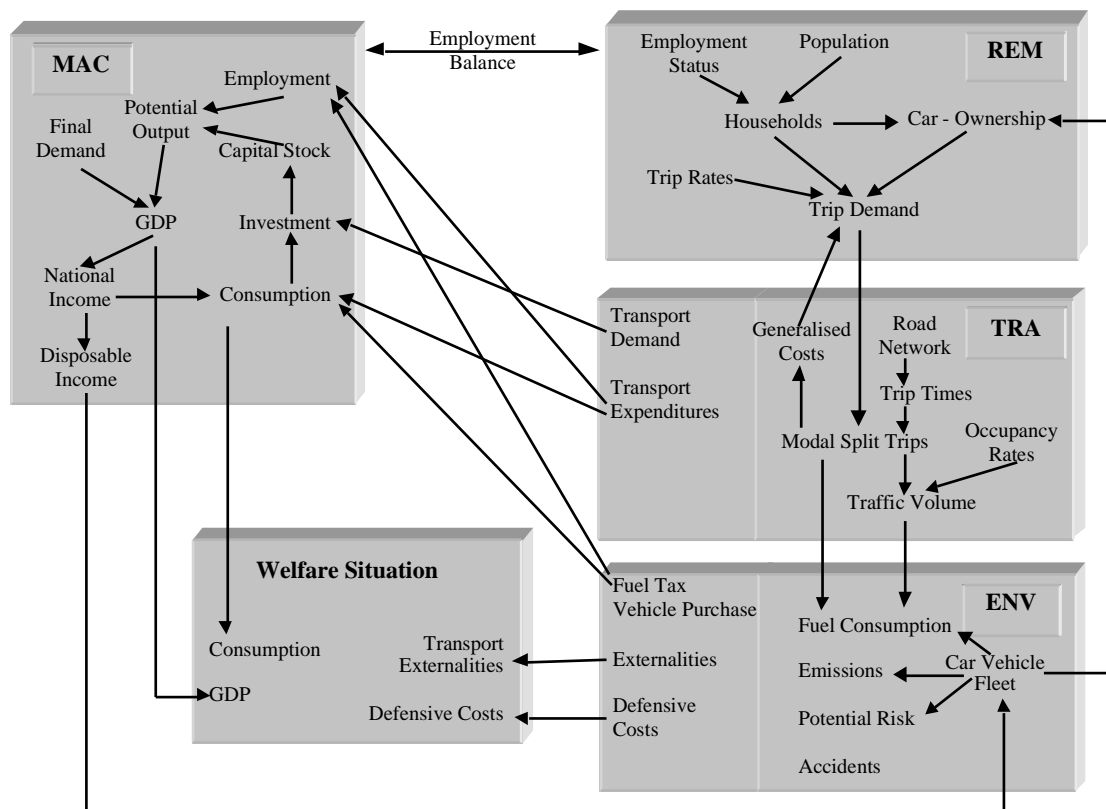


Figure 6: Aggregated Relationships of the Passenger Model

The fourth diagram (figure 7) 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 corresponding to goods production is transferred from MAC to REM where it forms an input to generate the transport flows. The resulting transport demand is transferred to the TRA where the modal-split is performed based on generalised cost and the traffic volume for the freight modes is calculated. Based on the traffic volume freight expenditures are calculated and

transferred to the MAC, where they influence investments and employment. 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 vehicle investments for all modes are calculated and transferred to the MAC, where they are a driver of investments and employment. The output relationships of the ENV are similar to the ones in the passenger model.

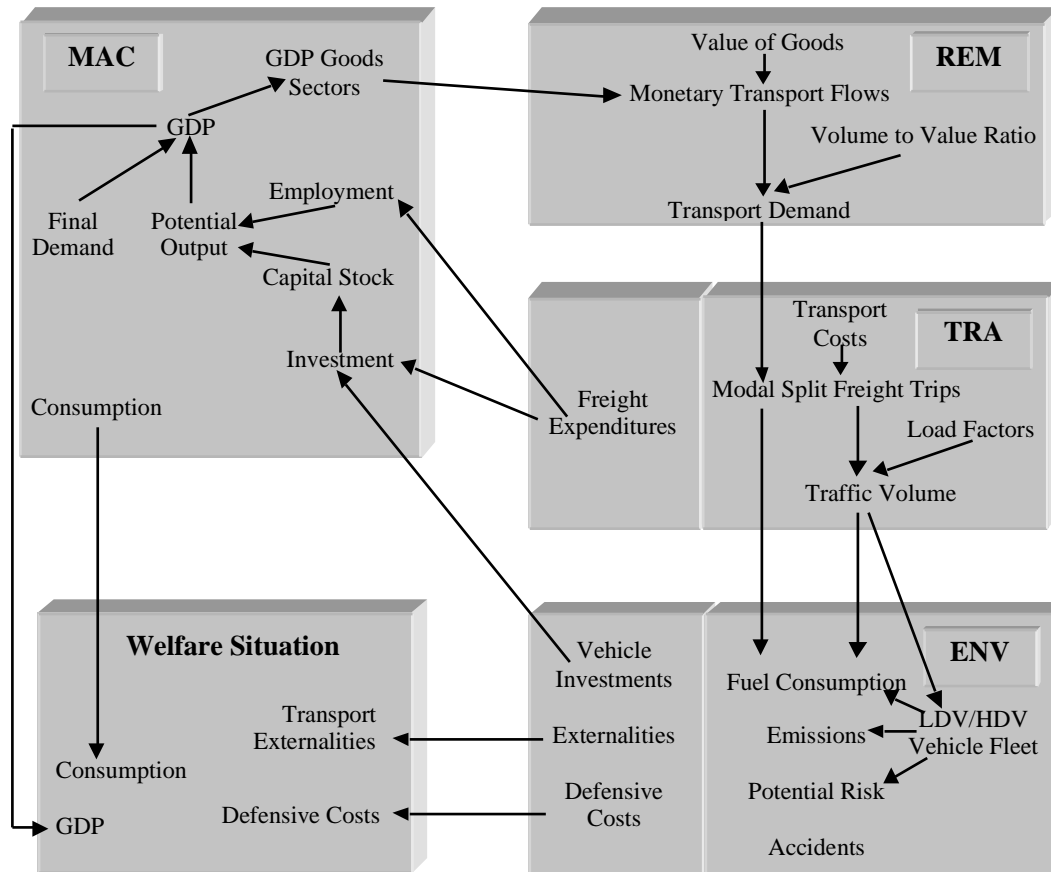


Figure 7: Aggregated Relationships of the Freight Model

4.1 Glance on the Vensim model

The Vensim¹² software provides two levels for model development and usage: the sketch level and the equations level. On the sketch level the model structure is developed and displayed. Also single equations can be edited with dialogue window support. The sketch level is divided into separate views. Each view is representing a model sector. On the equation level all equations are listed and can be edited.

¹² Details about the Vensim software can be obtained from the Vensim documentation distributed by Ventana Systems (VS 1997a, 1997b)

Policies can be implemented in four distinct ways. Simple policies can be introduced by the change of variables (constants or graphs) on the sketch level. Also Vensim provides a simulation control dialog on which the list of constants or graph variables is offered to change their values. Complex policies can be defined in specific policy data files, which can be loaded from the harddisk and then can be tested or modified. Finally with the most recent version of Vensim simple policy steering panels, which are called flight simulators in System Dynamics language, can be implemented. They might consist of switch buttons and sliders.

The results of policy runs can be presented with graphs or tables. Graphs can be used for display of time series data for different variables in the same policy (cross-variable comparisons) or in different policies (cross-policy comparisons). Additionally, with a separate Vensim tool, the Vensim application software (VenApp), easy-to-use applications can be developed for policy testing and displaying of results. As an example in figure 8 a time series of GDP is compared with the time series of CO₂ emissions from transport for the macro regions 1 to 3.

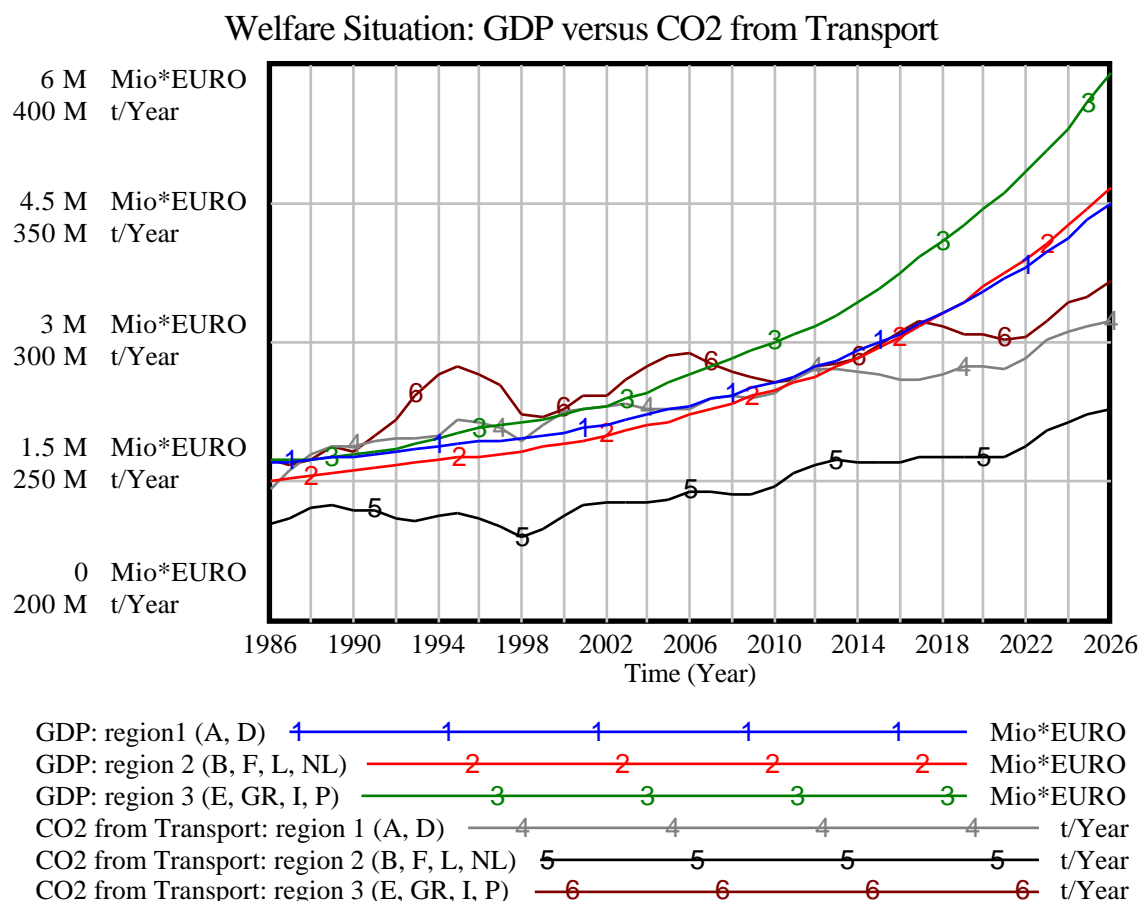


Figure 8: Comparison of development of GDP with CO₂ emissions from transport

Figure 8 consists of three important elements. The first element is the graph displaying the six curves in different grey tones (respectively in different colours) and with numbers assigned to each curve. The numbers can also be found in the second element, which is the legend below the graph. There one finds the variable name, the colour and number of the corresponding curve and the unit of measurement. In case of different policies or scenarios displayed in the graph also an indication is given to which scenario the curve belongs to. The third element are the x- and y-axis, where the x-axis is usually the time and the y-axis presents the unit of measurement and the quantity of the variable. On the y-axis different unit of measurements could be displayed as the variables can differ by their order of magnitude or by their physical meaning in reality (e.g. tons of emissions and monetary values of GDP).

5 General Features of the ASTRA Model

5.1 Introduction

The ASTRA Systems Dynamics Model (SDM) comprises four sub-modules. There are several features of the SDM which are common to two or more of the sub-modules and it is these features that are described in this chapter.

In general the following principles were adopted in the modelling process:

1. In the ASTRA modelling framework the elements of the classical 4-stage transport model have been retained in the modelling of the demand for transport. Trip and freight generation and distribution modelling were considered to belong to the regional economic sub-module (REM) set within the context of the activities which give rise to them, while modal split and assignment are considered as part of the transport sub-module (TRA).
2. The modelling of the demand for passenger and freight travel i.e. trip generation and trip distribution in the REM is done separately as is the modal split in the TRA. The derived road traffic by mode from the passenger and freight models is then assigned together to the transport network in the TRA.
3. The representation of space is treated in two distinct ways by the sub-modules within the SDM.

i. Macro regions

The macro-economic sub-module (MAC) works with a concept of “Macro Regions” which are defined in geographical space as aggregates of EU15 member countries. This same representation is used in the modelling of freight demand in the REM and TRA sub-modules. The issue of what was the appropriate spatial unit to be used in the modelling of freight movements was one of the unresolved issues in the model design highlighted in ASTRA D3.

ii. Functional zones

The passenger model in the REM uses an alternative representation of the spatial dimension thought to be more suited for modelling passenger demand in this particular application. This representation uses the concept of “Functional Zones” based on settlement type. The functional zones are formed by aggregating NUTS2 regions of the same settlement type together, consequently they are not geographically contiguous.

Both the “Macro Region” and “Functional Zone” representations of space cover the EU15 countries; see section 5.2 for an explicit description of the spatial dimension in the SDM. The decision on the appropriate spatial units for the modelling of freight and passenger demand was based on an analysis of the characteristics that affect the demand for that

type of travel. One of the major influences was the need to derive relatively homogenous geographical areas for which to generate and distribute the demand for travel and carry out the modal split. It was therefore decided on the basis of these considerations in light of analysis of trends in passenger and freight demand what the appropriate spatial unit would be. A fuller discussion of these trends influencing this decision is given in the chapter dealing with the design of the REM, chapter 6.2. The assignment of the travel demand in the TRA is done on the level of the macro regions, a level where it is easier to define the physical transport network. Table 1 summarises the spatial units used in the four sub-modules.

Table 1: Spatial units used by sub-modules in ASTRA Systems Dynamics Model Platform (ASP)

Sub-module	Spatial unit
Macro-economic (MAC)	Macro regions
Regional economic and land use (REM)	<i>Passenger generation & distribution</i> - Functional zones <i>Freight generation & distribution</i> - Macro regions
Transport (TRA)	<i>Passenger modal split</i> – Functional zones <i>Freight modal split</i> - Macro regions <i>Passenger and freight assignment</i> - Macro regions
Environmental (ENV)	Macro regions (in parts also Functional zones)

4. The explicit representation of the choice approach was adopted in preference to the accessibility index approach in both the regional economic sub-module (REM) and the transport sub-module (TRA).
5. Distance bands are introduced to reflect both the responsiveness of trip lengths and length of haul to travel supply characteristics, and the different modal choices selected on trips with different average distances between the zones. The definition of the distance bands used are different for passenger and freight travel demand, see section 5.4 for a more detailed description.

5.2 Spatial Structure

The ASTRA SDM combines two concepts of the modelling of the spatial dimension and consequently two different zoning schemes have been adopted. Although this is not ideal, substantial simplifications on the spatial side have had to be made in order to reduce the dimensions within the SDM, which otherwise would place an excessive computational burden on the system dynamics software. This is especially important for the core ASP implemented

with the itthink software. However, with the use of the more powerful Vensim software for the full ASP it can be thought about more detailed spatial representation in future versions of the ASTRA model.

The MAC sub-module follows the traditional approach to the modelling of space based on geographical definitions of 4 “Macro Regions” which are aggregations of the EU15 member countries. In the other sub-modules the representation of space relates to whether the passenger or freight demand is being modelled. The passenger demand (REM) and modal split models (TRA) use the alternative concept of space. The functional zoning approach was adopted rather than a classical geographic zoning system, this is described below, see section 5.2.2. For the freight model a more conventional geographical zoning scheme was considered more appropriate and consequently the macro region definition of space was used. It is the view here that it is not necessary for the same zoning scheme to be used in the modelling of both passenger and freight demand, the justification for this being the different nature of the influences that determine passenger and freight demand (see chapter 6.2). Therefore it is the position that in the ASTRA SDM it would be advantageous to make reference to a different set of zones for the passenger and freight models so as to model more accurately the driving forces that influence the different types of demand for passenger and freight transport. This argument is driven by the fact that the choice of the zone clusters then plays a crucial role in the generation of the demand for travel.

The functional zones approach to modelling passenger demand is certainly a significant simplification of the modelling approach on the spatial side, but is necessary in order to relieve some of the computational burden of the model by reducing the memory requirements. The implementation leads to the construction of functional zones that are non-contiguous in the spatial dimension but share similar transportation, demographic and economic structures and which are relatively homogenous, which is an important consideration when deriving the demand for travel. In the freight model it is important to be able to apply differential growth rates for different economic sectors of the economy in each zone and as this will be based on data from the MAC it is important that there is a strong correspondence between the zoning schemes.

5.2.1 Macroeconomic Regions

The macro-economic sub-module (MAC) uses a conventional representation of space based on geographical location and has divided the EU15 into 4 zones with a further zone representing trade with the rest of the world outside the EU15. The zones have been designed such that they are as homogenous as possible with respect to their economic structures. To avoid confusion with the functional zoning scheme these are named “Macro Regions”.

- Macro Region 1 (**MR1**). Germany & Austria
- Macro Region 2 (**MR2**). France, Belgium, Luxembourg & the Netherlands
- Macro Region 3 (**MR3**). Italy, Spain, Portugal & Greece

- Macro Region 4 (**MR4**). UK, Ireland, Sweden, Denmark & Finland
- Macro Region 5 (**MR5**). Rest of the World (ithink core version only)

This representation of space is also used in the REM and TRA in modelling freight demand and modal split. In the freight model the determinants of the demand for travel are somewhat different from those that drive the demand for passenger travel. As described in ASTRA D3 Chapter 2 consideration was given to several alternatives of representing the spatial structure of the EU15 with the final decision made to use a conventional geographical zoning scheme and consequently to use the same macro regions used in the MAC sub-module.

5.2.2 Functional zones

Six functional zones were defined based on settlement type and consisted of aggregates of the 201 STREAMS model zones covering the EU15, which are mainly at the NUTS 2 level, which were each assigned a settlement type. The functional zones defined in the ASTRA modelling framework are¹³:

- Large Stand Alone Metropolitan Centres (**LSA**).
- Metropolitan Areas plus Hinterlands (**MPH**).
- High Density Urbanised Areas (**HDU**).
- High Density Dispersed Areas (**HDD**).
- Medium Density Regions (**MDR**).
- Low Density Regions (**LDR**).

A full description of these functional zones was provided in ASTRA D3 and a full list of the STREAMS model zones and the functional zones to which they belong is provided in the Technical Annex of that Deliverable.

In a functional zone matrix, each cell represents all relations existing in the transport networks for a pair of geographic zones which belong to the origin and destination district types. The different relations, which build up a given cell, make reference to different distances and thus to different modal choices. Thus the functional zone matrix approach would make it possible to separate *intra-zonal* and *inter-zonal* flows by mode within the ASTRA SDM.

Let us consider a cell representing trips from the peripheral area of a big city to the centres of big cities. These trips might be metropolitan trips, when the two zones actually belong to the same city, as well as regional trips, when the two zones belong to different cities in the same region, or inter-regional trips, when the two zones belong to different cities in different regions. Modal choice of the represented trips is obviously not homogenous and it is strictly related to the distance between zones.

¹³ acronyms in parenthesis are those used within the SDM with a slight variation in the Vensim model in which E1, E2, E3 and E4 is used for the four macro regions.

Figure 9 illustrates the zoning schemes as implemented in the ASTRA SDM.

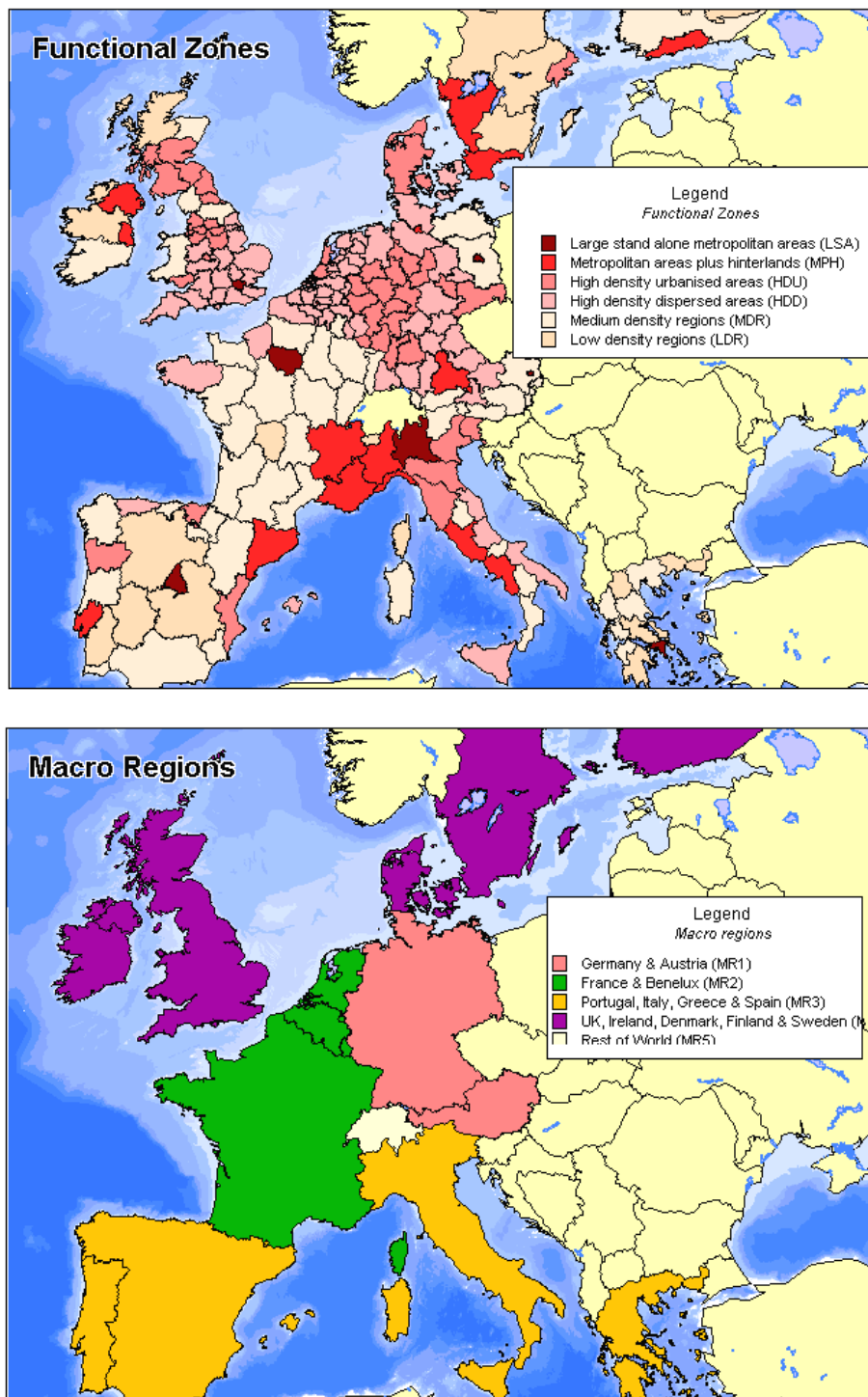


Figure 9: Zoning scheme for ASTRA System Dynamics Model Platform (ASP)

Figure 10 shows the basic relationship between the *macro regions* and the *functional zones*. It should be noted here that within the ASTRA SDM it is necessary within some of the interfaces between the various sub-modules to convert data from macro region to functional zones and vice versa. This is done using sets of co-efficients derived from the STREAMS model.

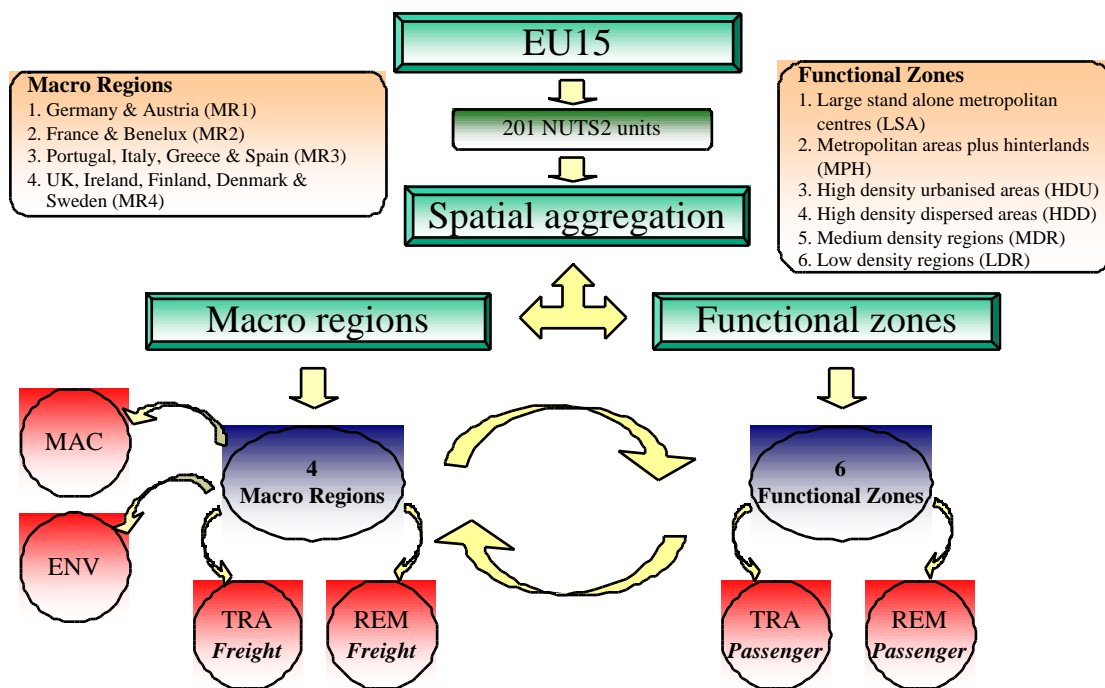


Figure 10: Schematic Representation of Spatial Dimensions of EU15 countries in ASTRA SDM

Note: The fifth “Macro-Region” which is not specified in Figure 11 is external to the EU15 and represents the trading position of the rest of the world with the 4 “Macro-Regions” internal to the EU15 which are explicitly represented in the ASTRA SDM.

5.3 Transport Flows Representation

Within the transport sub-module the movement of persons and freight is modelled as an explicit set of transport flows. In the context of the passenger demand these are represented as a set of trip purposes and for freight demand they are represented by freight categories.

5.3.1 Trip Purposes

In the classical transport model travel demand is considered to be relatively homogenous for different groups within the economy. In order to represent demand accurately it is necessary to correctly segment the market for travel. Many of the issues regarding the segmentation of demand for the purposes of generating passenger trips are issues relating to the design of the REM and are considered in that section of this report. However the definition of trip purposes is of equal relevance to both the REM and TRA sub-modules. The trips are generated and distributed in the REM by defined trip purposes that are sufficiently

disaggregated to ensure that the total demand for travel is accurate. It is the number of trips by each purpose between origin and destination zones that are transferred to the TRA for the modal split to be carried out.

In the passenger model three trip purposes were identified:

- commuting and business (**BU**)
- personal (**PE**)
- tourism (**TO**)

These trip purposes represent aggregations of a more disaggregate set of trip purposes used in the STREAMS transport model. Aggregation was necessary to allow this dimension to be included efficiently in the modelling structure but the disaggregate purposes were combined in such a way as to preserve homogeneity as far as possible.

5.3.2 Freight Categories

Within the REM sub-module, the economic sectors of the economy are represented and the value of the output is translated into tonnes that are distributed to destination zones and then aggregated to a number of freight categories that are passed to the TRA. In order to allow the most accurate modelling of relatively homogeneous categories of freight three freight categories were identified;

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

It was originally proposed in ASTRA D3 to model four freight categories with unitised freight being sub-divided into low and high value unitised freight. However principally due to the computational burden on the SDM highlighted elsewhere in this Deliverable it was decided to amalgamate these two categories.

5.4 Spatial Representation

When applying a classical transport model based on a geographic zoning system, modal split is performed for each origin destination pair according to the attributes of the transport modes: distance, cost, time, modal constant, etc. Among these characteristics, travel distance plays a significant role as both time and cost of the passenger or freight movements depend on it. At the same time, the amount of transport demand between two zones depends also on the existing distance (or better on the travel time): the closer the two zones, the more they will exchange transport flows (trips or freight).

When adopting a functional zoning system, distance between functional zones is no longer significant. Indeed functional zones represent clusters of zones that are homogenous with reference to population density, city dimensions, etc. Hence the distance between different functional zones (a cell of the functional zones matrix) would be represented better by a distribution function more than by a single average value, according to the actual couples of geographic zones belonging to the two clusters. As a consequence it would be extremely difficult to define the correct travel pattern (amount of transport demand and modal split) for a pair of functional zones, as this travel pattern would vary according to the distribution of distance.

The operational solution adopted in the ASTRA model was to break the distance dependence of the travel pattern into slices. In this way it is possible to work with the single slice using average values without losing significant information. The distribution component of the REM sub-module and the modal split component of the TRA sub-module were divided into sectors differentiated according to distance bands. Transport demand is generated by the REM for the different purposes and for the different distance bands corresponding to each origin/destination pair of the functional zones influenced by the generalised time from the TRA. These demand matrices are then used by the TRA. Different distance band sets were used for the passenger and freight models. This is justified from statistical evidence that the modal split by distance for passengers and freight demand are very different, such that for freight it is not necessary to make reference to disaggregate distance bands below a certain threshold. However for passengers the modal split for short distance journeys, which make up a large proportion of passenger trips, is very important.

5.4.1 Passenger Distance Bands

In the passenger model the distance bands were derived from the analysis of the National Travel Surveys of European member states carried out for the STREAMS passenger model. In each sub-module all transport modes characteristics (time, cost, etc.) for modal split make reference to average figures for that specific distance band on the basis of the results of the STREAMS model. For instance, the business & commuting transport demand between LSA and HDD zones generated by the REM is split among the different distance bands according to the pattern derived from the STREAMS model. This is assumed to represent the actual patterns of EU flows; the TRA then processes separately each distance band data set.

The operational transport sub-module is made up of a number of different modal split models each making reference to different average distances or distance bands. Within a model the relevant trip purposes are analysed and a specific modal split is modelled for each trip purpose. With reference to passengers, five distance bands are defined:

- local (distances below 3.2 km),
- very short (distances \Rightarrow 3.2 and $<$ 8 km),
- short (distances \Rightarrow 8 and $<$ 40 km),

- medium (distances ≥ 40 and 160 km),
- long (distances > 160 km).

5.4.2 Freight Distance Bands

In the freight model four distance bands have been selected according to an analysis of the results from the STREAMS model and also a statistical analysis of the trends over time in the length of freight movements in the EU15 from the Eurostat Carriage of Goods annual survey.

The four distance bands modelled were as follows:

- short (distances < 50 kms),
- medium - short (distances ≥ 50 and < 150 kms),
- medium – long (distances ≥ 150 and 700 kms),
- long (distances > 700 kms.)

The principles of modelling the freight movements by distance are the same as those described in the context of the passenger distance bands such that a specific modal split is modelled for each freight category.

6 Description of the four ASTRA sub-modules

The following chapters describe the internal structure and the output interface of each of the four ASTRA sub-modules. The description follows a sequence from the high level influences within the macroeconomics sub-module (MAC) via trip generation and trip distribution within the regional economics and land use sub-module (REM) and modal split and assignment within the transport sub-module (TRA) to the environmental consequences within the environment sub-module (ENV). The descriptions commence with the aim and basic structure of each sub-module. Subsequently the implementation, calibration and the output interfaces of the sub-modules is explained.

6.1 Macroeconomics Sub-module (MAC)

6.1.1 Aim of the MAC sub-module

The aim of the MAC sub-module is to provide an aggregate macroeconomic environment in which the REM, TRA and ENV sub-modules are embedded. With this macroeconomic information national and continental level influences can be integrated into the ASP. Also feedback loops, which commence on the micro- or meso-level in one of the other sub-modules (e.g. transport expenditures for one mode in one distance band) and then resume with an effect on the national level, can again influence the original sub-module such that the feedback loop is closed by the integration of the MAC sub-module.

6.1.2 Basic Structure and Future Expectations

The MAC sub-module is constructed as an extended Keynesian model. It follows a similar approach as the macroeconomic model within the ESCOT model, which has been developed as part of the project on Environmentally Sustainable Transport (EST) of the OECD.¹⁴ It consists of three major elements:

- supply side model based on supply of production factors,
- demand side model based on the elements of final demand and
- sectoral interchange model based on an input-output table.

For the purposes of analysis the EU has been split into 4 macro regions. These have been chosen to provide regions of approximately the same size and containing economies with roughly similar characteristics (see also figure 9).

- Macro region 1: Germany and Austria.
- Macro region 2: France, Belgium, the Netherlands and Luxembourg.

¹⁴ SCHADE B. ET AL. (1999), SCHADE B. ET AL. (2000)

- Macro region 3; Italy, Spain, Portugal and Greece.
- Macro region 4: UK, Ireland, Sweden, Denmark and Finland.

Each of the four regions is modelled using the same macroeconomic framework. All monetary values are calculated in real values of 1995 EUROS. Most variables are calculated net of all taxes as taxes are treated separately. The MAC works on a yearly time basis.

The interaction between supply and demand side can be adjusted such that the model can simulate supply-demand balanced economies but also either a supply side driven or a demand side driven economy. In the base run both sides are treated as their influence is of the same importance.

6.1.2.1 Supply side model

Basic element of the supply side is a production function of Cobb-Douglas type that incorporates the three major production factors labour supply, capital stock and natural resources as well as an exogenous technological progress given as a productivity influence. Labour supply and capital stock are calculated endogenously based on variables like labour force, investments and capital depreciation respectively scrappage. The influence of natural resources is considered exogenously but one could think of opportunities to endogenize the resource use in future versions at least by using one or more proxies like use of fresh water for production.

It should be mentioned at this point that technical progress is only included on the supply side, such that if the supply-demand balance is moved strongly towards the demand side the technical progress has only a very minor influence on the economic development. However in the long run especially technical progress drives the economic growth, such that a balanced or a supply side driven version of the supply-demand model should be applied.

Future expectations on the supply side are in line with the forecasts of the SCENES project. That means production potential will grow with rates around two percent a year, which is due to an increase in capital stock and technological improvements, while labour supply is stable or even decreases in the last two decades of the simulation.

6.1.2.2 Demand side model

The aggregated variable on the demand side is the final demand, which is driven by consumption, investments, government expenditures and export. Consumption and investment are split into a share that is independent from transport and a share that is dependent on the development of the transport markets given by the TRA and the ENV. Government expenditures develop according to GDP development, while export is driven by the aggregated demand for the three other variables.

Future expectations on the demand side indicate further growth of national income respectively personal income, which will lead to growing consumption. In the base run a

reduction of the share of government expenditures on GDP is not expected though it could be a reasonable and probable policy in the future.

6.1.2.3 Sectoral interchange model

The basic element of the sectoral interchange model is an aggregated input-output table with twelve economic sectors. The sectoral disaggregation is also applied for other economic variables like consumption to be able to consider the direct effects of transport developments within their corresponding sectors as well as the indirect effects in the sectors supplying intermediate products.

The data for the I-O-table is taken from the EUROSTAT R25 projection tables for 1995.¹⁵ The structure of the tables is not kept constant over time, instead the change of final demand alters the third quadrant of the I-O-table. Updating the inverse input coefficients and recalculating the I-O-table leads to a change of the sectoral relationships within the economic sectors of the MAC.

Two major outputs from the sectoral input-output-model are the sectoral gross-value-added that is used for the calculation of employment and the GDP share for goods production that forms an input for the transport generation model within the REM.

In the future it is expected that the service sectors will increase stronger than the agricultural sector and the industrial sectors. In other words, the share on GDP of the service sectors will increase, while the goods sector's share will decrease.

6.1.3 Implementation of the macroeconomics sub-module (MAC)

The following figure 11 presents the major models of the MAC and the structure of their main relationships, which is already explained in brief above.

¹⁵ The EUROSTAT Input-Output-Tables can be ordered from the EUROSTAT datashop in Luxembourg in electronic format (EUROSTAT 1995)

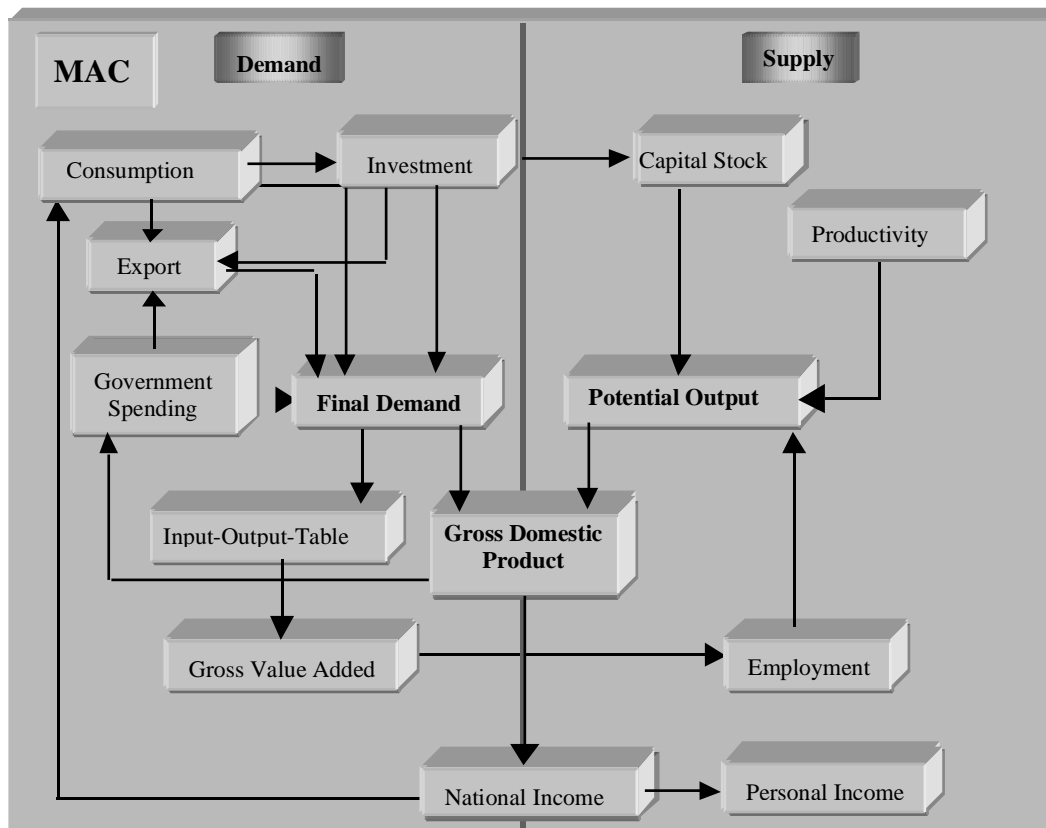


Figure 11: Relationships between the Models of the MAC

6.1.3.1 Potential Output Model

For the calculation of potential output an extended Cobb-Douglas function is used including labour, capital, natural resources and productivity as inputs:

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

where: PO = Potential Output [Bio*EURO]
 bPO = Base level variable for potential output
 cPO = Constant factor for potential output development
 PROD = Productivity development
 LS = Labour supply in working hours
 CS = Capital Stock
 NR = Natural resources
 , , = production elasticities

Labour supply stands for the total number of yearly worked hours. As such it is based on total employment calculated within the employment model and the number of average yearly worked hours. The capital stock depends on the initial gross capital stock, the investment (capital goods including transport investments) and the scrappage of the capital stock. The autonomous productivity influence is modelled with a diminishing increase over time. For further improvements of the model the productivity increase could be split into an

autonomous increase of productivity and a transport system dependent increase e.g. if time savings in the transport system are realized.

Basic information about production elasticities for labour, capital and resources are taken from existing studies.¹⁶ For labour supply the elasticity is in the range of 0.48 and for capital of 0.62. These values have been adjusted for the different macro regions in the calibration process.

6.1.3.2 Final Demand Model and GDP

Final demand is aggregated from the four major demand variables: consumption, investment, government expenditure and export. As the four drivers of final demand are disaggregated into 12 economic sectors (e.g. mineral oil industry) this is also valid for final demand.

$$FD_s = C_s + I_s + GE_s + EX_s \quad (\text{eq. 2})$$

where: FD = final demand [Mio*EURO]
 C = private consumption
 I = investments
 GE = government expenditures
 EX = exports
 s = index for 12 economic sectors

Aggregating final demand over all 12 sectors leads to the total final demand in each macro region. Total final demand and potential output are used to calculate the supply-demand balanced gross domestic product (GDP). The balance between demand and supply side can be adjusted in the model. For ASTRA both sides are treated with an equal weight.

6.1.3.3 Input-Output-Model

The objective of the input-output-model is to consider also the indirect effects of the varying sectoral developments in the ASP. For this purpose an aggregated input-output-table with 12 economic sectors¹⁷ is implemented:

1. Agriculture, forestry and fishery.
2. Energy, water-, mining products, crude oil.
3. Chemical-, mineral-, plastic- and petroleum products.
4. Ferrous and non-ferrous ores and metals.
5. Steel products, machinery, transport equipment.

¹⁶ MÜLLER/ROTHENGATTER (1988)

¹⁷ The concept of an aggregated input-output-table is established in the German system of national accounts, where a detailed I-O-table with 58 economic sectors and an aggregated I-O-table with 12 sectors is used (e.g. STATISTISCHES BUNDESAMT 1997a).

6. Electrical-, optical goods, office and data processing, toys.
7. Textiles, clothing, paper, wooden goods.
8. Food, beverages, tobacco.
9. Building and construction.
10. Services for repair, wholesale and retail, transport, communication.
11. Other market services like lodging, catering, credits, insurances.
12. Non-market services.

The sectoral split enables to consider effects of changes in the transport system directly in the economic sectors, in which they have an effect e.g. road vehicle production in sector 5 “Steel products, Machinery, Transport Equipment”. But also via the update of the input-output-table with the use of endogenously calculated inverse coefficients (see figure 12) the indirect effects of changes within one sector provided by another sector are covered. E.g. changes in vehicle production in sector 5 will have an effect on sector 4 on the production of ferrous and non-ferrous metals.

The changes in the input-output-table are driven by the changes in sectoral final demand e.g. consumption of transport services (e.g. passenger rail transport) that have an effect on sector 10 “Services for Repair, Wholesale and Retail, Transport, Communication”. With the use of the input-output-table several important economic indicators can be calculated and used for further purposes e.g. input of intermediate products per sector, production value, gross value added. An overview of the structure is shown in figure 12:

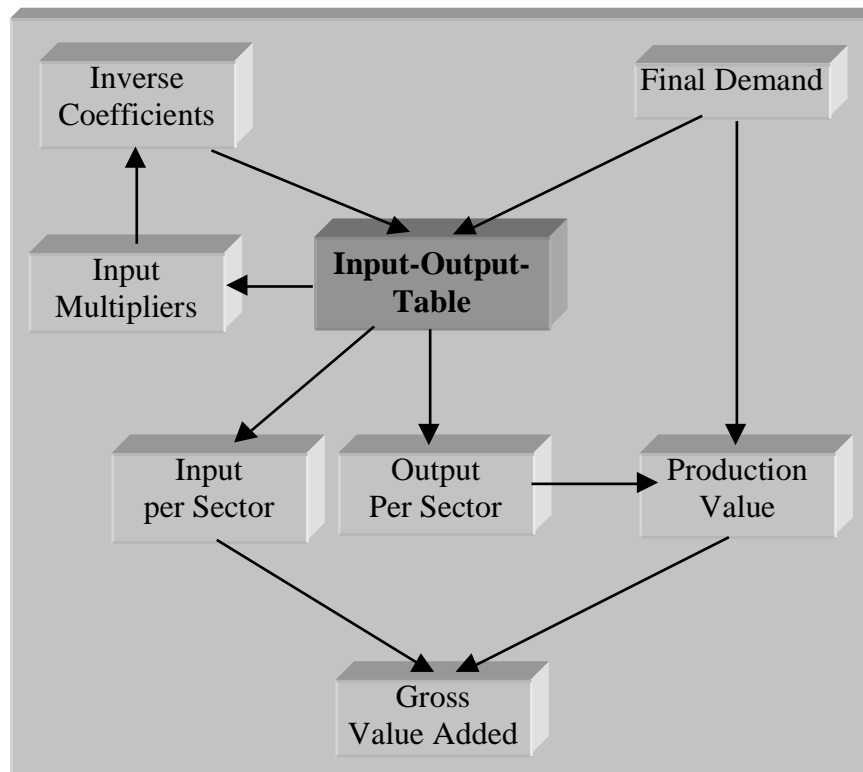


Figure 12: Structure of the Input-Output-Model

6.1.3.4 Consumption Model

The consumption model calculates the consumption of private households. The baseline for the consumption model is given by national income that is derived from GDP subtracting depreciation, indirect taxes and subsidies. The former two influences are calculated endogenously while subsidies are taken exogenously.

Considering savings national income is used to calculate the possible consumption of households. Then consumption is disaggregated twofold: first the sectoral split into 12 economic sectors is performed and second a split into consumption for non-transport purposes and consumption for transport purposes is introduced. The latter split actually only effects sectors that are **directly** influenced by transport, which are the sector 3 including petroleum products, sector 5 including car manufacturing and sector 10 including passenger transport services (bus, rail, air).

With this approach substitution effects between transport and non-transport consumption are considered in a way that e.g. a decrease of consumption in transport sectors leads to a non-negligible increase of consumption in non-transport sectors. This does not mean that there will be a complete compensation because of complementarities between transport and other activities and incentive effects.

As all variables in the consumption model are representing net values without any taxes it has to be taken into account that most transport related consumption is taxed different than non-transport consumption. That means without considering any secondary effects a decrease in transport fuel consumption (net!) would increase overall consumption (net!) as transport

taxes are higher than average taxes on consumption. Figure 13 gives an overview on the consumption model.

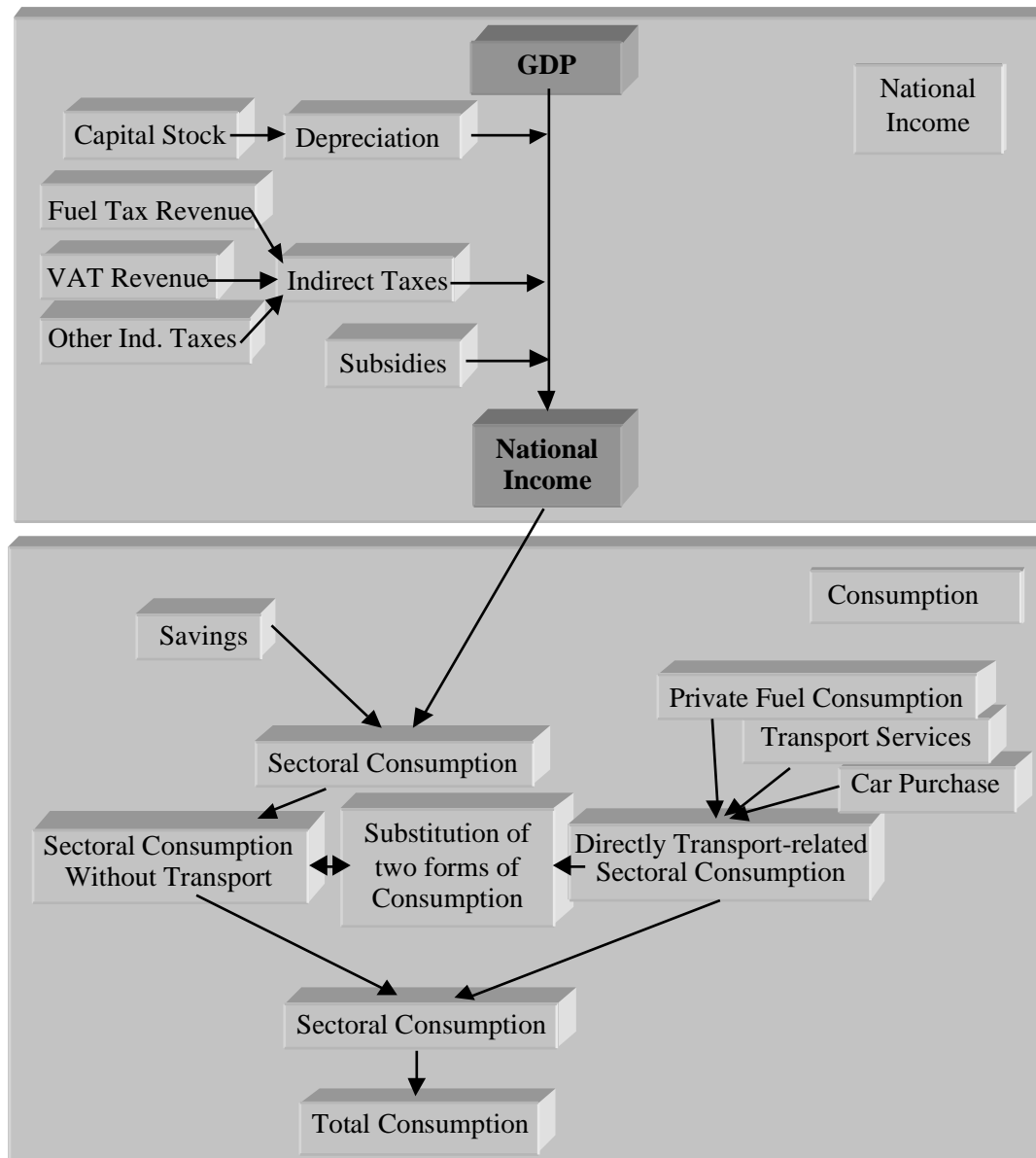


Figure 13: Structure of National Income and Consumption Model

6.1.3.5 Investment Model

The investment model calculates the investment of enterprises and government. Basically there is a similar disaggregation of investments as for consumption. That means, first a sectoral disaggregation into 12 economic sectors is applied and second investments are separated into the transport related and the non-transport investments. For the non-transport investments the development of investment in one sector depends on the development of consumption in the same sector.

Transport related investments describe the investments in vehicles for passenger transport (e.g. buses, planes) and in freight vehicles (e.g. LDV, HDV). Values for these investments are provided by the vehicle fleet models or in dependency of transport demand. These investments are included within sector 5 as transport equipment belongs to this sector. Investments in transport infrastructure belong to sector 9 building and construction. These investments can be private (e.g. for loading- and unloading facilities) or public (e.g. for most of the transport infrastructure network). Values for facility investments depend on transport demand, while network investments depend on GDP development and transport policy measures.

6.1.3.6 Employment Model

The employment model is also disaggregated into 12 economic sectors of which sector 5 with transport equipment and sector 10 with transport services include employment in the transport system while the other sectors represent only employment in non-transport sectors.

The basic calculation of employment depends on the sectoral gross value added (GVA) calculated by the input-output model and an inverse labour productivity expressed as employment over GVA. The productivity variable is changing over time because of higher labour productivity. Also there is a feedback implemented from unemployment to an enforced increase of labour productivity if unemployment rates reach very low levels.

Employment in the transport related sectors 5 and 10 depend on the transport expenditures paid either for transport services, for purchase of domestically produced vehicles or for vehicle export. These values that are provided by TRA and ENV can be assigned to the four modes road, rail, air and ship. For each mode a specific employment productivity is used to calculate the employment produced in the different modes. This enables to capture employment shifts e.g. caused by changes in modal split. The structure of the employment model is shown in figure 14:

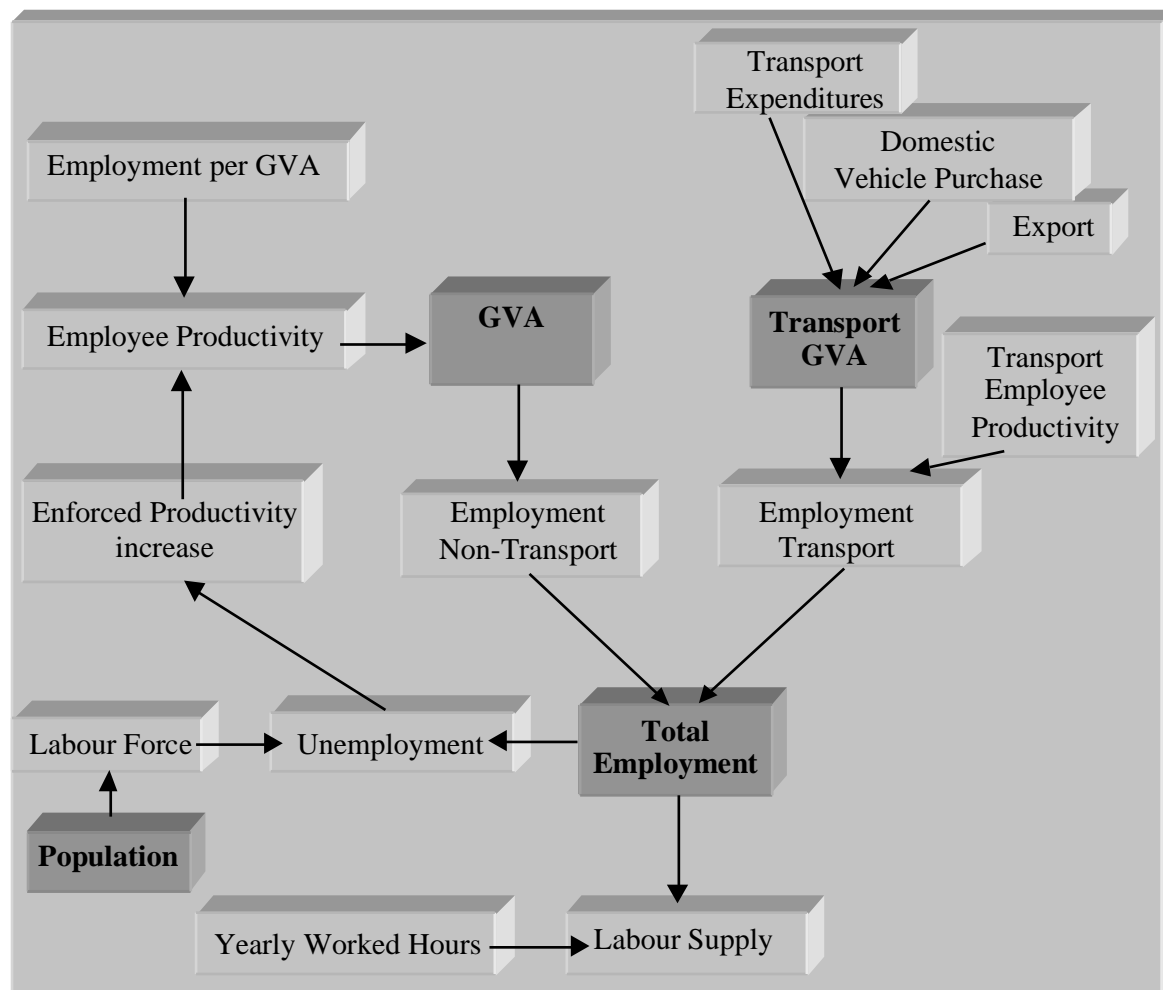


Figure 14: Structure of the Employment Model

Finally, based on the employment figure and the yearly worked hours the labour supply for each of the regions is derived. This forms an input to the calculation of the production potential.

6.1.3.7 Model of the Capital Stock

The capital stock is modelled from two viewpoints. The first view represents the gross fixed capital stock in each macro region, which is the relevant input variable for capital within the calculation of production potential. The second view stands for the net capital stock that forms the baseline for the calculation of depreciation in the macro regions. Gross and net capital stock are divided into public and private capital. The capital stock for both is increased by investments of which a defined share is private investment and the network infrastructure investment are treated as public investment. The decrease of gross capital stock is driven by scrappage depending on the average lifetime of capital while the decrease of net capital stock by depreciation depends on the average depreciation period for private and public capital.

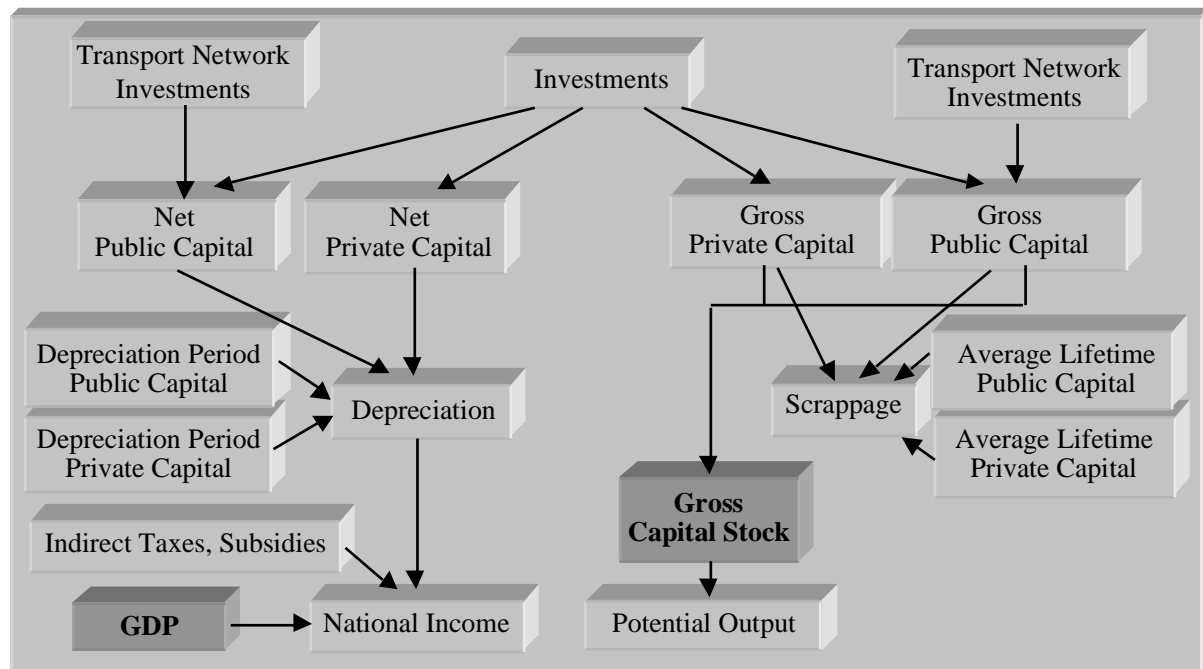


Figure 15: Structure of the Model of the Capital Stock

6.1.3.8 Model of National Income and Personal Income

The baseline for the calculation of national income is given by GDP. Considering the payments balance between foreigners employed in a country and nationals employed abroad the gross national product is derived. The payments balance is taken exogenously. It might even be omitted as it represents only a small number. In the following step depreciation, which is calculated in the capital stock model, is subtracted and one receives the net national product. Subtracting the indirect taxes (including VAT, fuel tax and other taxes) and adding subsidies the national income is calculated. This leads to equation 3:

$$NI = GDP - EBP - D - IndT + SUB \quad (\text{eq. 3})$$

where: NI = national income
 GDP = gross domestic product
 EBP = employment balance payments
 D = depreciation
 IndT = indirect taxes
 SUB = subsidies

In subsequent steps disposable income is calculated based on the national income. First direct taxes and social protection payments both given as shares of GDP are subtracted and second transfer payments to households (exogenously) are added:

$$DI = NI - DirT - SPP + THH \quad (\text{eq. 4})$$

where: DI = disposable income
 NI = national income
 DirT = direct taxes
 SPP = social protection payments
 THH = transfer payments to households

Finally based on disposable income and the employment figures an average personal income per employee is calculated, which for instance is used as an influence for the calculation of the vehicle fleet.

6.1.3.9 Tax Model

With the tax model direct and indirect taxes are calculated. The calculation of direct taxes follows a simplified approach that uses trend shares of direct taxes on GDP. Indirect taxes are treated more sophisticated as their influence on transport is stronger. Indirect taxes in the model consist of:

- fuel tax revenues,
- value added tax revenues from
 - fuel
 - other transport consumption
 - non-transport consumption
- other indirect tax revenues.

The total fuel price for gasoline, diesel and kerosene is calculated in the ENV. The fuel prices consist of a pure fuel price, a fuel tax for each type of fuel (in case of kerosene in the base run the tax is zero) and the value added tax. Based on this structure the fuel tax revenues are calculated using the fuel consumption by the different modes and combining it with the tax rates for the specific fuel.

$$FT_i = \sum_m (FC_{m,i} * TR_{m,i}) \quad (\text{eq. 5})$$

where: FT = fuel tax revenues
 FC = fuel consumption for transport
 TR = tax rate
 i = fuel types (gasoline, diesel, kerosene)
 m = transport modes (private car, business car, bus, LDV, HDV, diesel rail, air).

Until 1996 fuel prices and tax rates are taken from statistics. Afterwards increasing trends are applied (see annex A).

The revenues from the value added tax on fuel can be calculated similar to fuel tax considering not only the fuel consumption and the tax rates but also the pure fuel price for different fuel types. The VAT revenues from transport consumption stem from two sources: first private car purchase are used to calculate VAT from transport production and second the demand for transport services (bus, rail air) is used to calculate VAT from transport services. The calculation of VAT revenues from non-transport consumption is based on the consumption without-transport variable in the consumption model.

Finally other indirect taxes are also considered in the model as an input to VAT revenues. These revenues represent taxes on alcohol, tobacco, etc. The output of the tax model is used in the calculation of national income, personal income and for the shift of consumption between transport and non-transport consumption.

6.1.4 Calibration of the MAC

As major data sources for the MAC and also as sources for calibration data the following three sources are used:

- EUROSTAT harmonised input-output-tables for 1995 with 25 economic sectors (R25) for all EU15 member countries except Greece,¹⁸
- EUROSTAT statistical yearbook for 1997 including statistics from 1986 to 1996¹⁹ and
- from the German statistical office the statistical yearbook 1997 for foreign countries.²⁰

The latter two sources provide data as time series for the years (1986-) 1990 to 1996, while the harmonized I-O-tables are only available for the year 1995. So, basically the calibration period lasts from 1986 to 1995. Considering that within system dynamics models there can occur initial oscillations or other initial irregularities the core period for calibration is 1990 to 1995. Also for some (e.g. sectoral) data only the 1995 values are available such that for this year the strongest anchor to reality is attempted. Major variables used for calibration are:

- GDP
- Employment
- Consumption
- Capital

The objective for calibration is to keep the variables in a range of +/- 3% deviation from real variables for the core period. For variables of minor importance deviations can be in the range of +/- 10%. It has to be mentioned that because of recession tendencies in Europe in the years 1992-1993 e.g. GDP in real terms in some countries was constant or even declined. However

¹⁸ EUROSTAT (1995)

¹⁹ EUROSTAT (1997c)

²⁰ STATISTISCHES BUNDESAMT (1997b)

it is not aspired to model that short term economic oscillations and therefore also not to calibrate to these oscillations. Instead then the focus of calibration was put on the long term growth rates of GDP.

As the structure of the MAC enables to use the GDP development as a major driver for the future economic development, the calibration of GDP in the core period in the base scenario considers also that the future development of GDP is in the range of what is projected by other studies (e.g. SCENES).

6.1.5 Interfaces to other sub-modules

As one purpose of the MAC sub-module is to provide the other sub-modules with continental level influence it is obvious that macro variables have to be transferred from MAC to the other sub-modules. So, the following three links are established:

- GDP goods is transferred to the REM,
- employment and unemployment per macro region provided to the REM and,
- income per employee transferred to the ENV.

6.1.5.1 Interface MAC => REM

For the freight model the MAC provides data on the GDP produced by good sectors per macro region. This so-called GDP Goods is then used in the REM to drive the freight generation model for the 13 goods sectors within the REM. The GDP Goods value is derived from the agricultural sector and the 8 industrial sectors of the I-O-table.

For the passenger model the MAC transfers information on employment per macro region to the REM. This information influences the size of the economically active population, which performs an impact on the activity patterns.

6.1.5.2 Interface MAC => TRA

The MAC transfers information about GDP and annual GDP growth rates to the TRA, where it is used to calculate a kind of base level investment into road infrastructure. This base level investment drives the development of the road network.

6.1.5.3 Interface MAC => ENV

The ENV receives from the MAC data on the average income per employee within the different macro regions. This data is then used to calculate the changes in car vehicle fleet, which subsequently is transferred to the REM, where it forms an input to the car-ownership model.

6.2 Regional Economics and Land Use Sub-module (REM)

The post-war period has seen, in all developed countries, a “mobility explosion”²¹ and the countries of the EU15 are no exception. People are travelling more and longer distances than before and this increase in personal travel has been matched by a parallel trend in the growth of freight transport with traffic rising faster than the volume of goods carried. This growth is almost entirely due to the growth in road based transport and has consequently had a dramatic effect on the service levels of the transport system. It is these recent trends in passenger and freight transport, which have influenced the design of the REM sub-module. In order to accurately model this growth in the demand for travel it is necessary to represent the fundamental mechanisms that generate the demand for passenger and freight travel.

The Regional Economic and land use sub-module, hereafter known as the REM, performs the first two stages of the traditional 4-stage transport model, generation and distribution with the modal split and assignment stages being carried out in the transport sub-module (TRA).

The REM sub-module described here models passenger and freight movements between areas of the EU15. In the early stages of the modelling process effort was principally concentrated on implementing an operational passenger demand model within the “ithink” software. This was reflected in the description of the REM sub-module presented in D3, in which the emphasis was on the description of the passenger demand model, although it also described the proposed design of the freight model. This report revisits and expands on this description to incorporate the operational freight demand model and modifications in the structure of the passenger model since D3.

The first section describes the role of the REM sub-module within the ASTRA model, section 6.2.1, and the mechanisms that the sub-module seeks to represent. This is followed by a description of the broad structure of the passenger and freight demand models, section 6.2.2. Section 6.2.3 provides a description of the future trends that it is envisaged will influence the demand for passenger and freight travel in the EU15 over the forecasting period of the ASTRA model. This is based on research undertaken in other projects e.g. SCENARIOS, STREAMS and reports from statistical offices e.g. Eurostat. Further details of the projections used are contained in the Annex B. Section 6.2.4 describes the implementation of the modelling structures within the ASTRA model following on from the broad outline of the model structures presented in section 6.2.2. Section 6.2.5 deals with the model calibration over the period 1986-1995. Finally section 6.2.6 describes the feedbacks between the REM sub-module and the other sub-modules which would have also previously been highlighted in the discussions on the model structure and implementation (section 6.2.2 and 6.2.4).

6.2.1 Aim of the REM Sub-module

The primary purpose of the REM is to represent the fundamental mechanisms that generate the demand for travel. It is this demand for travel that is then used in the transport sub-module (TRA). The primary fundamental premise that underlies demand models of this type is that:

²¹ POTTER (1997)

For most journeys travel is not an end in itself. Rather, travel is a derived demand. In order to carry out a variety of discretionary and compulsory activities it is necessary for people to travel or for goods to be transported.

The REM therefore seeks to represent these underlying activities in sufficient detail to enable the resulting demands for passenger and freight transport to be estimated to the level of precision required by the TRA.

The implication of the above premise is that the model should contain sufficient detail on;

- the location of the actors which give rise to the demand/ consumption of activities (individuals, households, firms)
- the location of the supply/ production of the activities that meet these demands (shops, schools, labour, goods)
- the characteristics of the transport required between production and consumption

In this way the demand for, and supply of, transport should be segmented into reasonably homogenous categories to allow patterns of demand for travel to be estimated realistically. This issue of demand segmentation is returned to in section 6.2.2.2. The implication of the above is that in the design of the REM it is important to have an understanding of the mechanisms that drive the changes in the demand for passenger and freight transport so that those mechanisms can be implemented in the model. It is this understanding that had an important bearing on the level and type of demand segmentation adopted in the REM.

The design of the REM is also a reflection of observed historic trends and is influenced by the expected nature of future development in certain variables considered important in determining the demand for travel. Therefore two key questions were necessary to be answered in the model design phase;

- i. What are the key trends in passenger and freight demand? (Section 6.2.1.1),
- ii. Where in the model structure should these mechanisms should be captured? (Section 6.2.1.2)

The most pronounced trend in both passenger and freight travel has been increases in the length of passenger journeys and freight hauls. ASTRA D3 contained a description of this and a number of other identifiable historical trends affecting passenger and freight travel (ASTRA, 1999). It is not the intention to re-produce the entirety of that discussion here although the main strands are described in section 6.2.1.1 below.

It is the combination of these mechanisms, and how they evolve over time that will determine the rate at which the future demand for transport will grow on each competing mode in a given area. It is these factors, the variables that influence them and the relationships involved that are internalised within the model structure.

6.2.1.1 Trends in passenger and freight travel demand

As already highlighted the clearest trend in both passenger travel and freight movements over the last 25 years has been the rapid increase in car and road goods traffic. A major part of this historic growth in transport has arisen from increases in the length of passenger and freight journeys relative to the growth in the number of trips made and tonnes lifted respectively. Figure 16 and figure 17 below illustrate respectively the increase in passenger and tonne kilometres in the EU15, the main feature of which is the great increase in car passenger and road freight kilometres.

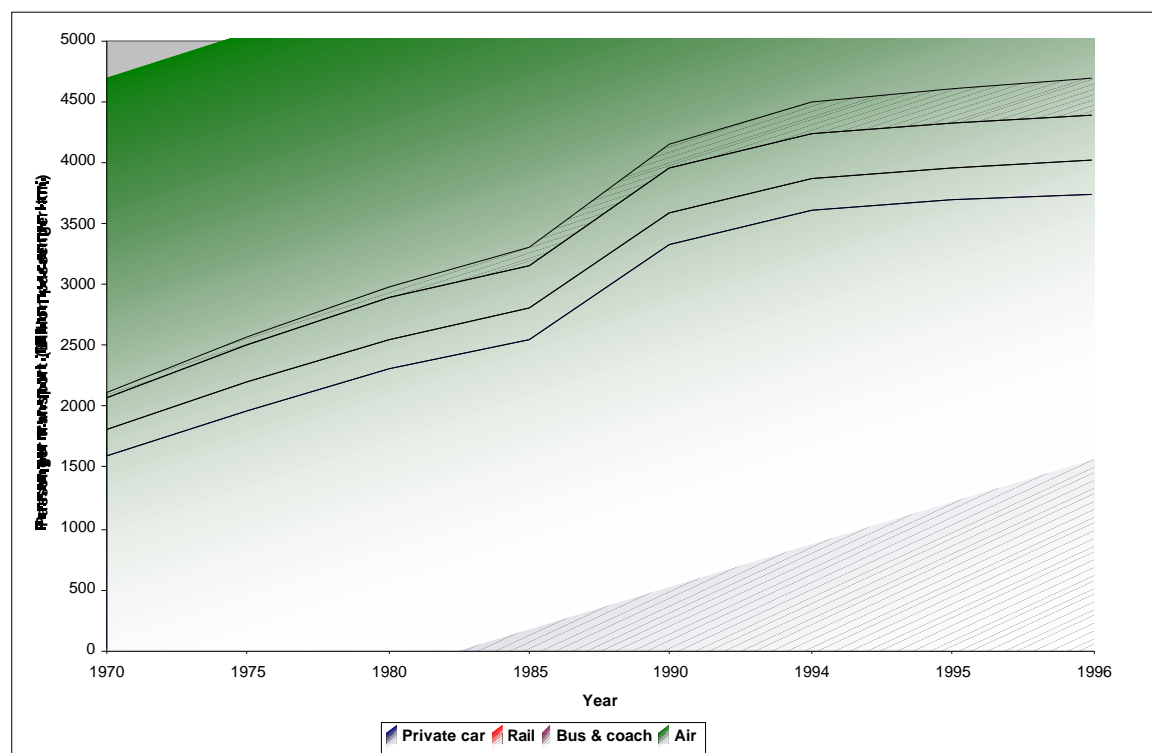


Figure 16: Passenger transport in billion passenger-kilometres by mode for EU15 countries²²

²² EUROSTAT (1997a)

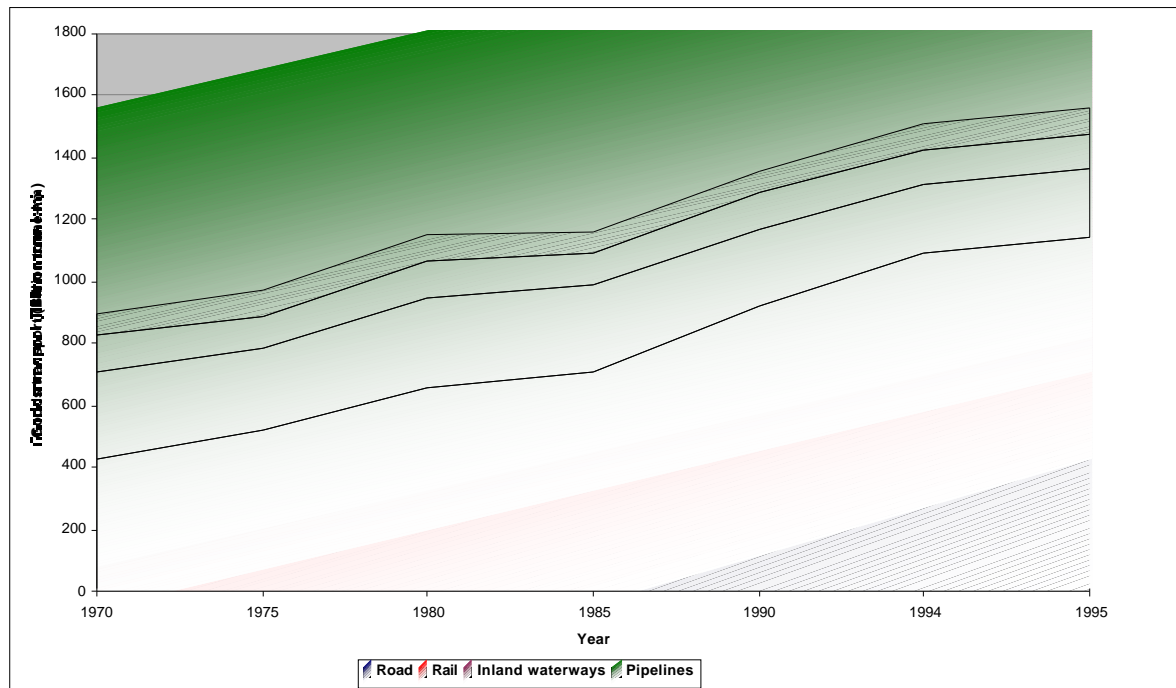


Figure 17: Freight transport in Billion tonne-kilometres by mode for EU15 countries²²

The two main factors that have underpinned the past growth in the overall demand for travel are the:

- improved characteristics of the supply of travel in terms of speed, comfort, reliability and cost
- strong positive relationships between the demand for travel and economic growth, in fact the major determinant of overall freight traffic is the rate of economic growth

Further discussion of trends in passenger and freight demand may be found in ASTRA D3 and in the Annex A to this Deliverable.

6.2.1.2 Model structure

The discussion in D3 led to the creation of a list of specific interrelated trends that can be identified from statistical sources that have caused rapid increases in traffic that have been experienced in the EU15 highlighted above. These are listed in table 2 below, which is a summary of the trends presented in D3 and also in the Annex A. In dealing with these trends there is a high degree of interdependence between the TRA and REM sub-modules and it is important to distinguish which sub-module deals with the modelling of each of the trends listed through time.

In general the key components making up the total volume of travel can be summarised as a function of;

- number trips (passengers) or tonnes lifted (freight)

- length of trips (passengers) or haul (freight)
- mode of transport
- size and occupancy of vehicles used

Of these factors the number and length of trips (1 and 2) are modelled in the REM sub-module and the mode of transport and size and occupancy of vehicles (3 and 4) are modelled in the TRA sub-module. Table 2 also indicates which part of this function each trend has an influence over.

Table 2: Trends in passenger and freight demand to be modelled in REM and TRA sub-modules

Trend	Description of Trend	Function	Sub-module	
			REM	TRA
Passenger				
1	Population growth over time	1	n/a	n/a
2	Higher proportion of population in higher trip rate age segments	1		n/a
3		1		n/a
4		Greater access to cars		3
5	Higher share of trips made by car	1,2		
6	Improved cost effectiveness of travel	1,2		
7	Increased average incomes (MAC)	2	n/a	n/a
8	Shift of population from urban areas	4		
	Lower car occupancy levels			
Freight				
1	Growth in value of freight goods	-	n/a	n/a
2	A greater proportion of high value freight	1		n/a
3	Reduced unit costs	4	n/a	
4	Growth in high value goods less sensitive to costs of travel.	2		
5	Attempts to create European markets (MAC)	2		n/a
6	Change in volume/ value ratios and density of goods	1		n/a

Note: i. - modelled; ii. - not-modelled in current version; iii. n/a - not applicable to sub-module

Now that the role of the REM sub-module has been described we move onto describing the broad structure of the sub-module in section 6.2.2.

6.2.2 Basic Structure of the REM

This section describes the structure of the passenger and freight models in the REM sub-module. At the time of the production of D3 the passenger demand model was operational within the SDM, however the design of the freight model was still in an embryonic state. Although the design was broadly described, there were a couple of issues that needed to be

resolved prior to an operational version being implemented within the SDM and integrated with the other sub-modules;

- The zoning scheme to be used in the freight model
- Segmentation of the markets for the estimation of freight demand

These issues have subsequently been resolved and an operational version of the freight model has now been implemented in the SDM and linked with the other sub-modules. The passenger demand model has also been improved. It now includes the endogenous modelling of changes in car ownership, which previously had been modelled using an exogenous trend from the STREAMS model.

6.2.2.1 Overview

As previously indicated, within the REM two types of demand are modelled, passenger and freight. It is recognised that the trends influencing the changes in passenger and freight transport demand over time are different, see section 6.2.1.1, and therefore necessitate different emphases in their design. An example of this is in the nature of the zoning system most appropriate to the modelling of passenger and freight flows. Although the structure within which both passenger and freight demand are modelled retain many similarities in their approach the mechanisms involved are different although. Common features of both the passenger, and freight models are:

- (i). **Model structure** - the REM sub-module contains the passenger and freight generation and spatial distribution stages, while the modal split and assignment to networks takes place in the transport module, TRA
- (ii). **Zoning** – both the passenger and freight models operate with a zoning system, but the number and definition of, these zones are different, recognising the different requirements of passenger and freight demand modelling
- (iii). **Distance Bands** – both models make reference to distance bands (see section 5.4), but, as with the zoning the bands used, are not identical. In the freight model there is less differentiation over short distances and more differentiation over long distances to take account of the much greater proportion of freight haulage that are long distance and of the relative competition between different modes over different distances
- (iv). **Base Data** – both models use aggregated data from the STREAMS transport model (see Annex A for description of the STREAMS model).

The main differences between the freight and passenger demand models are:

- (i). the set of transport modes (see section 6.3)
- (ii). in the freight model the O-D matrices of travel demand are in units of tonnes rather than person trips

- (iii). the procedure to generate and attract freight and passenger movements are different. The STREAMS model adopts an input-output model structure measuring freight in value terms, this sophisticated approach is not used within ASTRA as the modelling environment does not allow this to be easily implemented. Instead a simpler model with the share of GDP generated by the primary and secondary sectors of the economy (GDP – Goods) from the MAC for each region used as the generator of production in a zone (the link between economic growth and freight generation having been clearly demonstrated).

The key dimensions of the passenger and freight models in the REM sub-module are presented in table 3 below:

Table 3: Key dimensions of the passenger and freight models in the REM sub-module

	Model	
	Passenger	Freight
Actor/Generator	Individual	Industries
Zones	6 <i>LSA, MPH, HDU, HDD, MDR, LDR</i> Section 5.2	4 <i>MR1, MR2, MR3, MR4</i> Section 5.2
Segments	12 (<i>Age, economic position, car ownership</i>) <i>P1NC, P1PC, P1FC, P2NC, P2PC, P2FC, P3NC, P3PC, P3FC, P4NC, P4PC, P4FC</i> Annex A	13 <i>I1, I2, I3, I4, I5, I6, I7, I8, I9, I10, I11, I12, I13</i> Annex A
Purposes	3 <i>BU, PE, TO</i> Section 5.3	3 <i>Bk, SBk, Usd</i> Section 5.3
Distance Bands	5 <i>< 3.2 kms, 3.2 – 8 kms, 8 – 40 kms, 40 – 160 kms, >160 kms</i> Section 5.4	4 <i>< 50 kms, 50 – 150 kms, 150 – 700 kms, >700 kms</i> Section 5.4
Destination Zones	<i>Varies according to trip purpose</i> <i>15 BU, 9 PE, 12 TO</i>	10 <i>All sectors</i>

Note:

- i. Notation used in table above is that used in ASTRA model, the reader is referred to the listed table or section for full definition.
- ii. Destination zones are a combination of zone and distance band

Figure 18 and figure 19 below present the general structure of the passenger and freight models. They are followed by a brief description of the structure of each model followed by a more detailed description of some of the important aspects of the structure of each model. Further detailed description is included as part of the section 6.2.4.

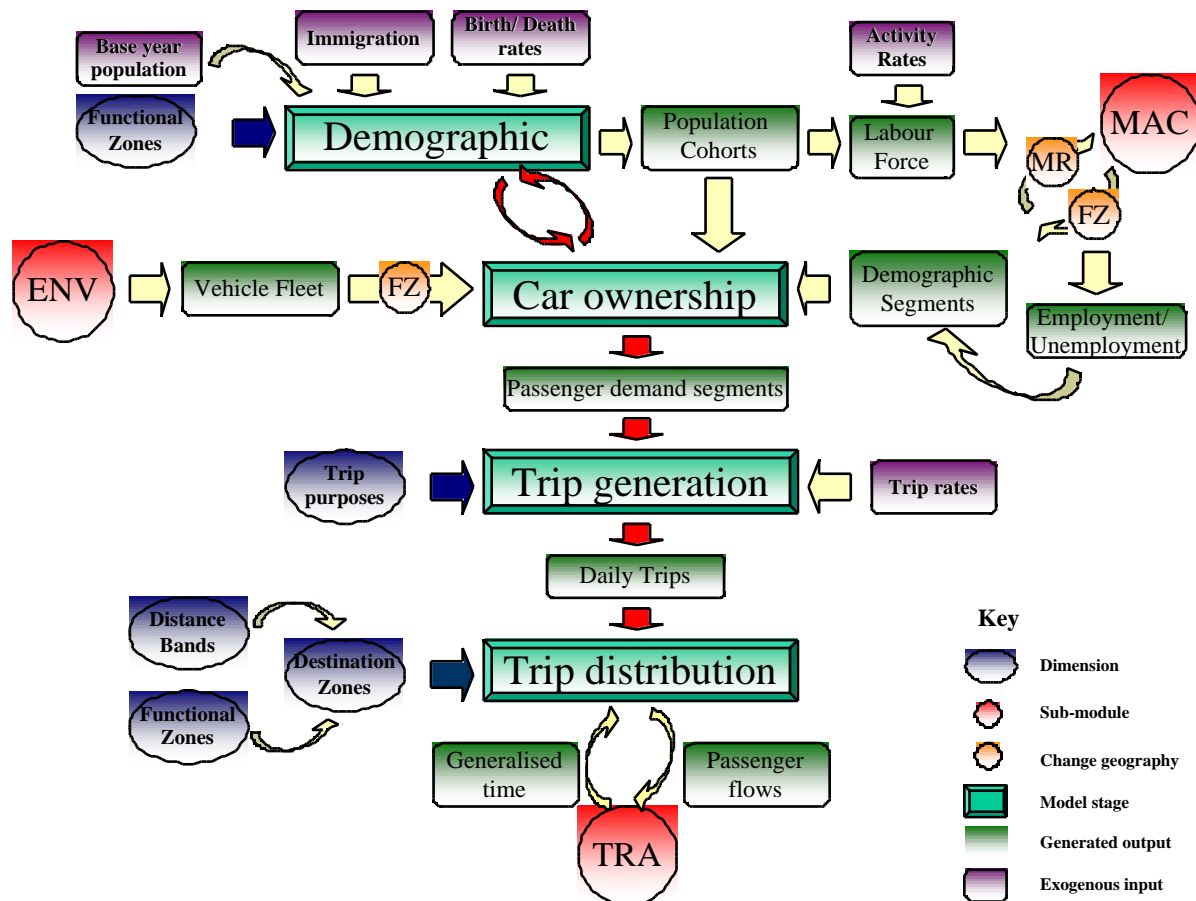


Figure 18: Structure of REM passenger model

In the passenger model the actor is the individual. The basic structure is that, using key demographic characteristics, the population of each of the six functional zones is segmented into groups or traveller type demand segments (by age, economic position and car ownership) that have different trip rates for specified trip purposes. On this basis the total number of daily trips by purpose by functional zone can be calculated for each time period. These trips must then be distributed according to a spatial pattern of origin and destinations where a key influence is the generalised time for each OD pair (from the TRA). In summary a key feature of the REM is that a choice approach was adopted for the purposes of obtaining the passenger demand. In this way passenger demand was considered as a function of five different characteristics:

- Traveller type (based on demographics and car ownership)
- Trip purpose
- Trip length
- Trip origin and,
- Trip destination

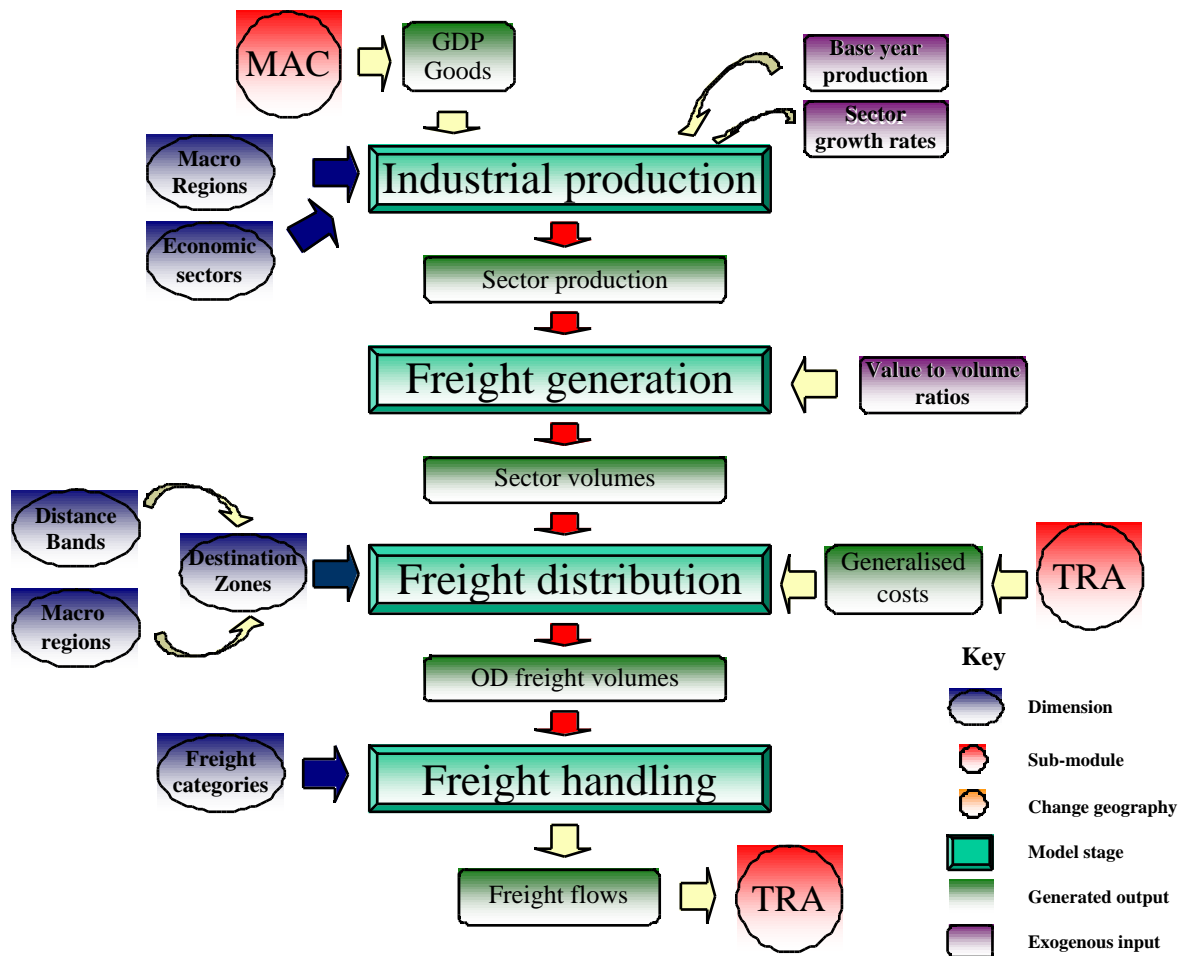


Figure 19: Structure of REM freight model

The role of the freight model is to provide a realistic representation of the demand for freight services, estimating the location of activities of production and consumption. In the freight model the actor is the industry and the economy of each macro region, segmented into a number of industrial sectors where production takes place. Trade volumes are generated (in monetary units) for the specified industrial sectors. They are then converted into freight volumes (tonnes) using a set of conversion (value to volume) ratios and distributed according to a pattern of origins and destination zones. These freight demand matrices for each industrial sector are aggregated to three freight handling categories and passed to the TRA. This description of the passenger and freight models is expanded on in sections 6.2.2.2- 6.2.2.4 below.

Common to both models is the importance of segmenting the actors²³ to form demand segments. Once this is done passenger and freight demand is calculated by combining the following elements;

- *Incidence*

²³ individuals in the case of the passenger model and industries in the case of the freight model

- | | |
|------------|---|
| Passengers | Forecasting the number of persons in each demand (traveller type) segment in each functional zone based on assumptions about demographic change. |
| Freight | Forecasting value of production in each industrial sector in each macro region based on assumptions about changes in industrial production in different industrial sectors. |
- *Generation of transport flows*

Passengers	Trip rates are used to forecast the annual number of trips by purpose for each traveller type segment.
Freight	Value to volume ratios used to calculate the tonnage generated by each industrial sector.
 - *Spatial distribution*

Passengers	Forecasts the spatial pattern of trips by purpose for each functional zone. Therefore creates passenger O-D matrices by trip purpose.
Freight	Forecasts the spatial pattern of freight distribution for each industrial sector. Therefore creates freight O-D matrices by industrial sector which are then aggregated to freight flows.

Each of these stages is now described.

6.2.2.2 Demand Segmentation

The first stage is to identify the incidence of the demand for transport for each of the identified demand segments. For both the passenger and freight models it is essential in the first instance to segment the actors into appropriate relatively homogenous groups. On the basis of this segmentation the demand for transport is derived for each of the functional zones (passenger model) and macro regions (freight model).

Demand segments represent users of the transport system. The necessity of segmenting transport demand stems from the fact that users have different requirements of transport, and they react in different ways to changes of transport supply. Passenger travel is subdivided by purpose such as business, personal and tourism and freight travel by freight handling category.

Passenger segmentation

In the passenger model a demographic model is used to model the changes in population in each functional zone through the use of birth and death rates, distinct modelled population cohorts are identified. Three age cohorts are modelled with no gender split:

- Children (< 15)
- Working age (15-64)

- Retired (64+)

These cohorts were chosen as, broadly speaking, members of these groups would possess similar characteristics in terms of trip making profiles. The working age population is then further disaggregated by their economic position i.e. economically active or inactive. The economically active population constitute the labour force, through a feedback with the MAC the employment/ unemployment split is calculated. The employed population are retained as a homogenous group and the unemployed are combined with the inactive population to form 4 segments. The zonal population is then distributed across 3 car availability segments and consequently 12 traveller type segments are identified for each functional zone based on a combination of three characteristics;

- Age
- Economic position
- Car ownership

It is the contention that segmentation based on these characteristics will provide a level of homogeneity between traveller types in terms of their trip making profile. In fact one of the key premises underlying the STREAMS passenger model was that;

The number of trips per persons varies by employment status, age and household car availability

Examination of the evidence from various EU country National Travel Surveys (NTS') collected in the STREAMS project clearly bore out this contentions (STREAMS, 1999). Analysis of the UK NTS also shows that there is little difference in the average number of trips made by men and women (Potter, 1997).

The traveller type segments are listed below in table 4.

Table 4: Traveller type segments in passenger model

Demographic category	Economic position	Car availability	Traveller type
< 15 (P1)	n/a	No Car	P1NC
		Part Car	P1PC
		Full Car	P1FC
15-64 (P2 & P3)	Employed (P2)	No Car	P2NC
		Part Car	P2PC
		Full Car	P2FC
	Unemployed & Economically inactive (P3)	No Car	P3NC
		Part Car	P3PC
		Full Car	P3FC
> 64 (P4)	n/a	No Car	P4NC
		Part Car	P4PC
		Full Car	P4FC

Note: The < 15 and > 64 population cohorts are not segmented by economic position

Within the above segmentation it is recognised that car ownership is an important characteristic influencing trip making. It is important to have car ownership endogenous to the model rather than exogenously driven by a trend derived from the STREAMS model as it was in the initial version, see D3. Considerable effort has gone into deriving a formulation for such a link and this is described more fully in section 6.2.3.3. However, broadly the approach has recognised the clear link between income and car ownership, although the income effect is incorporated within the modelling of the car fleet in the ENV. The role of the REM is to model the movement of the population in each zone between the car ownership categories identified.

Freight segmentation

Initially the economy of each macro region is segmented into a number of homogenous industrial sectors each representing a market segment that generates industrial production, in terms of monetary value. The market segmentation adopted here is based on the standard “NACE-CLIO” sector definitions for which suitable data is available and was used in STREAMS. The NACE-CLIO R59 branches form the starting point and the market segments are represented by an aggregation of these branches. The approach in ASTRA was to take the 20 market segments as defined in STREAMS based on the above classification, and further aggregate them to 13 industrial sectors whilst retaining as much homogeneity as possible. Table 5 below lists the industrial sectors in the freight model and their correspondence with the NACE-CLIO sector definitions. For each time period the value of production in each macro region is segmented across these sectors. Differential growth rates are applied to each sector to reflect the differential growth rates in industrial sectors.

In Annex A the correspondence between the industrial sectors used in ASTRA and the market segments used in the STREAMS model is identified.

Table 5: Industrial sectors in the REM freight model

Industrial sector	Sector name	NACE/ CLIO R59 Code
I1	Agriculture, forestry and fishing products	010
I2	Coal	031-033-050
I3	Crude petroleum	071
I4	Petroleum products	073
I5	Other energy	075, 095-110
I6	Ores	157
I7	Mineral products	135-137
I8	Chemical products	170
I9	Cement	151-153-155
I10	Metal products	190
I11	Paper	471
I12	Food, beverages & tobacco	310-330-350-370-390
I13	Manufactured articles	210-230-250,270-290,410-430-450,490,473-510

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

6.2.2.3 Passenger and freight generation

One of the key issues at the outset in the design of the REM was the appropriate spatial unit for the modelling of passenger and freight travel demand. The view taken, see section 5.2, was that the spatial unit used to model passenger trips was not necessarily the appropriate definition to model the demand for freight travel due to the different nature of the mechanisms involved. The first part of this section looks at this issue and offers a justification of the use of two different zoning schemes as described in section 5.4; the use of functional zones for passenger demand and macro regions for freight demand. Subsequently the trip and freight generation procedure is described.

The discussion of the appropriate spatial unit for modelling passenger trips is intrinsically linked to the trip making characteristics of the persons living in that spatial unit. The changes in journey purposes and mode of travel can be examined in conjunction with an analysis of variations in travel behaviour with type of area. Analysis of NTS data reveals that travel patterns vary particularly with the size of settlement (Potter, 1997).

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).

According to research by Potter (1997) using the UK NTS the number of trips undertaken by people living in major cities through to rural area varies in the range 16.1 to 21.3 trips per person per week (see table 6). Thus displaying, on the face of it, no particular association with settlement size. This evidence suggests that the size of settlement itself seems to have little influence on the number of trips people make. However, mode of transport and length of trip do vary with settlement size to a considerable degree. For example car use is generally highest in rural areas and small towns whilst public transport is used most by people in large cities.

Once travel is measured in terms of distance, differences with settlement size become more pronounced and changes over time indicate some significant trends.

Table 6: Average number of journeys per person per week according to type of settlement

Settlement	Average no. journeys
Inner London	19.4
Outer London	20.0
West Midlands	18.6
Greater Manchester	20.6
West Yorkshire	18.1
Glasgow	16.1
Liverpool	19.2
Tyneside	21.2
Urban Areas Over 250K Pop.	20.3
Urban Areas 100- 250K Pop.	21.3
Urban Areas 50-100K Pop.	21.0
Urban Areas 25-250K Pop.	20.7
Urban Areas 3-25K Pop.	20.7
Rural	19.9

Source: Table 3.5; Potter, S (1997) *Vital Travel Statistics*

The conclusion that is reached from this analysis is that the nature of passenger travel tends to vary with settlement patterns. Therefore the use of a zoning scheme based on settlement pattern would be more rewarding in terms of modelling passenger demand than a conventional geographical zoning scheme used for freight modelling.

Passenger model

Once the demand segments have been identified the next stage is to derive the incidence of trips by purpose accruing to each of the demand segments. Three trip purposes were chosen based on an analysis of data used in the STREAMS model where a more disaggregate set of trip purposes was used. The aggregate trip purposes used in ASTRA were chosen in such a way as to maintain as much homogeneity as possible. Annex A provides a table listing the correspondence between the STREAMS trip purposes and the ASTRA trip purposes. Subsequently a set of trip rates for each demand segment by trip purpose is applied to generate

the total annual number of trips by purpose for each demand segment in each origin functional zone. The trip rates applied to the passenger demand segments only increase slowly over time, this is consistent with another of the assumptions that underlay the STREAMS model;

The number of trips is largely constant through time however the average distances per journey have increased through time

For example it was reported in “Billion Trips per Day” (Salaman, 1993) that German trip rates remained stable at 970 per person per year between 1976 and 1986. The second part of the hypothesis was that trip lengths have increased over time, hence the importance of modelling changes in trip length in the subsequent trip distribution stage in the REM sub-module. This contention is further backed up by evidence from the UK NTS, see table 7.

Table 7: Average journeys and kilometres travelled per person a year in Great Britain

Year	Journeys	Kilometres	Average Length (kms)
1972/73	956	7,189	7.5
1975/76	935	7,583	8.1
1978/79	1097	7,961	7.3
1985/86	1024	8,560	8.4
1989/91	1091	10,425	9.6
1991/93	1055	10,417	9.9
1992/94	1053	10,367	9.8
1995/97	1052	11,039	10.4
1972/73 – 1995/97	+96 (+10.1%) (+0.4% p.a)	+3850 (+53.4%) (+1.8% p.a)	+2.9 (+38.7%) (+1.4% p.a)

Note: All purpose and modes

Source: Table 3.1; Potter, S (1997) *Vital Travel Statistics*
Table 2.12: DETR (1998) *Focus on Personal Travel*

However it is true that there is a degree of variation across the traveller type segments. This is illustrated in figure 20 which is based on data from the UK NTS. It is noted that the 64+ age group experienced the highest per annum increase in trip rates over the period 1985/86 and 1989/96 particularly in the full car owning segment. This is mainly due to the increasing numbers of car owning retirees entering that cohort.

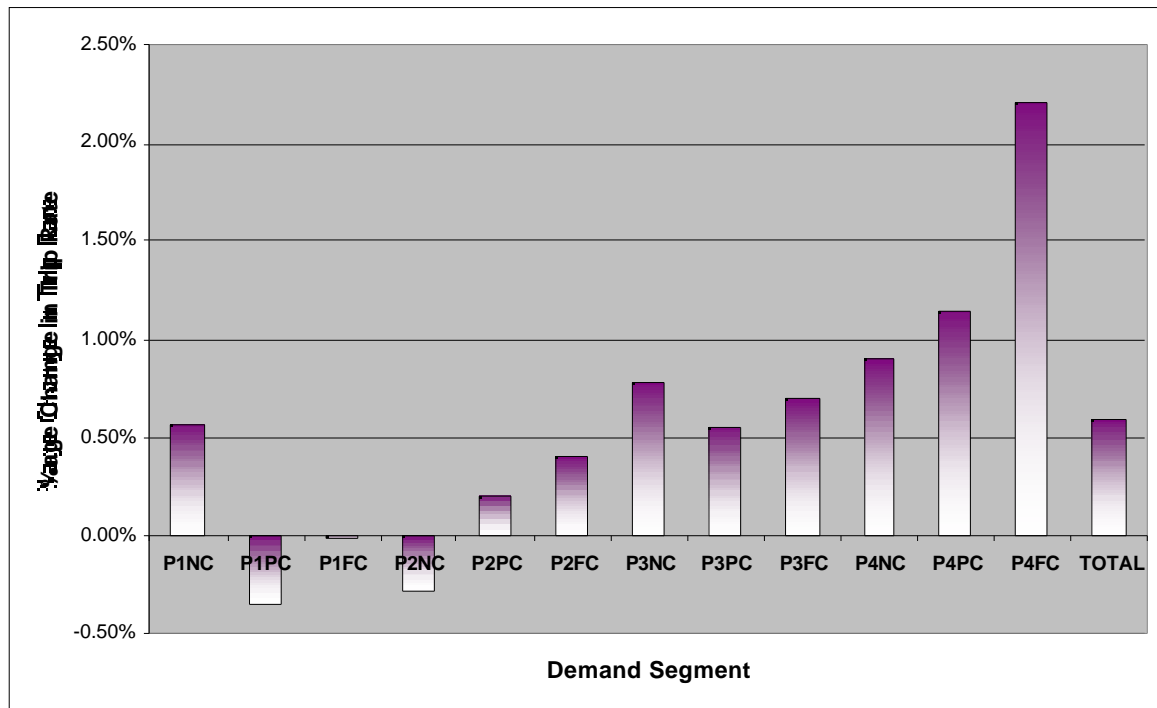


Figure 20: Comparison of annual change in trip rates by demand segment (UK NTS – 1985/86 – 1989/96)

Source: UK NTS

After the trip generation by trip purpose has been applied for each functional zone the output is aggregated across all demographic/ car ownership segments to form three zonal vectors, one for each trip purpose.

Freight model

In the freight model demand is generated at the level of the macro region. The overall growth in the value of production for each time period is obtained from the MAC sub-module at the level of the macro-regions and this is used as a control total to weight the growth across the industrial sectors based on observed trends. The use of differential growth rates reflects the changing structure of the economy over time, at the same time the MAC models the general trend towards a more service based economy.

Each sector has a set of conversion factors, value to volume ratios, which convert the value of production into physical volume (tonnes). The use of conversion factors to transform the value of production into physical volumes is somewhat analogous to the use of trip rates in the passenger model and these ratios represent, for each sector/ flow pair, the number of physical units per unit of value. They are average values which apply to the entire amount of each trade by macro region. In this way the total annual volume of freight in tonnes lifted is generated for each region. Freight volumes are generated for all the industrial sectors in all macro regions except for industrial sectors 3 (Crude petroleum) and 5 (Other energy – incl. natural gas and water and manufactured gas). These sectors are not considered as freight generators for the purposes of this freight model because their output is mainly carried by pipelines and ship to

and from storage areas and refineries, mainly located at ports. Therefore the effect of such flows on land networks in EU countries is negligible and therefore not considered to give rise to any transport flow in ASTRA. This is the same assumption made in STREAMS. The result of this stage is a total annual number of tonnes lifted by macro region by industrial sector. It is on the basis of the freight volumes generated by industrial sector that the distribution stage is carried out, see section 6.2.2.4.

6.2.2.4 Passenger and freight distribution

Distribution of passenger trips

These vectors of trip origins are then carried forward into the trip distribution stage where for each trip purpose vector the trip distribution is carried out. The total number of trips for a specific purpose in each origin functional zone, as generated in the trip generation procedure, are distributed across the distance bands in a form where the trip length is influenced by the generalised times of transport for each distance band as obtained from the TRA. At the end of this procedure O-D travel demand matrices are produced which are then input into the TRA.

As previously described the picture emerges of growth in personal travel fuelled not by people travelling more often but by travelling further. This can be illustrated by looking at trends in the UK using the NTS. As figure 21 shows there has been an increase in the proportion of long distance trips (> 40 kms) with the strongest growth being in the middle distance bands (8 – 40 kms) with a drop in the proportion of journeys under 3 kms. This shift has taken place, as figure 20 shows, whilst the total number of journeys has actually fallen by 4%.

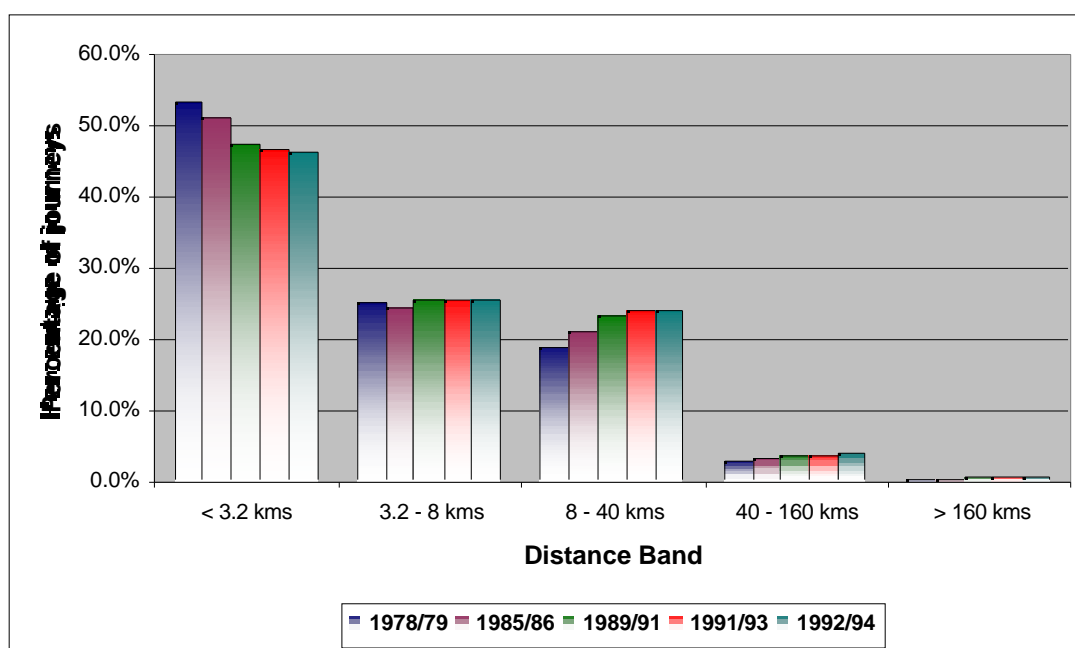


Figure 21: Comparison of proportion of journeys by distance band over time (1978/79 – 1992/94)

Source: UK NTS

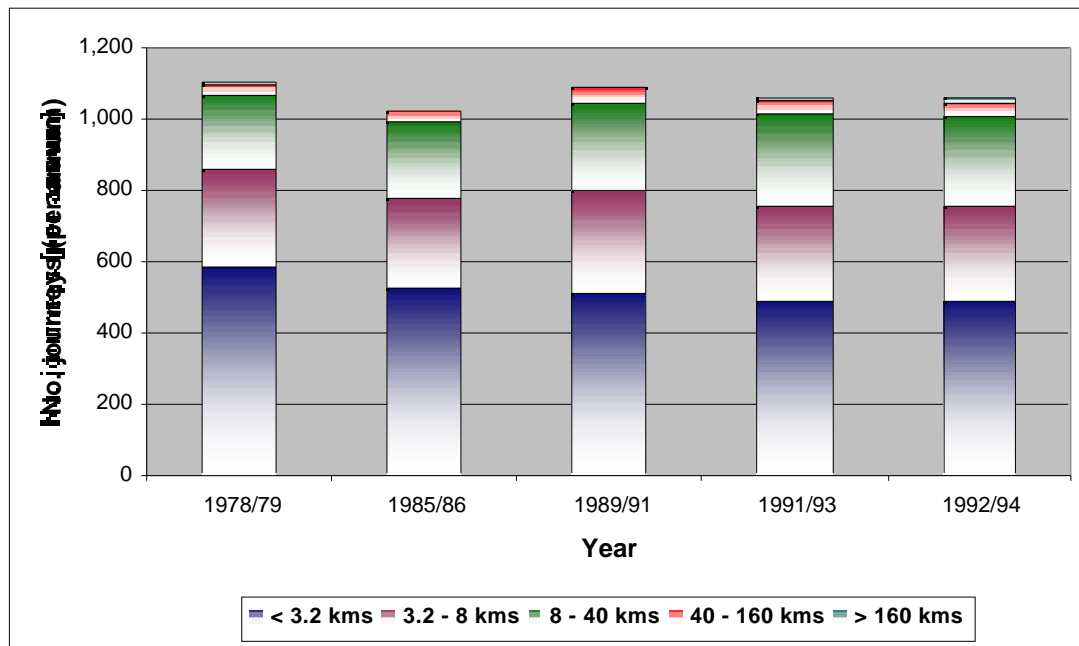


Figure 22: Comparison of number journeys by distance band over time (1978/79 – 1992/94)

Source: UK NTS

Potter (1997) described this trend as a “surge” from short journeys to medium and longer distance journeys. With this growth concentrated on medium distance trips, journeys that were previously typically less than 5 kms in length are now regularly greater than 20 kms. With a number of previously short trips extending beyond walking distance this has led to an increasing use of the car for shorter as well as medium length trips.

An analysis of results from the STREAMS passenger model for 1994 and 2020 (see Annex A) gave us an idea of the combinations of trip purposes, distance bands and destination zones required to be modelled in the REM and TRA. The results of this analysis were:

- Only a very small proportion of personal trips were greater than 160 kms in length
- Those trips classified as tourism trips were generally greater than 40 kms in length
- Trips of less than 40 kms ie. distance bands 1, 2 and 3 were generally within the same NUTS2 zone and therefore considered intrazonal

Table 8 and table 9 summarise these findings.

Table 8: Correspondence of trip purpose and distance bands (Passenger model)

Distance Band (DB)	Type	Trip Purpose		
		Business (BU)	Personal (PE)	Tourism (TO)
DB 1 - <i>Local</i> < 3.2 kms.	<i>Short</i>			-
DB 2 - <i>Very short</i> 3.2 – 8 kms.	<i>Short</i>			-
DB 3 - <i>Short</i> 8 – 40 kms	<i>Short</i>			-
DB 4 - <i>Regional</i> 40 – 160 kms	<i>Long</i>			
DB 5 - <i>Inter-regional</i> > 160 kms	<i>Long</i>		-	

Note: a “-” indicates that combination not modelled in REM

Table 9: Correspondence of direction of movement and distance bands (Passenger model)

Distance Band (DB)	Type	Direction of movement	
		Intrazonal	Interzonal
DB 1 - <i>Local</i> < 3.2 kms.	<i>Short</i>		-
DB 2 - <i>Very short</i> 3.2 – 8 kms.	<i>Short</i>		-
DB 3 - <i>Short</i> 8 – 40 kms	<i>Short</i>		-
DB 4 - <i>Regional</i> 40 – 160 kms	<i>Long</i>		
DB 5 - <i>Inter-regional</i> > 160 kms	<i>Long</i>		

Note: a “-” indicates that combination not modelled in REM

Consequently the O-D matrices for each of the three trips purposes were of different dimensions i.e a different number of destination zones as shown in table 3.

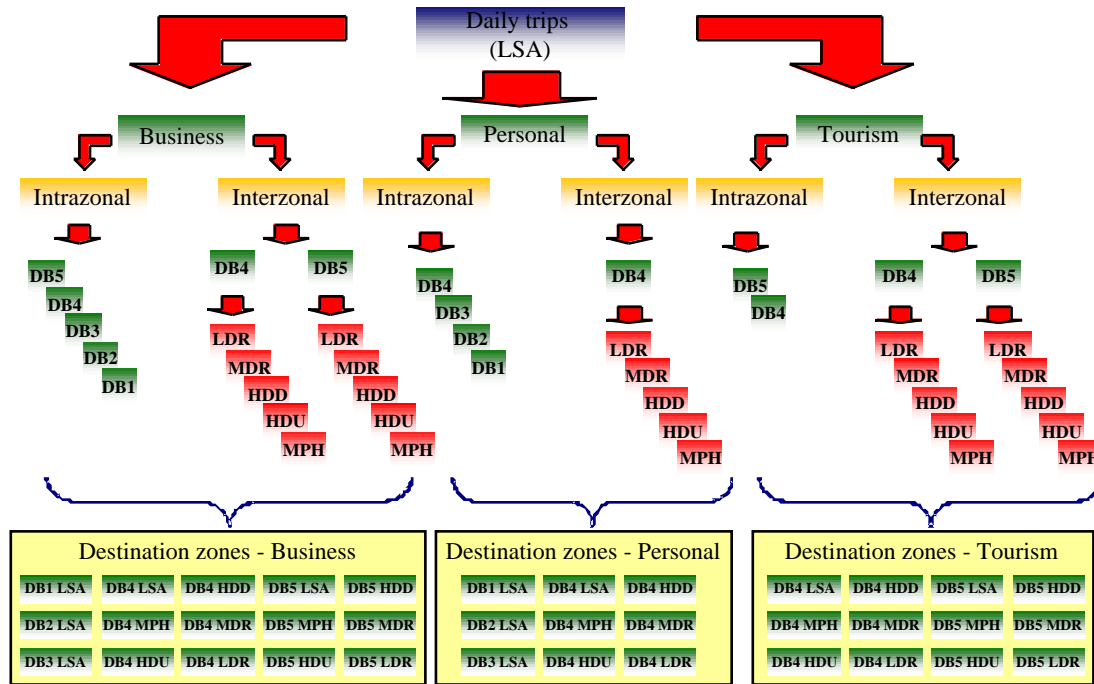


Figure 23 shows graphically the choice of destination zones for each trip purpose. Note that the distribution shown is for one illustrative origin functional zone, LSA, however the structure is exactly the same for all other functional zones.

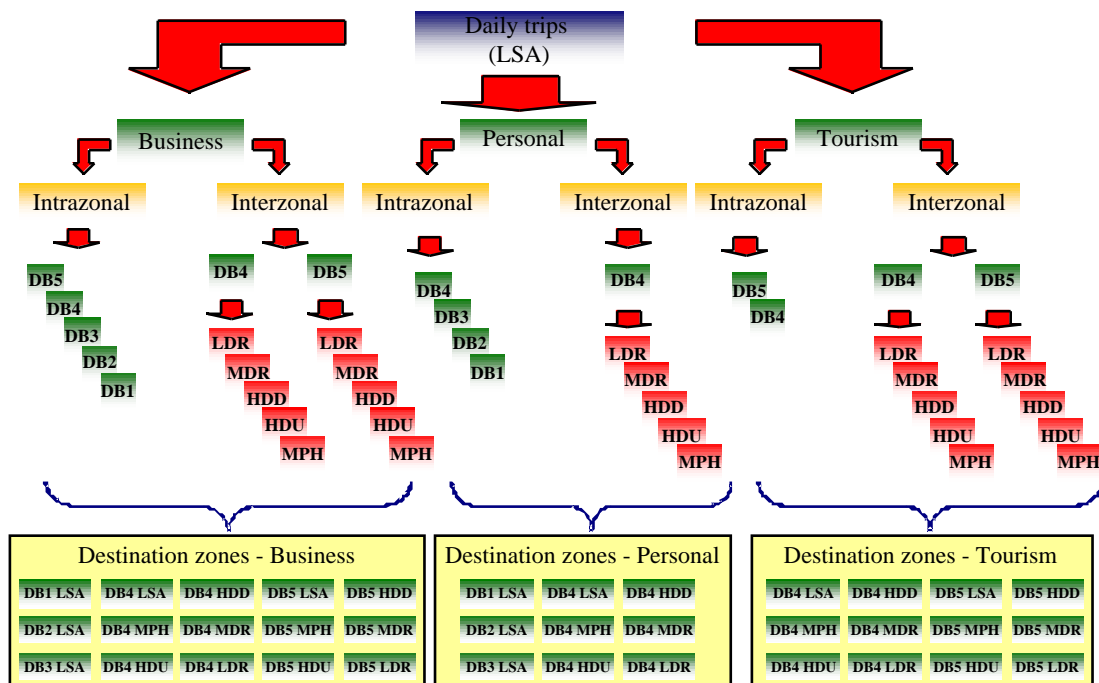


Figure 23: Trip distribution in REM passenger model

A multi-nomial logit function is used to perform the trip distribution for each origin functional zone and trip purpose. This involves a feedback between the TRA sub-module as one of the

component inputs into the equation is generalised time. The specification of this function is further described in the Annex A.

The pattern of trip lengths is modelled based on the travel disutility, which is a combination of the monetary cost, the travel time and the quality of the journey. There are strong benefits to measuring the disutility for passengers in units of generalised time, rather than of generalised cost. It leads to calibrated values for the concentration parameters within the spatial distribution model that are more constant across different traveller segments and across different years, than those based on cost units. This has significant operational advantages in terms of lessening the complexity of the calibration of the disutility function parameters and of the need to adjust in the future years.

In particular, time based concentration parameter values, even when held constant, still automatically encourage a general tendency to increases in trip lengths in response to rising traveller incomes through time. This occurs because the monetary cost element of the travel disutility declines in relative importance as a function of increasing income, while the time component remains unchanged. The observation that trip lengths, generally, are an increasing, rather than a decreasing function of income, is common to many trip purposes in many different countries, so that there is every reason to believe that it will persist into the future.

Distribution of freight tonnes lifted

The vectors of freight origins by industrial sector are then carried forward into the distribution stage where for each industrial sector a distance based distribution model is used, analogous to that used in the passenger trip distribution model. The total tonnes of freight for a specific industrial sector in each origin zone, as generated in the freight generation stage, are distributed across destination zones which are a combination of macro region and distance band. This is in a form where the length of haul is influenced by the generalised costs of transport for each OD pair, as obtained from the transport (TRA) sub-module for the related freight handling category.

An analysis of results from the STREAMS freight model for 1994 and 2020, see Annex A, gave us an idea of the combinations of freight flow, distance bands and destination zones required to be modelled in the REM and TRA. The main result of this analysis was;

- Generally all freight carried less than 150 kms can be considered as intrazonal ie. within the same macro region

Consequently the two shorter distance bands i.e. < 50 kms. and 50-150 kms. are considered to be wholly intrazonal and only the longer two distance bands give rise to inter-zonal flows of freight, table 10 illustrates this.

Table 10: Correspondence of direction of movement and distance bands (Freight model)

Distance Band	Direction of movement	
	Intrazonal	Interzonal
DB 1 < 50 kms		-
DB 2 50 – 150 kms		-
DB 3 150 – 700 kms		
DB 4 > 700 kms		

Note: Intrazonal does not imply national traffic as the macro regions are country aggregates

Consequently the O-D matrices for each of the industrial sectors has the same number of destination zones as indicated in table 3. Figure 24 shows graphically the choice of destination zones for each industrial sector. Note that the distribution shown is for one illustrative macro region, MR1, however the structure is exactly the same for all other macro regions. Further the distribution is shown only for 2 sectors as the structure is the same for all sectors. The output of this procedure is a set of O-D matrices representing flows of freight in tonnes for each industrial sector.

Similar to the passenger distribution model a multi-nomial logit function is used to perform the distribution for each origin macro region and industrial sector. This involves a feedback between the TRA sub-module as one of the component inputs into the equation is generalised cost.

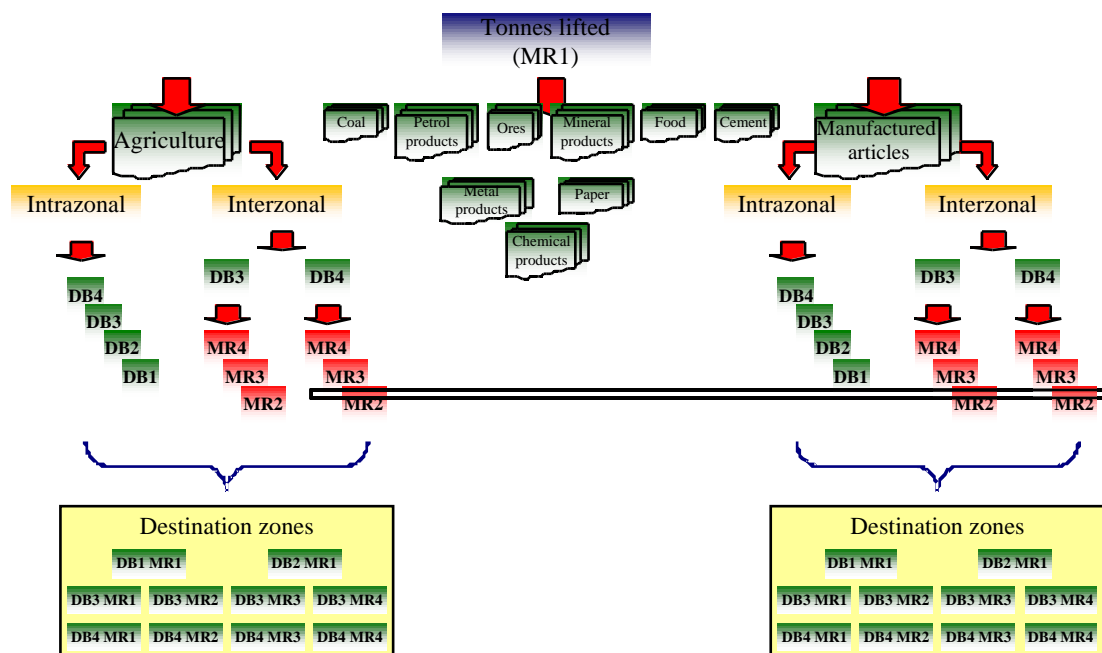


Figure 24: Freight distribution in REM freight model

After the total level of freight tonnes has been generated for each industrial sector in each macro region and distributed across the destination zones, the output is aggregated up to form freight flows which are used for the modal split and assignment in the TRA. Therefore there is a correspondence between the industrial sectors and the freight flows and for each origin and destination zone the flows are aggregated across the industrial sectors that comprise that flow.

The definition of freight transport flows was based on the need to create homogenous segments for modal split e.g all the NST/R²⁴ groups including solid fuel and metal products give rise to solid bulk flows which tend to use slower modes like ship. At the same time it was necessary to maintain the size of the model within a reasonable threshold. In the initial design of the freight model (ASTRA D3) four freight flows were identified:

- Solid & liquid bulk
- Semi bulk
- Low value unitised
- High value unitised

After further consideration it was decided to amalgamate the low and high value unitised categories into a single unitised category. The main determining reason being concerns about the size of the model. The freight handling categories are reported in table 11. Within the STREAMS model the general approach was to implement a clear separation between unitised and non-unitised flows (bulk or semi-bulk flows) with the advantage of reducing the number of transport modes available to each flow (or group of flows) in the mode split. In as far as possible this principle was maintained in the ASTRA approach.

Table 11: Freight flows in the REM freight model

Freight transport flow	Freight flow name	NST/R Groups
1	Solid and liquid bulk (S&L Bk)	00 – 01 – 02 – 03 – 04 – 05 – 06 – 09 – 18 – 21 – 22 – 23 – 41 – 45 – 46 – 32
2	Semi bulk (S Bk)	51 – 52 – 53 – 54 – 55 – 56 – 61 – 62 – 63 – 65 – 84
3	Unitised (Usd)	11 – 12 – 13 – 14 – 16 – 17 – 64 – 69 – 71 – 72 – 81 – 82 – 83 – 89 – 91 – 92 – 93 – 94 – 95 – 96 – 97 – 99

Note: NST/R groups 31,33,34 (Crude petroleum, Gaseous hydrocarbons, liquid or compressed and Non fuel derivatives) are not considered

The missing link so far is the connection between the “Industrial sectors” and the “Freight transport flows.” The production of each industrial sector is in units of value, millions of ECU, whereas the term freight transport flow defines production in terms of physical units of volume, thousands of tonnes. The patterns of correspondence between the industrial sectors and freight transport flows is shown in table 12.

²⁴ NST/R is a standard goods classification for freight transport statistics

Table 12: Correspondence between "Industrial sectors" and "Freight transport flows" in the REM freight model

Industrial sector	Industrial sector name	Freight transport flow
I1	Agriculture, forestry and fishing products	Solid and liquid bulk
I2	Coal	Solid and liquid bulk
I3	Crude petroleum	n/a
I4	Petroleum products	Solid and liquid bulk
I5	Other energy	n/a
I6	Ores	Semi bulk
I7	Mineral products	Solid and liquid bulk
I8	Chemical products	Unitised
I9	Cement	Unitised
I10	Metal products	Semi bulk
I11	Paper	Semi bulk
I12	Food, beverages & tobacco	Unitised
I13	Manufactured articles	Unitised

Note: Industrial sectors 3 and 5 do not generate transport flows in the ASTRA SDM, see below

It should be noted that the generalised cost that is used in the freight distribution stage is from the TRA where it is output by freight handling category. Therefore the assumption is the generalised cost is the same for each industrial sector that is a component of that freight category.

6.2.3 Future development

The discussion presented here relates to the expected trends of relevance to the REM sub-module over the 30 year forecasting horizon of the ASTRA model i.e. 1996-2026.

These trends can be grouped into the following categories;

- Demographic
- Car ownership
- Industrial production
- Passenger transport
- Freight transport

These trends are based on several reports including;

Eurostat (1997) Beyond the predictable: demographic changes in the EU up to 2050

Eurostat (1998) Demographic statistics Data 1995-96

DGXVI (1999) Sixth Periodic Report on the social and economic situation and development of the regions of the European Union

SCENARIOS (1998) Global reference scenarios, Deliverable C5

EUFRANET (1999) Study of long term flows scenarios, Deliverable D3

STREAMS (1999) STREAMS model structure and results, Deliverable D8/D10

6.2.3.1 Demographic

Over the next 30 years the population of the EU15 will continue to grow²⁵ but growth will slow and sooner or later the population is expected to stagnate and decline. 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

6.2.3.2 Labour force

The demographic prospects will certainly have implications for the size and age composition of the labour force. These, however, are as much influenced by changes in participation as by 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 than 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;

- i. Demographics i.e. working age population and
- ii. Participation rates

²⁵ 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

In the past population growth has contributed significantly to the increase in the labour force especially baby boomers. 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.

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.

6.2.3.3 Car ownership

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 elderly are learning to drive, but instead it is cohort driven. 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.

6.2.3.4 Industrial production

It is expected that the manufacturing sectors of the economy will continue to grow faster than the primary sectors. This will thus encourage faster growth in road haulage, than in the modes that have traditionally been used to carry bulks. Likewise, the increasing sophistication in logistical structures and their requirements for high quality transport, and predictable delivery times, has again favoured road haulage to date.

6.2.3.5 Trends in passenger transport

The recent trends in passenger transport have previously discussed elsewhere in this report, section 6.2.1.1 and in D3. It is expected that those trends will continue with the number of passenger kilometres rising much faster than the number of journeys made. Trip rates per capita will remain relatively stable whilst trip lengths continue to increase.

6.2.3.6 Trends in freight transport

The recent trends in freight transport have previously discussed elsewhere in this report, section 6.2.1.1 and in D3. Analogous to passenger demand it is expected that the length of haul

will grow at a faster rate than the number of tonnes lifted thereby continuing the existing trend. There will continue to be a strong link between industrial production and freight transport

6.2.4 Implementation

As in common with the other sub-modules the REM was initially developed in a stand alone form with feedbacks identified between the sub-modules but replaced in the first instance by exogenous data. Subsequently the REM was fully integrated with the other sub-modules although the option remains to run the REM as a stand-alone sub-module. This section is divided into two dealing with the mechanisms contained within the passenger model and freight model respectively.

The STREAMS transport model of the EU15 has been used by both the REM and TRA sub-modules as a benchmark model. It has provided base data for initialising the REM and TRA sub-modules in the base year, providing exogenous trends in variables and parameters governing relationships which are important for model calibration purposes. The role of the STREAMS model in the REM sub-module is mentioned in the following section where necessary and a fuller description of the STREAMS model is included as part of the Annex A.

Table 13 summarises the main units used in the passenger and freight model.

Table 13: Units in the REM sub-module

Variable	Units	Magnitude
Passenger		
Population	Persons	Thousands
Trips	Daily trips	Thousands
Freight		
Value	ECU's	Millions
Volume	Tonnes	Thousands

6.2.4.1 Passenger model

As shown in figure 25 the passenger demand model can broadly be divided into four components:

- Demographic model
- Car ownership model
- Trip generation
- Trip distribution

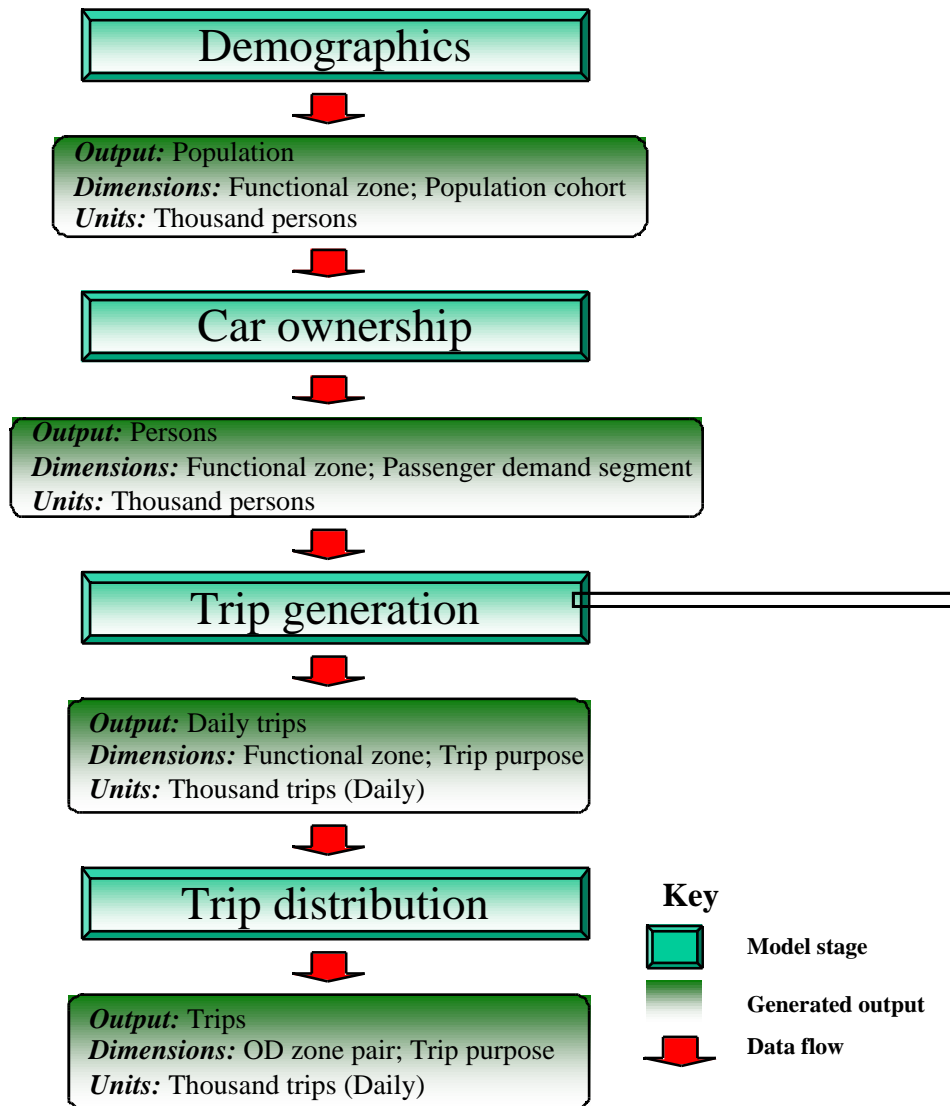


Figure 25: Data flows in REM passenger model

Each of these model stages is now described in turn.

(a) Demographic model

For each of the 6 functional zones a demographic cohort model was set up to model changes in the population of each zone and the distribution of the population between the three identified age based cohorts. To initialise the demographic model a population distribution was input into the model which represented the population of each zone in the model base year, 1986. The population at a given point in time is a function of the population in the previous time period in that zone and the respective birth and age cohort specific death rates and immigration. For each time period the demographic model produces the population in three age based cohorts.

- Under 15 (P1)
- 15 – 64 (P2+ P3) and
- Over 64 (P4)

The 15-64 age group is then split into two further cohorts using an activity rate to calculate the labour force. The activity rates are determined exogenously based on expected and observed trends and are specific for each functional zone. Although the male/ female split of the population is not modelled for reasons mentioned earlier, see section 6.2.2, it is felt that changes in the activity rate should be able to pick up the trend of the increasing participation of women in the labour force.

Cohort P3 includes the unemployed component of the labour force in addition to the economically inactive. The employed component of the labour force forming cohort P2. The reasons for this are that unemployed persons show a greater degree of homogeneity in terms of trip making with economically inactive members of that age group. In order to get the employed/ unemployed split of the labour force, which is directly linked to the conditions of the economy, a feedback loop is formed with the MAC. This feedback is further described in section 6.2.6.1. The labour force by functional zones is transformed into the labour force by macro regions using a set of employment co-efficients derived from the STREAMS model, see Annex A. The labour force by macro region is then input into the MAC and once the employed/ unemployed split is calculated the data is transformed back to functional zone values.

The key inputs into and outputs from the demographic model for each functional zone are listed in table 14 below, more detail on these is provided in Annex A.

Table 14: Inputs to and outputs from REM demographic model

Demographic model (by functional zone)	
Inputs	Outputs
Base year population (1986) - by age cohort (thousands)	Births - thousands
Zonal area (X) - total area of zone km ₂	Deaths by age cohort - thousands
Birth rates (X) - births per 1000 persons	Labour force - thousands persons
Death rates by age cohort (X) - deaths per 1000 persons	Population density - persons per km ₂
Life expectancy (X) - years	Population by; i . age cohort (P1, P2+P3, P4) ii. age/ economic cohort (P1, P2,P3, P4) - thousands
Activity rates - proportion of working age population	Employment - thousands
Employment/ Unemployment (from MAC)	Unemployment - thousands

Note: X – exogenous input

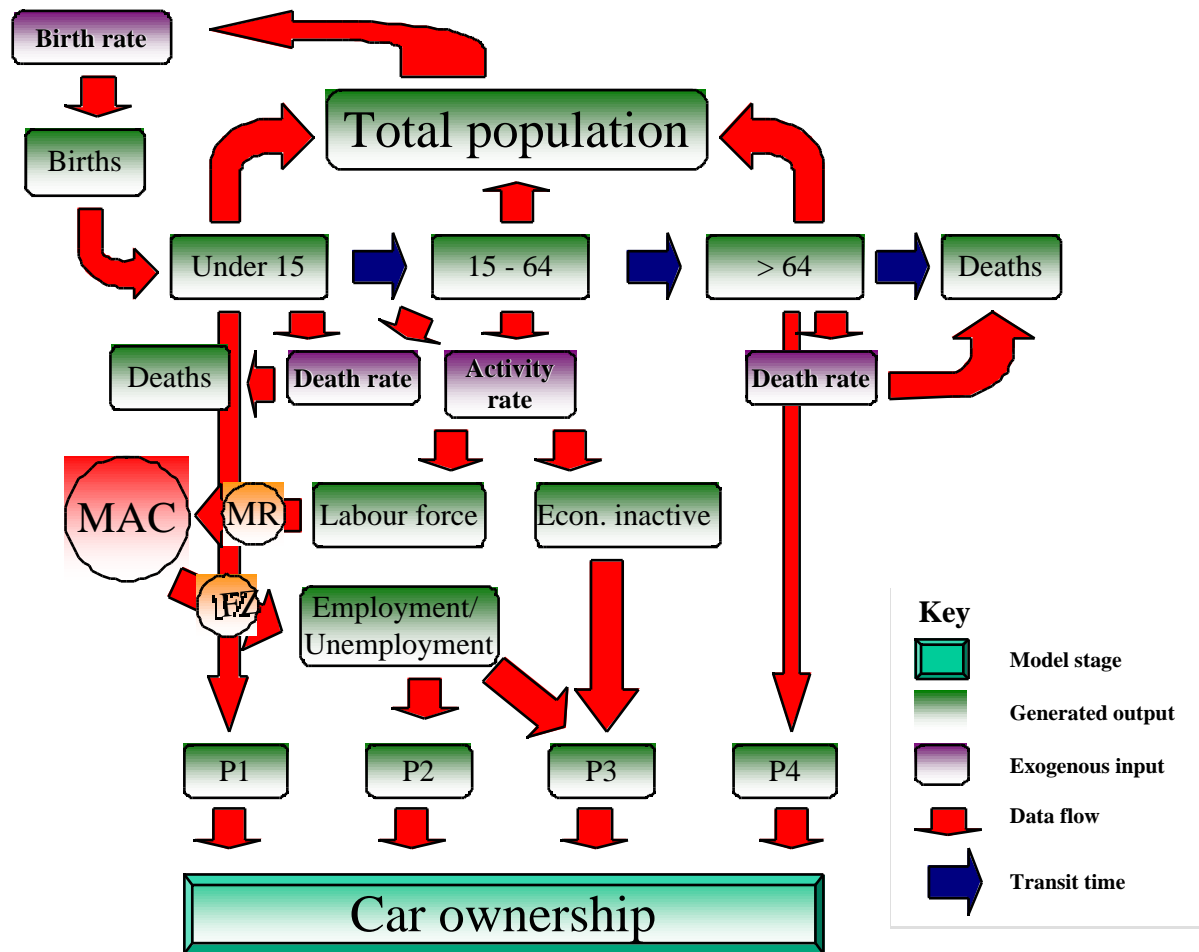


Figure 26: Structure of demographic model in REM

(b) Car ownership model

The purpose of the car ownership model is to further segment the population of each functional zone according to car ownership, as it is clear that car ownership is a significant factor in determining an individual's trip making profile. The procedure works by assigning each person in each of the four population cohorts, to one of the following segments:

- No car
- Part car or
- Full car

This gives us a total of 12 demand segments.

In the initial version of the REM passenger demand model this was modelled as an exogenous trend derived from the output of the STREAMS model. However it was felt that this should be modelled endogenous so that the effects of policy trends in car ownership could be evaluated within ASTRA. The approach adopted in the passenger demand model was to model person car ownership, rather than household car ownership rates. In this way the aim of the model was to distribute the available car stock input from the ENV sub-module where the car stock

and the income effects (MAC) are modelled. The car stock model is described in the section on the ENV sub-module, section 6.4.3.1 (b).

In summary the car ownership model takes into account the following effects on car ownership:

- Demographic changes
- Income via the modelling of the car fleet in the ENV.

The key inputs into and outputs from the car ownership model are listed in table 15.

Table 15: Inputs to and outputs from REM car ownership model

Car ownership model (by functional zone)	
Inputs	Outputs
Population by age/ economic cohort (P1-P4) - <i>thousands</i>	Passenger demand segments (P1NC – P4FC) - <i>thousands</i>
Change in car fleet (from ENV) - <i>thousands</i>	Cars per head population - <i>cars per person</i>
Average cars per person (X)	Persons by car availability (NC, PC, FC) - <i>thousands</i>
Alpha calibration parameters (X)	Cars per thousand adults - <i>cars per adult (15-64)</i>

Note: X – exogenous input

The mathematical specification of the car ownership model can be found in the Annex A but essentially there are two stages to the model;

- For each time period, t , the four population cohorts (P1 – P4) are scaled by age/economic group in line with the demographic change in the period in order to take account of implications for the size of the car fleet. Therefore there is a feedback loop between the car ownership and demographic models.
- The next stage is to implement the switching between car ownership categories such that it will match the constraint of the growth in the car fleet which is input from the ENV sub-module. The approach is based on people switching from their current car ownership category to the neighbouring category.

The output from the car ownership model is the population of each functional zone segmented into the 12 homogenous demand segments defined in section 6.2.1. These are then passed into the passenger trip generation stage, described in the next section.

(c) Trip generation

For each time period once the population has been distributed amongst the demand segments the next stage is to generate the number of trips by each of the three trip purposes (commuting and business, personal and tourism identified in Section 6.2.2.3) for each functional zone. A set of trip rates was derived exogenously from observed time-series data and the STREAMS model

for each demand segment and purpose (see Annex A for details). These are applied, by a simple multiplicative process, to the demand segments to calculate the number of daily trips by each segment by purpose. The number of trips is then summed across the demand segments with the result that for each functional zone there are a total number of daily generated trips for each purpose. It is this data that is passed onto the next stage, trip distribution.

The key inputs into and outputs from the trip generation stage for each functional zone are listed in table 16.

Table 16: Inputs to and outputs from REM trip generation

Trip generation (by functional zone)	
Inputs	Outputs
Passenger demand segments (P1NC to P4FC) - <i>thousands of persons</i>	Daily trips by purpose - <i>thousands</i>
Daily trip rates by demand segment and purpose (X) - <i>daily trips per 1000 persons</i>	Annual trips by purpose - <i>thousands</i>
	Average annual trips per person - <i>trips per person</i> (can be disaggregated by demand segment and purpose)

Note: X – exogenous input

Figure 27 illustrates the structure of the trip generation stage for an illustrative functional zone. The demand segments output from the car ownership model are processed by the trip generation model by applying daily trip rates to give a total number of daily trips by each of the three purposes for each of the functional zones. These vectors are then passed to the trip distribution stage.

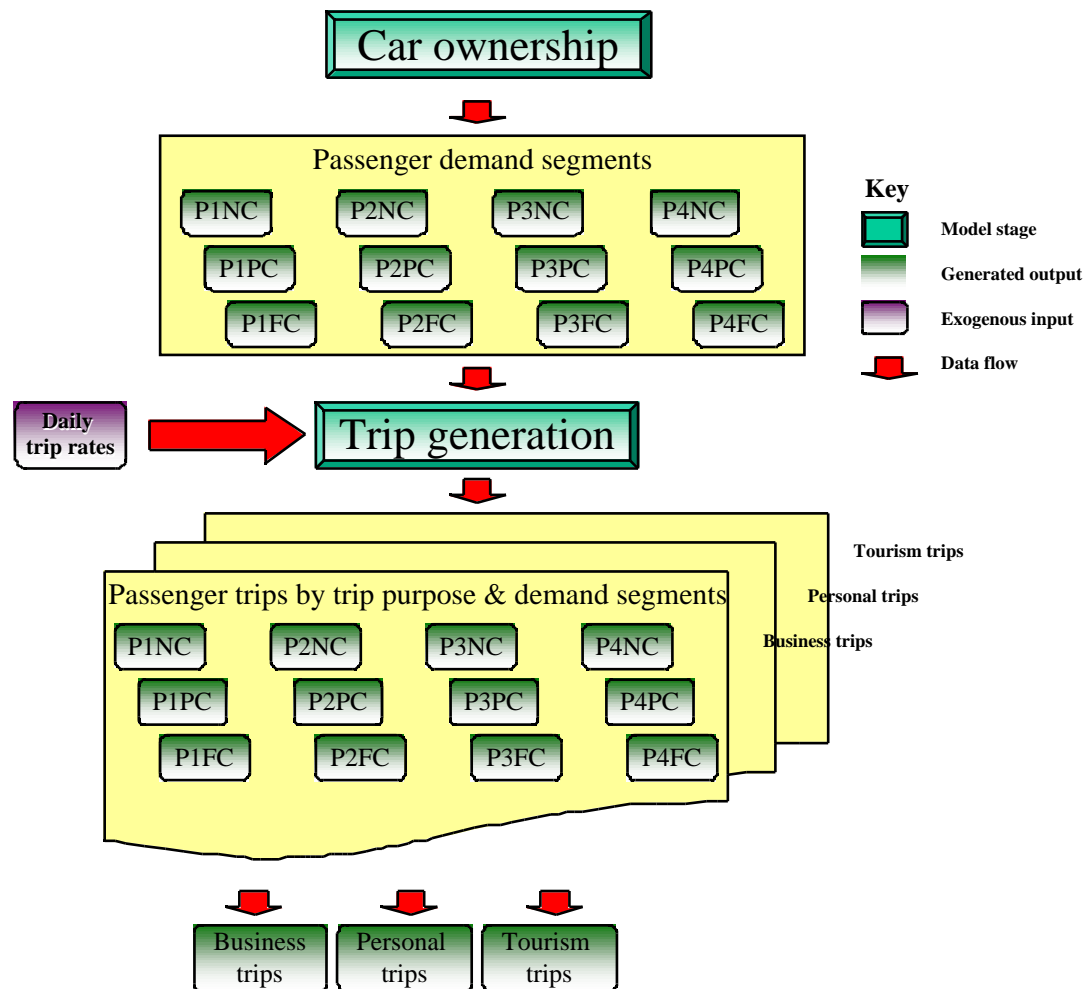


Figure 27: Structure of trip generation stage of REM

Note: This figure represents the trip generation process for one functional zone

(d) Trip distribution

The total number of trips by purpose and origin functional zone is then distributed to the destination zones. As previously described in section 6.2.2.3, these are a combination of distance band and functional zone and vary according to trip purpose.

The passenger trips are distributed by purpose and origin functional zone through the use of a multi-nomial logit function similar to that used in the modal split of the TRA sub-module. A specification of the function can be found in the Annex A. Briefly the volume of trips by purpose for each functional zone is distributed to the destination zones based on the generalised time of that O-D pair and the relative attractiveness of that destination. The generalised time is obtained for each O-D pair from the TRA sub-module via an interface in the ASTRA model.

The key inputs into and outputs from the trip distribution stage are listed in table 17 below.

Table 17: Inputs to and outputs from REM trip distribution

Trip distribution (by functional zone)	
Inputs	Outputs
Daily trips by trip purpose - <i>thousands</i>	Daily trips by trip purpose and O-D pair - <i>thousands</i>
Generalised time by O-D pair and trip purpose (TRA)	
Base year residual disutility by OD pair and trip purpose (X)	
Size term for each zone (X)	
Lambda distribution parameter (X)	

Note: X – exogenous input

The output from this stage is a set of OD matrices of daily trips for each trip purpose. These are then passed to the TRA sub-module for modal split and assignment to be carried out.

Figure 28 illustrates the information flows in the passenger trip distribution stage of the REM sub-module. It illustrates that the trips by functional zone are distributed across the destination zones using a set of proportions calculated using the generalised time for each O-D pair from the TRA and other data including the size of the zone (population). The lambda parameter is used to control the distribution of trips across the destination zones. It is calibrated for the period 1986-95 to fit the modelled distribution to the observed data. By using generalised time in the distribution function it is expected that increasing trip lengths will be modelled without having to alter the lambda parameters.

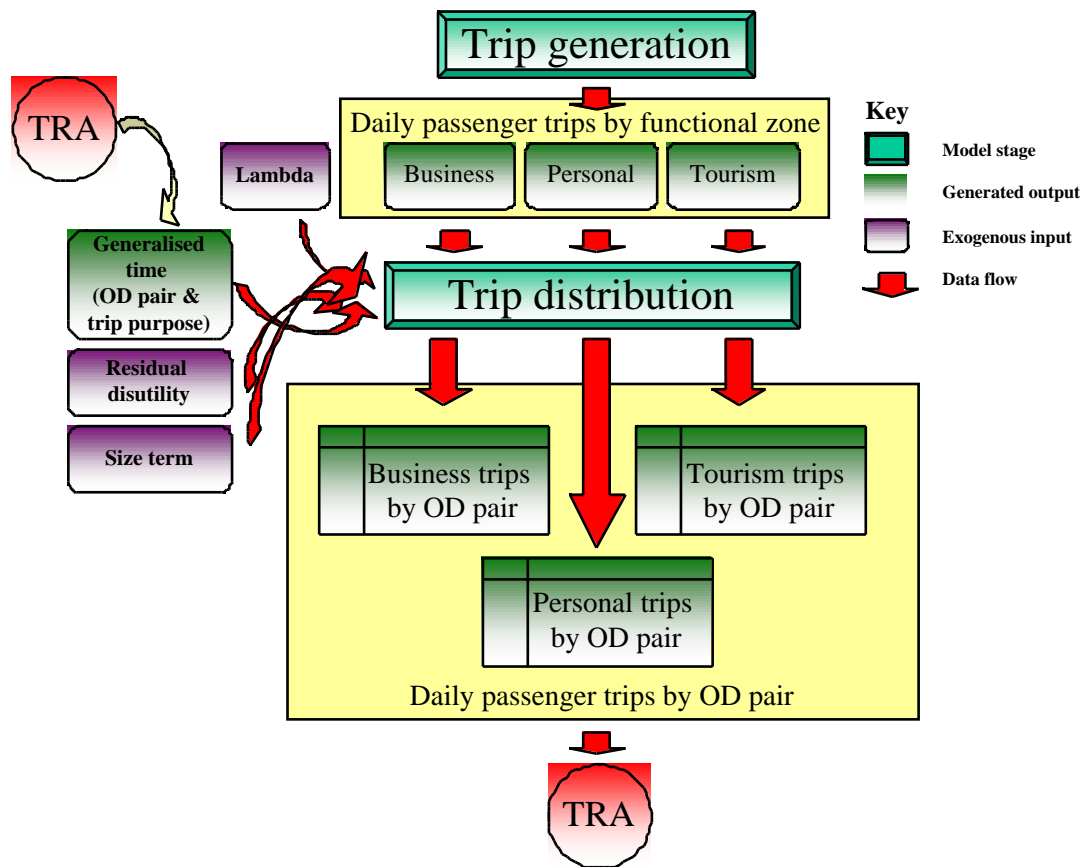


Figure 28: Structure of trip distribution stage of REM

6.2.4.2 Freight model

A similar approach to that adopted in describing the passenger model in the section above is now used to describe the implementation of the freight model. As shown in figure 29 the freight model can broadly be divided into four parts:

- Industrial production
- Freight generation by industrial sector
- Freight distribution by industrial sector
- Aggregation to freight flows

Also indicated in figure 29 are the data flows between the component models of the REM freight demand model.

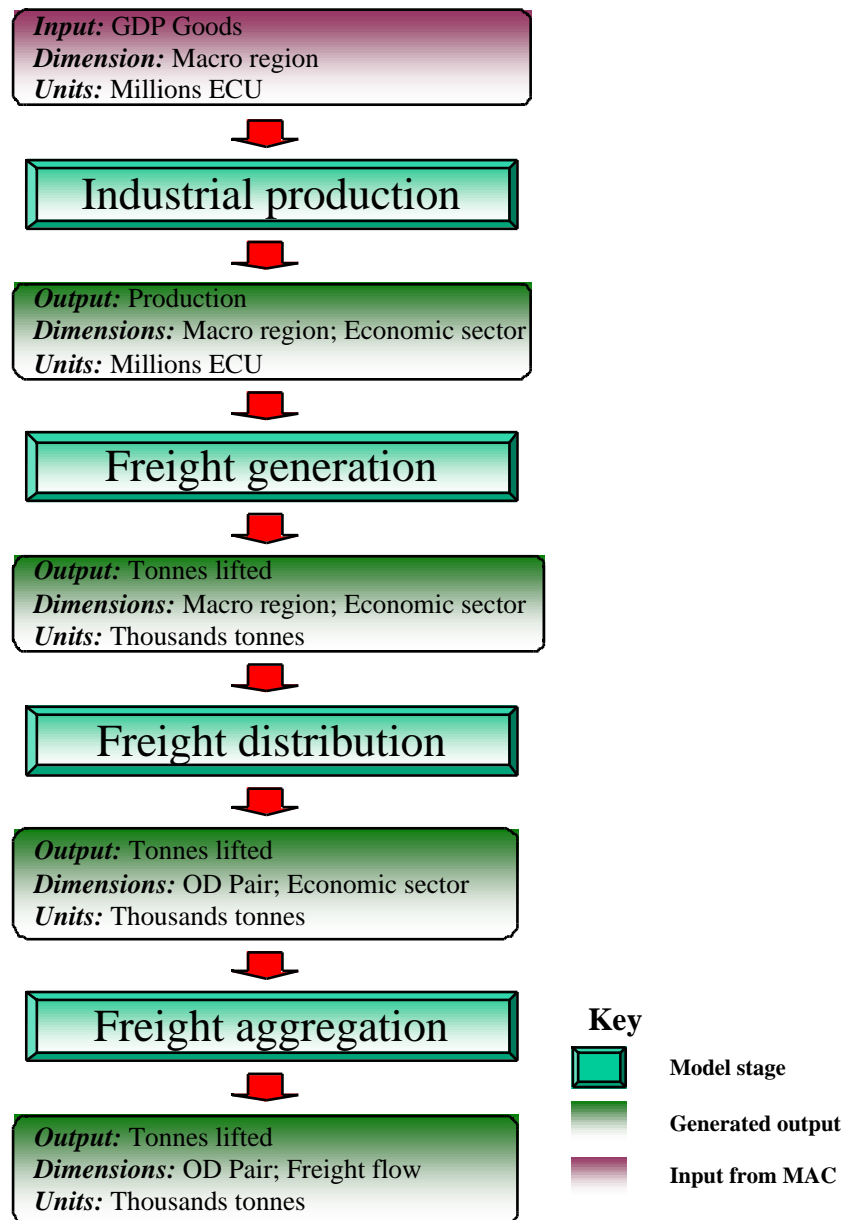


Figure 29: Data flows in REM freight model

(a) Industrial production

There is clear positive relationship between economic growth and freight transport and to this end it is the role of the industrial production model to generate the value of production by each of the industrial sectors identified in section 6.2.2.1. The general condition of the economy is modelled in the MAC where the GDP (Millions ECU) for each macro region is calculated and subsequently broken down into:

- GDP – Goods and
- GDP – Services

The REM freight model takes the GDP goods for each year as the control total for the sum of the GDP for all the 13 industrial sectors.

In order to obtain the base year distribution the initial value of GDP – goods are distributed across the 13 industrial sectors using a set of weights derived from observed data. In each subsequent year it is then necessary to distribute the change in GDP for the goods category, input from the MAC, across the industrial sectors. However the change in GDP cannot be distributed equally, or even proportionally according to their relative contribution to GDP, across all sectors because different sectors have different growth rates for example electrical goods is likely to grow faster than agricultural production. Therefore the approach adopted in the REM was to apply a growth rate by industrial sector which reflects the expected relative growth of various sectors of the economy. This is then applied to the GDP for that sector in the previous time period. The calculated GDP by sector will not at this stage match the GDP from the MAC as account has not been taken of the overall growth in the economy only of the relative growth of different sectors. The second stage therefore is to generate a new set of weights which are then used to distribute the change in GDP input from the MAC. In summary the updating procedure takes into account two effects:

- Total growth in GDP, governed by the MAC and
- The relative growth of different industrial sectors

The output from this stage of the freight model is the value of production for each of the industrial sectors in the economy.

Table 18 summarises the inputs to and outputs from the REM industrial production model.

Table 18: Inputs to and outputs from REM industrial production model

Industrial production model (by macro region)	
Inputs	Outputs
Initial distribution of GDP by Industrial sector (1986) - <i>proportions (X)</i>	GDP by industrial sector - <i>Millions ECU</i>
GDP Goods (from MAC) - <i>Millions ECU</i>	
Sector growth rates - <i>percentage per annum (X)</i>	

Note: X – exogenous input

(b) Freight generation

The next stage is to transform the value of production for each industrial sector and macro region into tonnes of freight. This is done through the use of a set of value to volume ratios which are normally specific for each type of production and OD pair. Within this freight model a simplification is made where the value to volume ratio is applied to industrial production by sector and origin macro region, rather than the OD pair. This is done for technical reasons. The value to volume ratios are determined exogenously using the STREAMS model data for the calibration period and then assumptions are made regarding their value for the forecast period, see section 6.2.3 and Annex A. The output from this model stage is tonnes lifted by industrial sector for each macro region. This data is then used in the freight distribution stage. Table 19 shows the key inputs to and outputs from this stage for each macro

region and figure 30 illustrates graphically the freight generation stage for a particular macro region. It should be noted that as stated in section 6.2.2.3 that freight is not generated for industrial sectors 3 and 5 and so for these industries the value to volume ratios are set to zero.

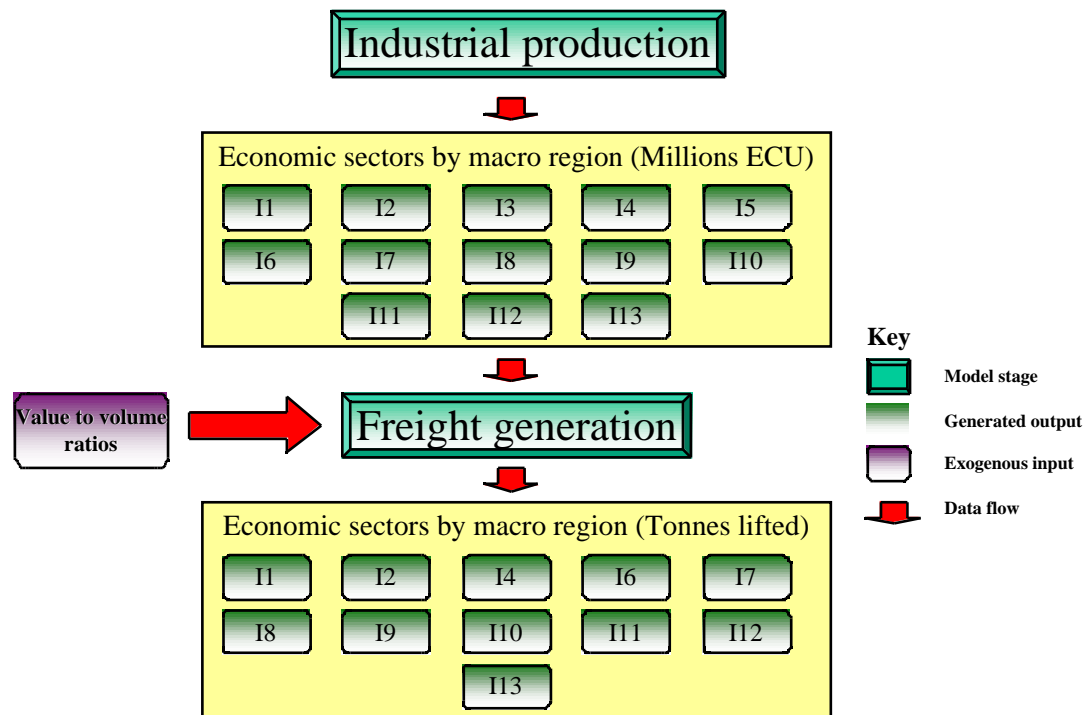


Figure 30: Structure of Freight generation stage of REM freight model

Table 19: Inputs to and outputs from REM freight generation model

Freight generation model (by macro region)	
Inputs	Outputs
GDP by industrial sector - Millions ECU	Tonnes lifted by economic sector - thousands of tonnes
Value to volume ratio - thousand tonnes per Million ECU's (X)	

Note: X – exogenous input

(c) Freight distribution

The tonnes lifted by industrial sector and macro region are then distributed across the destination zones, which as previously described in section 6.2.2.4, are a combination of the 4 freight distance bands and 4 macro regions. The number of destination zones is the same for all industrial sectors, 10, with the shorter two distance bands representing intrazonal movements only.

The tonnes lifted are distributed by industrial sector and macro region through the use of a multi-nomial logit function. This function specified in almost the same way as in the passenger model except that generalised cost is input for each O-D pair rather than generalised time. Generalised cost for freight transport includes both the direct costs e.g. haulage, loading/

unloading and other handling charges and other indirect logistic costs. The indirect costs are represented in the form of a user perceived valuation of transit time.

The output from this stage are a set of OD matrices for each industrial sector. Before these OD matrices are passed onto the TRA sub-module it is necessary to aggregate the tonnes lifted to the three freight categories which are used in TRA. It should also be recognised here that the generalised costs used in the distribution of the freight generated by each industrial sector are by freight category and therefore the same OD generalised costs are applied for each industrial sector that is a component of that freight flow.

Table 20: Inputs to and outputs from REM freight distribution model

Freight distribution model (by macro region)	
Inputs	Outputs
Tonnes lifted by economic sector - <i>thousands of tonnes</i>	Tonnes lifted by economic sector and O-D pair - <i>thousands of tonnes</i>
Generalised time by O-D pair and industrial sector	Tonnes lifted by economic sector and distance band - <i>thousands of tonnes</i>
Base year residual disutility by OD pair and trip purpose (X)	
Size term for each macro region (X)	
Lambda distribution parameter (X)	

Note: X – exogenous input

(d) Freight aggregation

The final stage within the REM freight demand model is to aggregate the tonnes lifted by industrial sector to the three freight flows as defined in table 20. This is a simple addition of the volume for each O-D pair for each industrial sector that is part of that freight category.

Figure 31 illustrates the information flows in the freight distribution and aggregation stages of the REM sub-module.

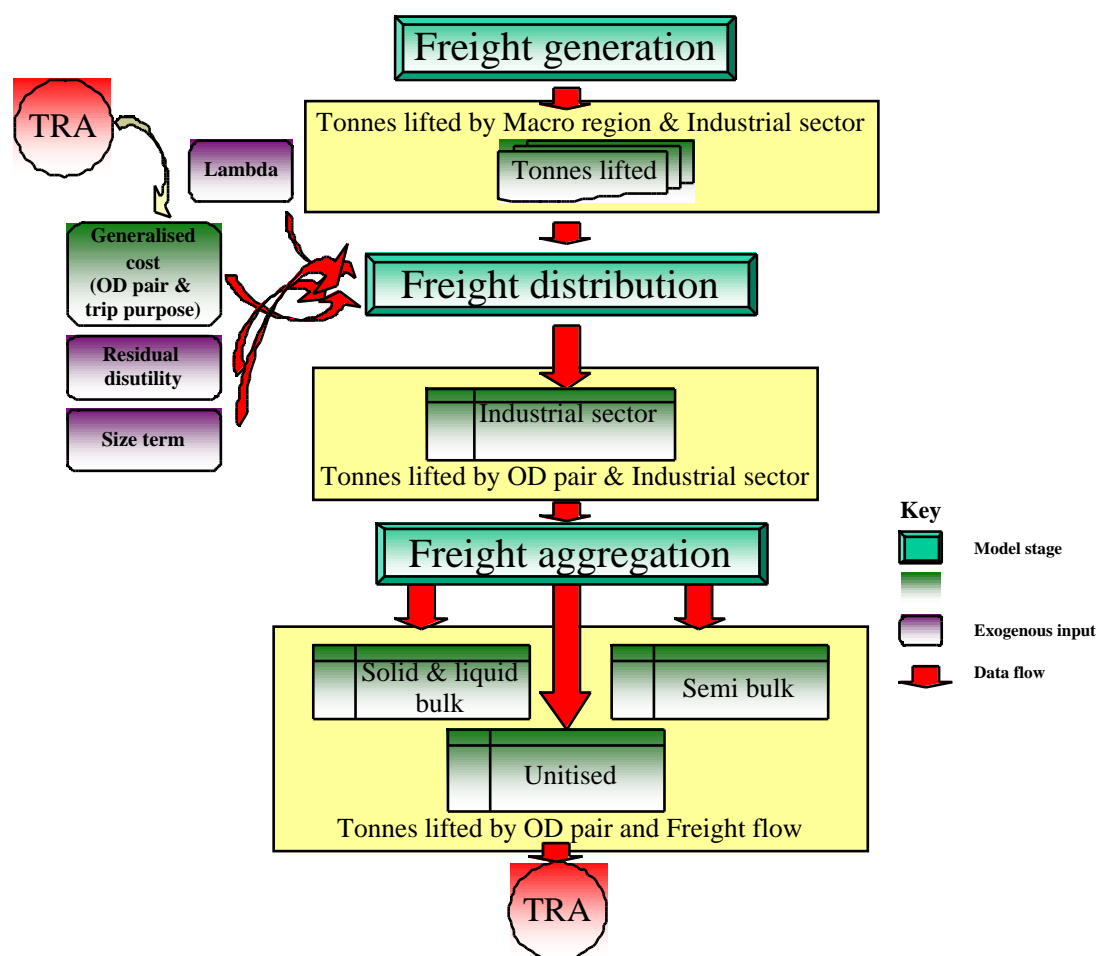


Figure 31: Structure of Freight distribution and aggregation stages of REM freight model

Table 21: Inputs to and outputs from REM freight aggregation model

Freight aggregation model (by marco region)	
Inputs	Outputs
Tonnes lifted by economic sector and O-D pair - thousands of tonnes	Tonnes lifted by freight category and O-D pair - thousands of tonnes
	Tonnes lifted by freight category and distance band - thousands of tonnes

6.2.5 Calibration of the REM sub-module

The core calibration period for the REM is the period between 1986 and 1996 and for this period it is intended that the main stock variables in the passenger and freight model would be calibrated against observed data to ensure that their modelled trajectory through time and space is realistic.

The calibration is achieved by adjusting the parameters that are embedded in each component of the overall model, in a manner that enables the results of that model component to match by time period and/or by zone the observed values.

6.2.5.1 Passenger model

Within the passenger model the following variables are checked in the calibration process.

- Population – the demographic structure in each of the zones will be calibrated against observed data from Eurostat and the STREAMS model.
- Car ownership – the relative rates of growth in car ownership rates for each of the different population cohorts.
- Trip lengths – the rate of growth in trips for each purpose and person type combination. This ensures that the correct response is given to changing levels of income, travel disutilities and car ownership over time in the passenger model.

6.2.5.2 Freight model

Within the freight model the following variables are checked in the calibration process.

- Production – in the freight model the value of production by broad industrial sector will be calibrated against observed data from STREAMS and Eurostat.
- Trip lengths – to ensure that the correct response is given to changing levels of international trade and transport costs.

Otherwise the principal source of data for passenger calibration will be the national passenger travel surveys from those EU countries which publish them regularly, and for freight the Eurostat Carriage of Goods database and publications, but other sources will be used where available.

6.2.6 Interfaces to other sub-modules

The ASTRA SDM whilst including four distinct sub-modules described in this section also includes feedback loops between the sub-modules and in some instances this involves the development of explicit interfaces to transform the outputs from specific sub-modules so that they can be input into another sub-module. This part of the report is structured so that the description of each sub-module includes a further description of any interface that facilitates the use of its outputs in the other three sub-modules.

Figure 32 shows the feedback loops between the REM and the other sub-modules.

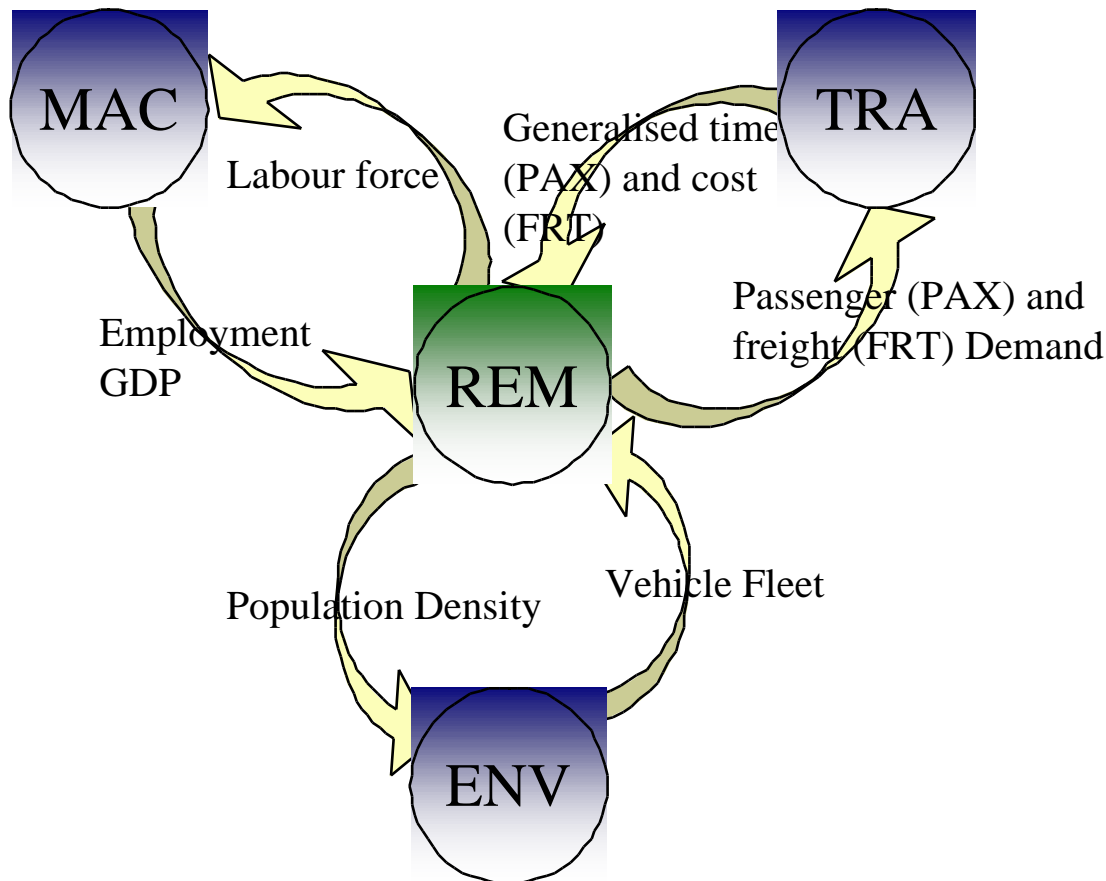


Figure 32: Feedback loops between REM and other ASTRA SDM sub-modules

As shown in figure 32 the REM sub-module provides three sets of data to the other sub-modules;

- labour force to MAC by macro region, section 6.2.6.1
- passenger and freight demand to TRA, section 6.2.6.2
- population density to ENV, section 6.2.6.3

6.2.6.1 Macro-Economic sub-module (MAC)

It is the MAC sub-module that drives the economy with the REM using these conditions to determine the demand for transport. These inherent links between the two sub-modules mean that a number of variables output from the MAC are utilised within the REM structure. These are:

- Industrial production - Goods i.e. GDP
- Levels of employment and unemployment

The REM sub-module, through the demographic model, provides the MAC sub-module with the labour force with which to calculate the employed/ unemployment split which is based on the condition of the macro economy. The fundamental problem is that the MAC and the passenger model in the REM operate with different zoning systems and it is necessary to convert the labour force from functional zones to macro regions and vice versa with the employment data.

A number of different approaches were discussed to create an explicit link between the zoning schemes. The conclusion was that an intermediate matrix would be created as an interface. This would be a 24 cell matrix i.e. the 4 internal “Macro-Regions” by the 6 “Functional Zones” and would include coefficients to convert between zoning schemes. The data used to derive the matrix was from the STREAMS model. As the freight demand model and the MAC operate with the same zoning scheme this problem does not arise.

6.2.6.2 Transport sub-module (TRA)

There is a natural link between the REM and TRA sub-modules; between them they form the four stages of the classical 4-stage transport model. Trip generation and trip distribution being done within the REM and modal split and assignment in the TRA. Consequently the primary output from the REM forming an input to the TRA are travel demand O-D matrices of:

- passenger movements by trip purpose and distance band,
- freight flows by handling category and distance band.

These O-D matrices can be directly input into the TRA. Similar style O-D matrices of generalised cost/time aggregated across all transport modes for each trip purpose are transferred back from the TRA to the REM sub-module, through an interface, for use in the next time period for the distribution in the passenger and freight models. As the REM and TRA use the same spatial structure no co-efficients are required to weight the output model variables.

6.2.6.3 Environmental sub-module (ENV)

Currently the REM sub-module calculates a population density indicator for each of the six functional zones that can then be directly used by the ENV sub-module. There is also a link between the sub-modules relating to car ownership integrating the level of car ownership in the REM with the vehicle fleet that is part of ENV sub-module, see section 6.4.

6.3 Transport Sub-module (TRA)

6.3.1 Aim of the TRA Sub-module

The ASTRA transport sub-module simulates the modal split of passenger and freight travel demand at European scale. Travel demand is generated and distributed among the zones by the REM regional economic sub-module and is transferred to the TRA transport sub-module according to distance bands and purpose/freight category. The transport sub-module performs the modal split separately by purpose/freight category for each distance band and supplies the ENV environmental sub-module with the information about traffic by mode for the calculation of externalities and environmental indicators. It also supplies the REM regional economic sub-module with the generalised costs and generalised times among the zones and the MAC macroeconomic sub-module with travel time and cost savings.

Next section 6.3.2 gives a general description of the transport sub-module, while the implementation in itthink software is illustrated in the annex. A description of the calibration and validation process can be found in section 6.3.4. The interaction with other sub-modules of the ASTRA platform is presented in section 6.3.5. More details can be found in the technical Annex A 12.3.

6.3.2 Basic structure of the TRA

The main difficulty while designing the transport sub-module for the ASTRA system dynamic model has been the change of perspective in comparison to the classical modelling applications. Classical transport models are based on a detailed and explicit representation of spatial factors, whereas they pay less attention to the time factor. As an example, a network based transport model covering the same geographic area of ASTRA (the EU Member States) actually deals with thousands of links and hundreds of geographical zones. Space then plays a dominant role and each transport infrastructure is very well described in its characteristics: length, capacity, speed allowed, etc. Network based transport models adopt a cross sectional approach: they reproduce transport flows and loads on links at a given time, the base year, while the evolution through time is performed running the model at one or two horizon years on the basis of a number of exogenous assumptions.

Switching from the classical approach to the System Dynamic Modelling, it has been necessary to change the usual point of view giving more emphasis on time and less on space. ASTRA model had to operate at the EU scale, but it was not feasible to simply transfer the network transport model approach into the system dynamic framework, as the philosophy behind the two methodologies is definitely different. Furthermore the software adopted for the development of the ASTRA system dynamics model has much more limitations in terms of memory size and computational time.

The design of the transport sub-module is based on two key concepts: the simplified zoning systems and the distance bands (both are described in detail in chapter 5). The simplified zoning system was based on settlement type for passengers and on economics macro-regions

for freight and in both cases made it possible to use small vectors and matrices, in place of the very big geographical vectors and matrices of the STREAMS model (which was adopted as benchmark model).

The adoption of the simplified zoning system required the definition of distance bands, intended as distance ranges with homogenous modal split characteristics (modes availability, performances, etc.), to be analysed separately. Considering the example of the passenger functional zones based on settlement types, it became clear since the beginning that the origin/destination matrix of Europe could not be directly squeezed into a unique functional matrix, as this would have meant the loss of the information about the physical distance between each couple of zones. In fact, passenger flows among the different geographic zones of Europe were transformed in flows among functional zones according to the characteristics of both the origin and destination zones and according to the distance involved (see chapter 4). For instance, passenger flows between zones belonging to the medium density regions (MDR) and zones belonging to large stand-alone metropolitan centres (LSA) were classified as journeys from MDR and LSA functional zones of local, short, medium or long distance on the base of the network distances among the original geographic zones.

It is important to notice that the TRA sub-module is strictly connected with the REM sub-module, as the modal split performed in the TRA directly influences the trip (and freight) distribution performed in the REM. Within each distance band sector of the TRA sub-module, modal choice and assignment are performed independently for each purpose/freight category and average transport costs are then passed by to the REM. And the REM sub-module allocates the transport volumes between the different distance bands sectors according to a logit choice model based on the generalised transport costs. Therefore the growth of average distances through time (or of passenger*km or tons*km) is modelled in terms of an increase of transport demand allocated by the REM to the longer distance bands sectors of the TRA.

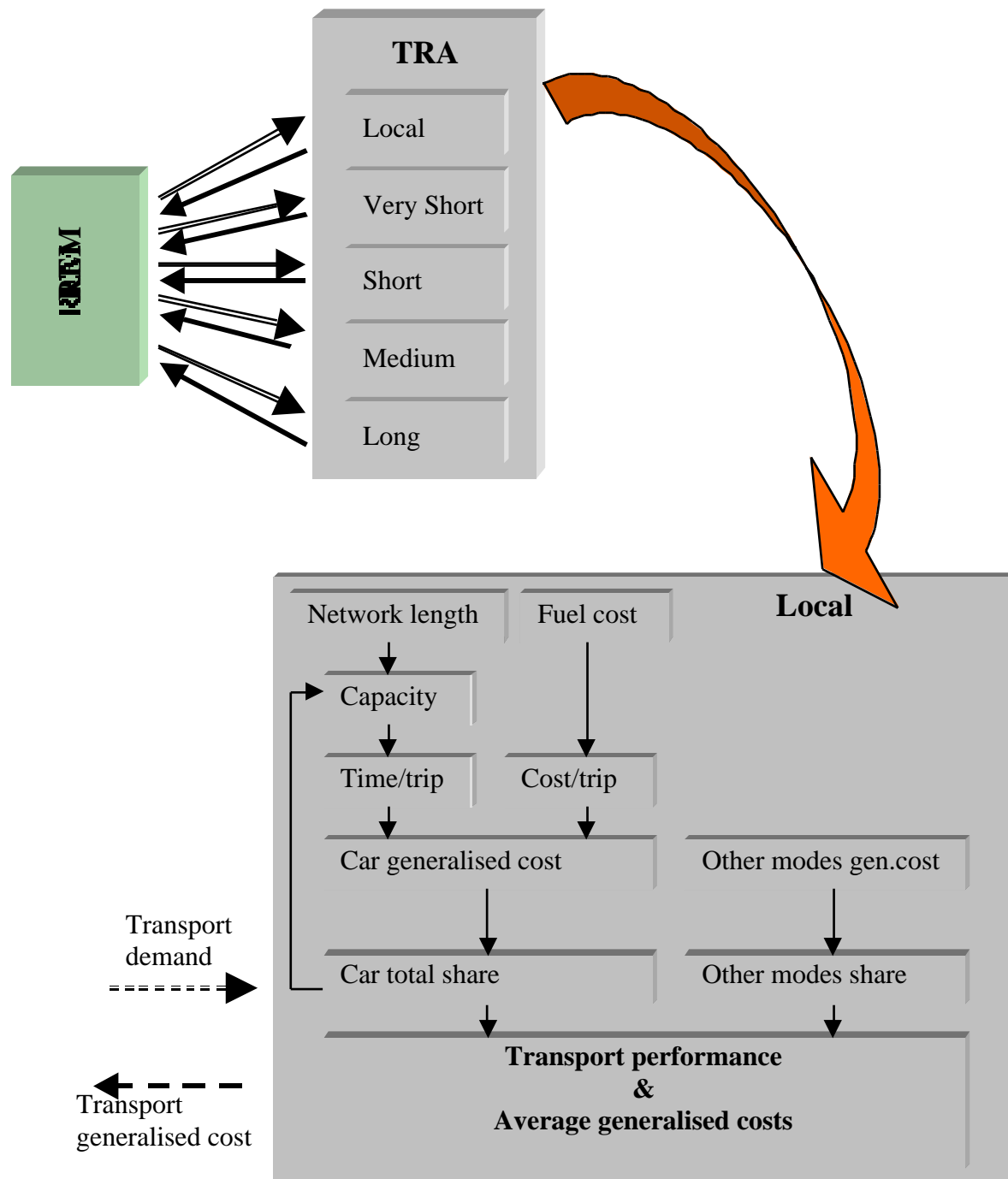


Figure 33: Impact chain in ASTRA

6.3.3 Implementation

The transport sub-module is composed by five passenger sectors and four freight sectors. Sectors²⁶ are built according to distance bands in order to retain the different travel patterns occurring in passenger trips or freight shipments with different average distances. Passenger

²⁶ The distance bands or distance band segments are modelled each in one ithink sector. Therefore the denotation distance band sector refers to the distance categorisation and to the corresponding implementation in ithink respectively in a view of the Vensim model.

distance bands were derived from the analysis of the National Travel Surveys of European member states carried out for the STREAMS project. Freight distance bands were defined starting from the analysis of the Eurostat data. Within each trip distance related sector, the relevant trip purposes or freight categories are analysed separately, i.e. a specific modal split is modelled for each purpose/ category.

The TRA sub-module can be divided in three parts: the passenger component, the freight component and the road capacity component. These are discussed in turn in the following text.

6.3.3.1 Passenger component

The five passenger sectors are as follows:

- Local distance, between 0 and 3.2 km.
- Very-short distance, between 3.2 and 8 km.
- Short distance, between 8 and 40 km.
- Medium distance, between 40 and 160 km.
- Long distance, over 160 km.

Three passenger travel purposes (commuting&business, tourism and personal) have been selected (see Annex A 12.2). The passenger transport sub-module tries to represent all transport flows - from local movements to long distance journeys - and includes: slow modes, car, bus, train and air. Obviously not all modes are represented in each distance band sector, i.e. tourism flows are modelled for long distance movements only.

Each sector is able to perform the modal choice of the travel demand produced by the REM sub-module. Trip purposes and travel modes represent aggregations of trip purposes and travel modes used in the STREAMS transport model (see section 6.2.2.4). As an example, in the local passenger sector local trips, between 0 and 3.2 km, are modelled. The trip purposes considered are business & commuting and personal, while the travel modes are car, bus and slow.

Road modes of Local, Very-short and Short sectors refer to the local road network, while Medium and Long ones refer to the inter-regional network.

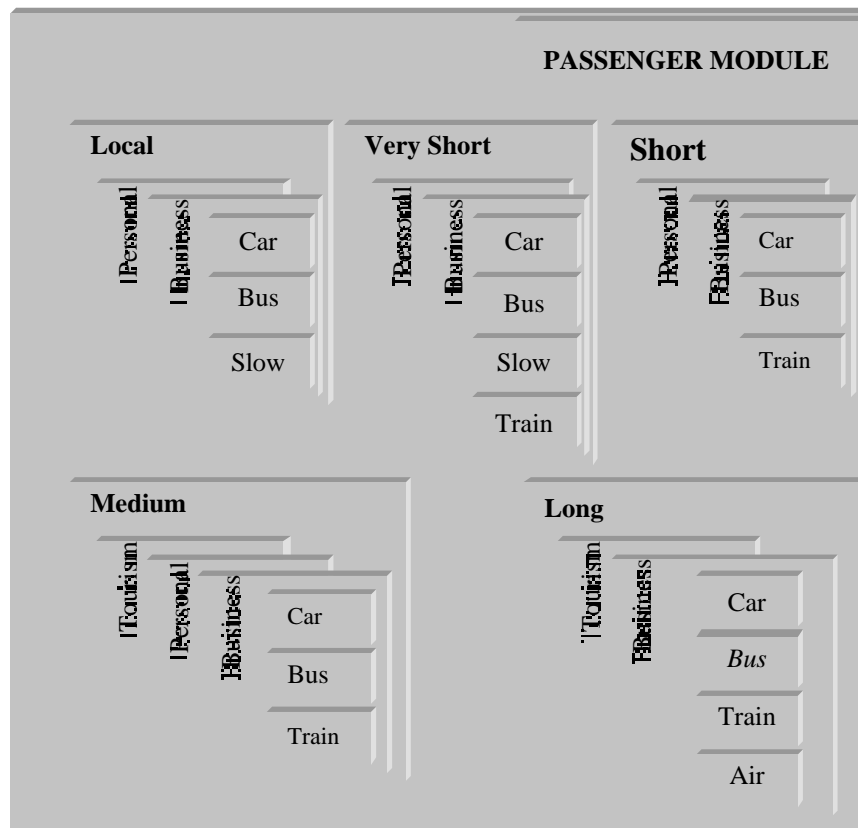


Figure 34: Transport sub-module structure - Passenger component

6.3.3.2 Freight component

The four freight sectors are as follows:

- Short distribution, between 0 and 50 km.
- Medium-short distance, between 50 and 150 km.
- Medium-long distance, between 150 and 700 km.
- Long distance, over 700 km.

STREAMS model freight flows are aggregated into a set of homogeneous handling categories (see Annex A 12.2) on the basis of the value of time, the handling and the carriage requirements of each commodity.

Transport modes modelled are: trucks, rail/iww and shipping. For the need of simplification, minor modes have been ignored: pipeline - which is relevant for liquid bulk flows only - and air cargo - which carries a very tiny share of goods. Bearing in mind the need to keep the model as simple as possible, rail and inland waterway have been aggregated into a single mode of transport as they offer very similar transport characteristics and compete on the same products and on the same distances. Furthermore inland waterway transport mode is available in some geographic areas only and then its modelling in a functional zoning approach would

have been unsatisfying, as there would have been an inland shipping mode available for each functional zone pair and it would have represented a minor share.

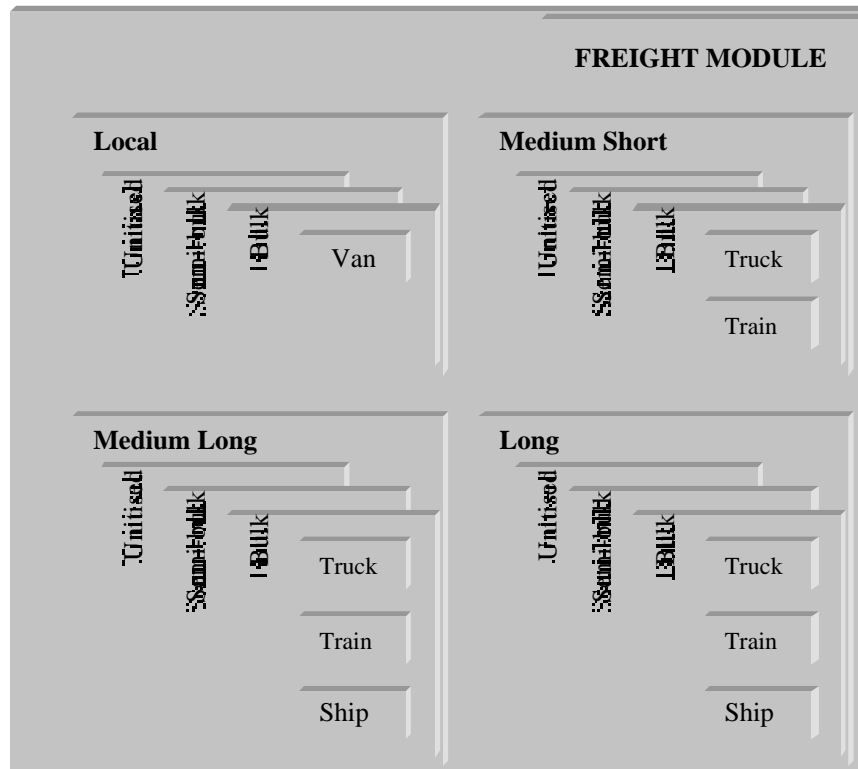


Figure 35: Transport sub-module structure - Freight component

Each sector is able to perform the modal choice of the freight demand produced by the REM sub-module. Freight categories and distribution modes represent aggregations of freight categories and distribution modes used in the STREAMS freight transport model (see section 6.2).

Road modes of Medium-short, Medium-long and Long freight sectors refer to the inter-regional network, while only the Short freight sector refers to the local road network.

6.3.3.3 Modal choice

The modal choice is based on the generalised costs associated to each mode of transport, which in turn are calculated according to transport times and costs. The choice process is simulated using a multinomial logit model (MNL). In each distance related sector and for each trip purpose or freight category, the calculation of the generalised cost derived from the monetary cost, which depends on the specific average distance, and the time, which is either exogenous for non road modes or calculated endogenously for road modes - according to the ratio between the number of vehicles and the road capacity in the previous year (T-1).

The generalised cost and the modal constant are the deterministic components of the utility function by mode and by purpose. The equation which calculates the probability to choose a mode of transport k for a given travel purpose or freight category has the general form:

$$P_k = \exp (V_k) / \sum_j \exp (V_j) \quad (\text{eq. 6})$$

Where: k represents a transport mode,
 T represents all transport modes available in the sector,
 V_k is the deterministic component of the utility function of mode k ,
 θ is a calibration parameter

Cost and time by modes of transport are different according to distance bands sectors and travel purposes or freight categories. For each mode and each sector:

- Transport times are the same for all trip purposes or freight categories, i.e. train time is constant for a given year for all purposes represented in the local distance sector;
- Transport costs are different by trip purposes or freight categories: i.e. air costs are not the same for commuting&business (mainly full price tickets on flag air companies) and tourism trips (mainly package tours on charter flights) in the long distance sector.

Transport times by non-road modes of transport in the different sectors are constant, or they might vary through time according to exogenous criteria. Transport times by road modes (i.e. car and bus) are updated, time-by-time, on the basis of road traffic congestion.

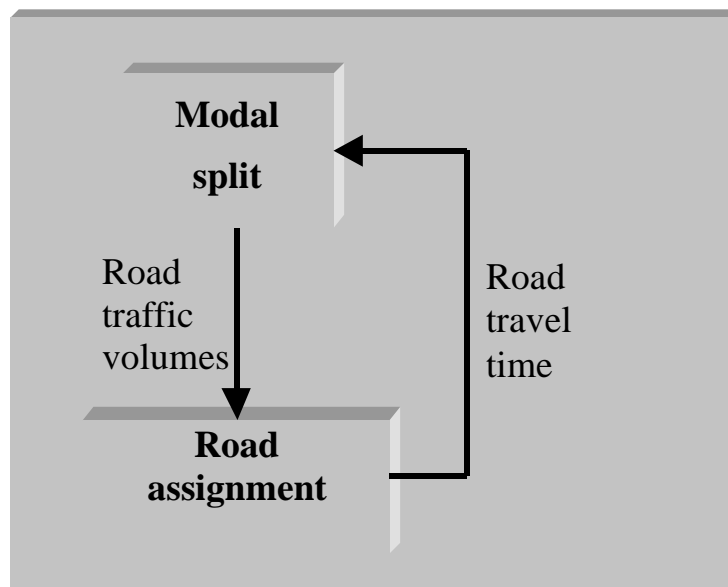


Figure 36: Modal split and road assignment

6.3.3.4 The road traffic assignment

In general terms the passenger and freight distance bands sectors work independently from each other, but indeed there is an interaction in the road usage. As an example congestion on the long distance road network would affect regional and inter-regional passenger flows

(medium and long distance sectors) on cars and buses as well as freight trucks (medium-short to long distance freight sectors) as they all compete for the same road space.

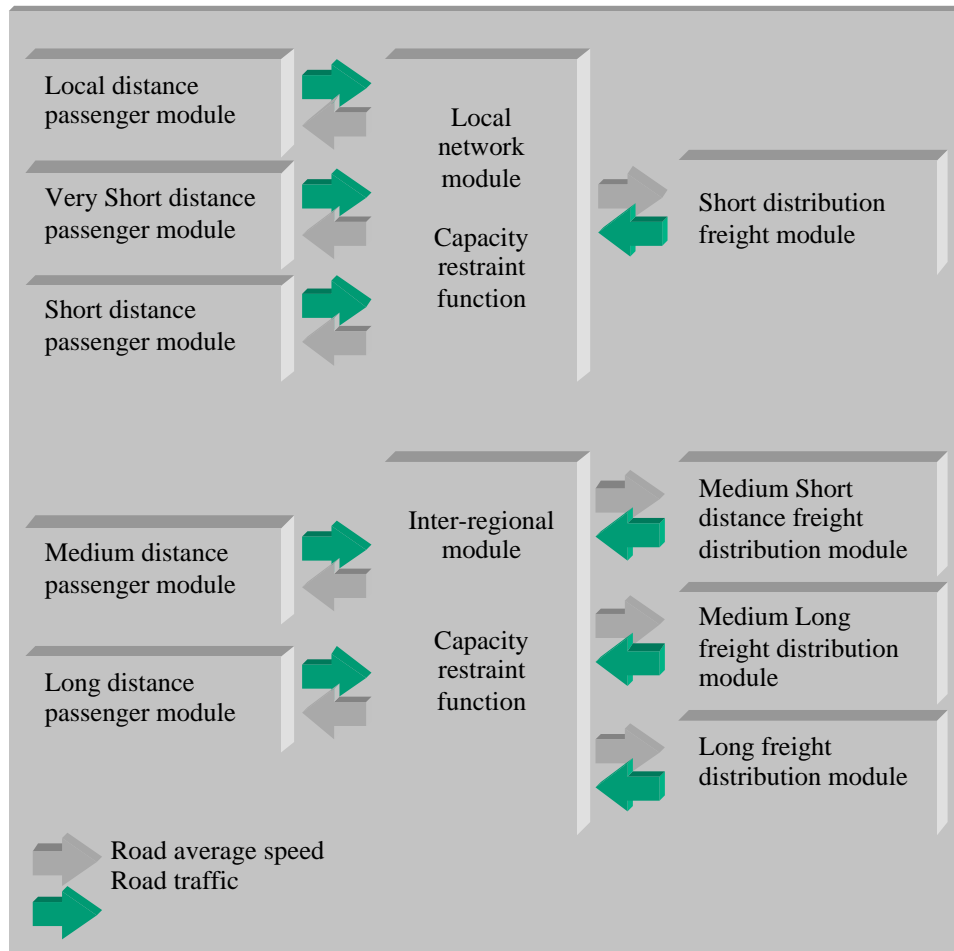


Figure 37: Interaction of passenger and freight sectors with the road network sectors

Two different sectors are devoted to the modelling of road congestion: the local road network sector and long distance road network sector. Each of the sectors simulates the congestion at its own scale. In particular the *inter-regional network* is used by the passenger traffic modelled in the medium and long distance sectors and by the truck traffic modelled in the medium-short, medium-long and long distance freight distribution sectors, whereas the *local network* is used by the traffic modelled in the passenger local, very short and short distance sectors and in the short freight distribution sector. In the two sectors, congestion is modelled using a capacity restraint function, which modifies the average speed according to the capacity of the network and the actual flows.

A road infrastructure sector explicitly simulates the relation between the performance indices (the speed) of the *virtual* links and the actual characteristics of the network (average number of lanes, share of motorways, etc.). The road infrastructure sector starts from the road length data by macro-regions and output the road capacity of the *virtual* links used in the capacity restraint functions.

The general form of the speed -flow function that has been implemented in ASTRA for the road speed is as follows:

$$t = t_0(1 + \alpha (V/Q_p)^\beta) \quad \text{if load} < \text{capacity (eq. 7)}$$

$$t = t_0(1 + \alpha + \beta (1 - 1/(V/Q_p)^\beta)) \quad \text{if load} > \text{capacity (eq. 8)}$$

Where:

- t is the travel time per unit of distance,
- t_0 is the travel time per unit distance under free flow conditions,
- V is the flow,
- Q_p is the capacity of the link,
- α, β, γ are positive valued parameters that govern the shape of the capacity restraint curves.

The greater is the value of α , the greater the reduction of speed with increased congestion. The more by which the value of β exceeds unity; the more non-linear will be the shape of the time curve. The parameter γ is determined by the minimum speed to which the traffic can fall when the flow is greater than the capacity of the road. The more by which the value of γ exceeds its minimum value of zero, the more rapidly will be the descent to the minimum speed as the load exceeds the capacity.

It is important to remember that the transport sub-module is based on a simplified zoning system (either functional or macro regions) and therefore also the road connection among the zones is based on a *virtual* network. Within the ASTRA model, each origin/destination zone pair is connected by a single link that represents all network paths between all geographic zone couples belonging to the two ASTRA zones. In other words the single link that connects each origin/destination zone pair is not to be intended as a corridor (typical of aggregated networks) or as a specific transport infrastructure (a specific motorway between two junctions); indeed it is a virtual connection, whose characteristics are the average values derived by the actual road transport network modelled in the STREAMS model.

6.3.3.5 The road capacity sector

The road capacity sector calculates the road capacity (to be used in the road network sectors) as a function of the length and the quality of the road network by macro-region. Inputs of this sector are the percentage of GDP invested in new road construction by macro-regions and the road km divided by type of road and by macro-regions.

The road capacity sector simulates the road network growth on the basis of the public expenditure. The yearly investment of a given GDP share by macro-region in new road construction determines the increase of road network stock in terms of km and quality. Then the sector derives a growth in road capacity which is passed by to the road network sectors

which in turn predict a growth in the average speed of the road modes, which attracts more cars and truck thus generating more congestion, etc.

Types of road are:

- Motorway,
- Main roads (dual carriageway),
- Secondary roads (single carriageway),
- Local

Road types 1 to 3 are related to the long distance traffic, while type 4 is intended for the local traffic according to the TRA sub-module framework.

(a) Road network length

Calibration data were derived by international statistics and institutional sources (such as Eurostat, ECMT European Conference of Ministers of Transport, IRU International Road Federation, etc.), but unfortunately the statistical data do not differentiate the length of the network by the four categories²⁷. STREAMS data were also available, taking into consideration that the total length of the model network is obviously smaller than the real network and this is more evident for secondary roads. The adopted solution has been to use both ECMT and STREAMS data in a way that guarantees to keep the right overall total:

- Type 1 (motorways) and 2 (main roads) are derived directly from ECMT
- Type 3 (secondary roads) are calculated subtracting the STREAMS local network from the ECMT data for other roads
- Type 4 (local roads) is taken from the STREAMS local network.

Table 22: ASTRA road network km by macro-regions

Macro-regions	Motorway	Dual carriageway	Single carriageway	Local	Total
1	12860	225973	435463	1028	675324
2	11287	50805	979141	1165	1042398
3	13297	150685	741014	1666	906662
4	5296	127320	671817	1400	805833
Total	42740	554783	2827435	5259	3430217

Source: ECMT and STREAMS model

²⁷ Eurostat publications provide motorways data only, ECMT tables provide data for types 1, 2 and 3 and 4 together (i.e. they do not distinguish between local and secondary roads), while IRU data have different level of detail by different countries

(b) The growth rate

The yearly growth rate of the road network length was derived interpolating data from the ECMT trends tables (1985-1992), Transport Statistics Great Britain trends tables (1994) and EU Transport in figures trends tables (1990-1994). Analysing these different sets of data, skipping anomalous data derived from a change in road denomination, the yearly growth rate of the road network length shown in the following table were finally extracted. Specific rates by macro-region were extracted only for motorways, while the rate is unique for the other road categories because no detailed data were available.

Table 23: ASTRA - Growth in the length of roads (1992-1994)

Road type	Macro region 1	Macro region 2	Macro region 3	Macro region 4
1 – motorway	0.8%	2,1%	2,3%	2,5%
2 – dual carriageway	0,2%	0,2%	0,5%	0,4%
3 – single carriageway	0,2%	0,2%	0,5%	0,4%
4 – local	0,2%	0,2%	0,5%	0,4%

Source: TRT elaboration on ECMT, Transport Statistics Great Britain and Eurostat

Growth rates of road length were then smoothed on the basis of the 1994 ratio between of road km and country surface (km²), in order to avoid the unrealistic land coverage ratios due to transport infrastructures. Assuming the smoothing factor, in the base scenario the general growth of length of roads are resumed in the following table.

Table 24: ASTRA length of road network increase by macro-regions(1986-2026)

Macro-region s	Motorway (kms) 2026	Tot. increase	Rest of network (kms) 2026	Tot. increase
1	16 254	+29%	700 389	+7%
2	13 451	+35%	1 090 142	+7%
3	23 202	+100%	1 038 987	+17%
4	10 592	+100%	891 013	+14%
Total	63 499		3 720 532	

(c) Transforming the road network length in road capacity

The road capacity sector produces the road capacity by macro-region for the two road network sectors (local and inter-regional distance). The transformation of the road length into the road capacity is a numerical operation, i.e. the road capacity by macro-region is the one that guarantees both a correct average speed and load elasticity in the capacity restraint functions implemented in the two road network sectors.

For the local network the calculation is straightforward as there is only one type of road: km by local roads (type 4) are converted into capacity for each macro-region. For the long distance network, it is necessary to add up the contribution of the different road types (1, 2 and 3) to get a total long distance capacity for each macro-region. The contribution of each road type is weighted according to the distribution of the vehicles*km calculated by the STREAMS model in the base year 1994 (see the following table).

*Table 25: Distribution of the vehicles*km by macro-regions and type of road*

Macro-regions	Motorway	Dual carriage	Single carriage	Local	Total
1	11 735 200	482 400	3 432 500	1 027 730	16 677 830
2	11 662 300	5 096 700	5 137 500	1 164 880	23 061 380
3	9 930 300	5 950 200	13 537 000	1 666 180	31 083 680
4	4 717 600	2 902 600	15 307 900	1 400 280	24 328 380
Total	38045400	14431900	37414900	5259070	95 151 270

Source: STREAMS model - 1994

Table 26: Weights matrix

Macro-regions	Motorway	Dual carriage	Single carriage
1	0.93	0.01	0.06
2	0.79	0.13	0.08
3	0.67	0.17	0.16
4	0.63	0.20	0.17

6.3.3.6 The local network sector

The local network sector is based on the macro-region zoning system. The input from both the freight and the road capacity sectors is direct (as they all based on the macro-regions and so no transformation is required), while the input from the passenger sectors needs to be filtered in order to take into account the different zoning systems (from functional zoning to macro-region zoning). It is then necessary to define a conversion table to transform cars by functional zones produced by the TRA passenger sectors into cars by macro-regions.

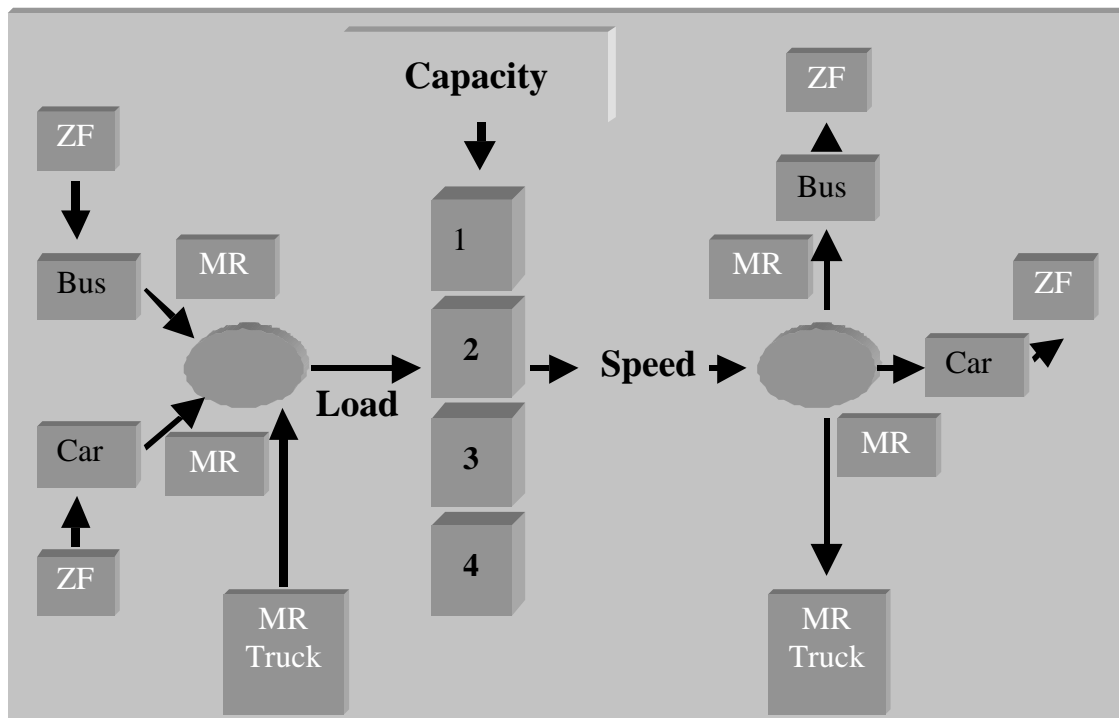


Figure 38: Local road network sector

This conversion table is based on the STREAMS model data and in particular on the distribution of vehicles*km by functional zones and by macro-regions at year 1994. In order to calibrate the capacity restraint functions by macro-regions, average travel times by road modes derived by the STREAMS model at year 1994 are used. In the final vector which represent the total local traffic, all vehicles are homogenised in terms of car-equivalents, i.e. vans and buses are multiplied by a factor according to their occupancy of the road capacity.

6.3.3.7 The inter-regional distance network sector

The general structure of the long distance network sector is similar to the previous one: it calculates the average road speed by macro-regions according to the passenger and freight Inter-regional distance traffic using capacity restraint functions.

The main difference in comparison to the local network module is the dimension of the inputs data: in fact cars and buses produced by the medium and long distance passenger sectors are two-dimension arrays as well as trucks produced by the freight sectors and they have to be reduced to single dimension arrays. Furthermore in the first case (passengers) it is also necessary to change from the functional zoning to the macro-regions system.

Capacity restraint functions by macro-regions are calibrated according to average times derived by the STREAMS model at year 1994, as for the local distance sector.

6.3.4 The calibration process

The ASTRA calibration process was divided in two steps, first the model parameters were adjusted using the stand-alone sub-modules and then an overall fine-tuning calibration was

performed in the ASTRA platform. The reason of this two steps process is due to the high interrelation of the four sub-modules in the ASTRA platform, which made not possible to perform an overall calibration until each sub-module was able to properly model its own patterns.

The TRA stand-alone module was built deleting all interfaces with other sub-modules and therefore it was fed by an exogenous transport demand and not by the REM regional economic module.

6.3.4.1 The STREAMS benchmark model

The STREAMS model has been used as benchmark model in order to define reference patterns for the ASTRA transport sub-module, providing data to calibrate information variables (*parameters*) and initial values for state variables (*levels*), which accumulate information during the dynamic process. Information variables (*parameters*) are the specific transport costs and times by mode, by distance band and by purpose or by freight category. State variables (*levels*) represent the current state of the dynamic system at each time interval; appropriate initial values are necessary in order to avoid model oscillations at the beginning of the evolution process. Results from the STREAMS model have been used in order to check the path of the ASTRA transport sub-module at certain time thresholds, i.e. the STREAMS model base year 1994 and horizon year 2020.

The basic step in this calibration process is the conversion of the STREAMS model results, based on the conventional geographic zoning system, into a format which makes reference to the distance bands and the simplified zoning systems of passenger and freight sectors of the ASTRA model. Data required from the STREAMS model were:

- i. Average transport costs for each of the 5 distance bands by mode and trip purpose in case of passenger and for each of the 4 distance sectors by mode and category in case of freight,
- ii. Average transport times for each distance band or sectors by mode (except road modes),
- iii. Occupancy coefficients or load factors for each of the road modes i.e. car, bus, van or truck,
- iv. Value of time for each trip purpose or freight category,
- v. Average trip length by each distance band or sector.

Most of these data were directly extracted from the STREAMS model, however the calculation of the transport costs and times, (i & ii) above, involved the zone conversion processing (details are reported in the technical appendix).

6.3.4.2 Elasticity tests

Elasticity parameters were tuned using the stand-alone model and each purpose/category for each distance band sector was analysed separately testing the transport demand reaction at the year 1994 and at the 2026 year. Logit model parameters were calibrated in order to achieve model elasticities within an acceptable range. Results of the elasticity tests are summarised in the following tables.

Table 27: Passenger Time and Cost Elasticity

Sector	Mode	Scope	Cost elasticity	Time elasticity
Local	Bus	Business	-0,07	-1
	Car		-0,05	-0,13
	Bus	Personal	-0,08	-0,9
	Car		-0,03	-0,09
Very Short	Bus	Business	-0,51	-0,64
	Car		-0,23	-0,2
	Bus	Personal	-0,33	-0,12
	Car		-0,12	-0,04
Short	Bus	Business	-0,56	-0,12
	Car		-0,16	-0,04
	Bus	Personal	-0,78	-0,13
	Car		-0,15	-0,05
Medium	Bus	Business	-0,07	-1,4
	Car		-0,01	-0,05
	Bus	Personal	-0,31	-1
	Car		-0,03	-0,16
	Bus	Tourism	-0,3	1,3
	Car		-0,03	-0,3
Long	Train	Business	-0,74	-0,64
	Car		-0,42	-0,6
	Train	Tourism	-0,52	-0,53
	Car		-0,2	-0,23

Table 28: Freight Time and Cost Elasticity

Sector	Mode	Scope	Cost elasticity	Time elasticity
Medium Short	Train BK	Bulk	-0,21	-0,64
	Truck BK		-0,15	-0,12
	Train UD	Unitised	-0,35	-1,29
	Truck UD		-0,01	-0,02
Medium Long	Train BK	Bulk	-0,23	-0,72
	Truck BK		-0,3	-0,32
	Train UD	Unitised	-0,39	-0,95
	Truck UD		-0,07	-0,07
Long	Train BK	Bulk	-0,06	-0,4
	Truck BK		-0,4	-0,58
	Train UD	Unitised	-0,47	-0,82
	Truck UD		-0,39	-0,48

Results are within a reasonable range and, in general, parameters were tuned so that elasticities in the longer distances passenger and freight sectors were higher than in the shorter. Great

attention was paid to the cost elasticity considering its relevance in terms of pricing policy packages. In some distance bands, higher elasticities resulted for those modes of transport having minor modal shares (i.e. bus for medium distance passenger sector).

6.3.4.3 The validation data

Passenger*km and ton*km by mode of transport regularly published by Eurostat-DGVII were used to validate the results of the TRA stand-alone model. The following tables show the comparisons at year 1994 for passenger and freight data. In general, the TRA sub-module reproduces very well the statistical data available. A minor over-estimation of the passenger*km data is due to the fact that the sub-module is fed by the STREAMS transport demand which covers all trips and includes also very short distance trips. With reference to passengers, the ASTRA air share of passenger*km is lower than the observed data and the STREAMS data and this is because the long distance sector average distance is common to all modes of transport competing in this sector and then it is a little bit too short for air trips.

On the freight sectors, the ASTRA ton*km are similar to the STREAMS model and both are smaller than the observed data from Eurostat, which include double counts of national data. In the modal split, train (which includes also inland waterway) modal share is lower than in the observed and STREAMS data. The following tables present the comparison of the TRA stand-alone trend through time with the Eurostat data for the time period 1990-1997.

Table 29: Passenger*km by mode (1000 millions, year)

Year 1994	ASTRA	Eurostat	STREAMS
CAR	4 006	3 584	3 888
BUS	480	334	388
TRAIN	257	311	280
AIR	105	254	242
TOTAL	4 848	4 483	4 798
SLOW	240	231	265
GRAND TOTAL	5 088	4 714	5 063

Source: Eurostat-DGVII *EU Transport in figures. Statistical pocketbook*. 1999
STREAMS Final deliverable D8D10, 1999

Table 30: Passenger modal split

	Modal split (passenger*km)			Modal split (volumes)	
Year 1994	ASTRA	Eurostat	STREAM S	ASTRA	Eurostat
CAR	78,8%	76%	76,8%	57,1%	56,7%
BUS		7,1%	7,7%	9,1%	9,6%
TRAIN	5%	6,6%	5,5%	1,8%	1,6%
SLOW	4,7%	4,9%	5,2%	32%	32%
AIR	2,1%	5,4%	4,8%	0,1%	0,1%

Note: the underestimate of air passenger*km is due to the adoption of a single weighted average distance for all modes of transport in the longer distance band sector; this average distance is obviously lower than the specific value observed for air mode.

Source: Eurostat-DGVII *EU Transport in figures. Statistical pocketbook. 1999*
STREAMS Final deliverable D8D10, 1999

Table 31: Tons*km by mode (1000 millions, year)

Year 1994	ASTRA	Eurostat	STREAMS
TRUCK	1 094	1 094	1 011
TRAIN	300	331	197
SHIP	699	1 012	822
TOTAL	2 093	2 437	2 030

Note: the underestimate of ship ton*km is due to the adoption of a single weighted average distance for all modes of transport in the longer distance band sector; this average distance is obviously lower than the specific value observed for ship mode.

Source: Eurostat-DGVII *EU Transport in figures. Statistical pocketbook. 1999*
STREAMS Final deliverable D8D10, 1999

Table 32: Tons by mode (millions, year)

Year 1994	ASTRA	Eurostat	STREAMS
TRUCK	10 708	10 700	11 017
TRAIN	762	1 300	1 019
SHIP	520	500	717
TOTAL	11 991	12 500	12 753

Source: Eurostat-DGVII *EU Transport in figures. Statistical pocketbook. 1999*
STREAMS Final deliverable D8D10, 1999

Table 33: Freight modal split

	Modal split (tons*km)			Modal split (volumes)		
Year 1994	ASTRA	Eurostat	STREAM S	ASTRA	Eurostat	STREAM S
TRUCK	52,3%	44,9%	49,8%	89,3%	85,6%	86,4%
TRAIN	14,3%	13,6%	9,7%	6,4%	10,4%	8%
SHIP	33,4%	41,5%	40,5%	4,3%	4%	5,6%

Source: Eurostat-DGVII *EU Transport in figures. Statistical pocketbook. 1999*
STREAMS Final deliverable D8D10, 1999

Table 34: Passenger*km trend 1990-1997 (1000 millions, year)

	Car		Bus		Train		Slow		Air	
Year	ASTRA	Eurostat	ASTRA	Eurostat	ASTRA	Eurostat	ASTRA	Eurostat	ASTRA	Eurostat
1990	3 798	3 302	448	369	248	322	245	220	94	204
1994	3 998	3 584	467	334	265	311	250	231	107	254
1995	4 050	3 665	471	384	270	311	251	233	111	274
1996	4 102	3 710	476	386	275	320	253	-	115	290
1997	4 154	3 787	480	393	280	323	256	-	119	322

Source: Eurostat-DGVII EU Transport in figures. Statistical pocketbook. 1999

Table 35: Tons*km trend 1990-1997 (1000 millions, year)

	Truck		Ship		Train	
Year	ASTRA	Eurostat	ASTRA	Eurostat	ASTRA	Eurostat
1990	966	929	618	919	282	363
1994	1 094	1 094	699	1 012	300	331
1995	1 130	1 145	722	1 070	305	335
1996	1 168	1 151	747	1 070	309	332
1997	1 206	1 202	773	1 124	314	356

Source: Eurostat-DGVII EU Transport in figures. Statistical pocketbook. 1999

6.3.5 Interaction with other sub-modules

The flow of information among the different sub-modules of the ASTRA system dynamic platform is extremely important. Through the exchange of input and output among the sub-modules it become possible to model the reciprocal impacts and the feedbacks among the different sectors. The transport sub-module is in the core of the whole system as it provides data to all the other sub-modules: macroeconomic, regional economic and environmental. Main inputs of the transport sub-module derive from the regional economic sub-module.

In brief the main outputs of the transport sub-module are:

- Transport generalised passenger times by purpose and by distance band to the regional economic sub-module;
- Transport generalised freight costs by category and by distance band to the regional economic sub-module;
- Road vehicles traffic by distance band to the environmental sub-module;
- Total mileage by mode of transport to the environmental sub-module;
- Total passenger travel time savings to the macro-economic sub-module;
- Total passenger travel cost savings to the macro-economic sub-module;
- Total freight cost savings to the macro-economic sub-module;
- Transport infrastructure expenditure to the macro-economic sub-module.

The main inputs of the transport sub-module are:

- Transport demand by purpose and by distance band from the regional economic sub-module.
- Fuel transport costs from the environmental sub-module.
- Yearly GDP growth rate from the macroeconomic sub-module.

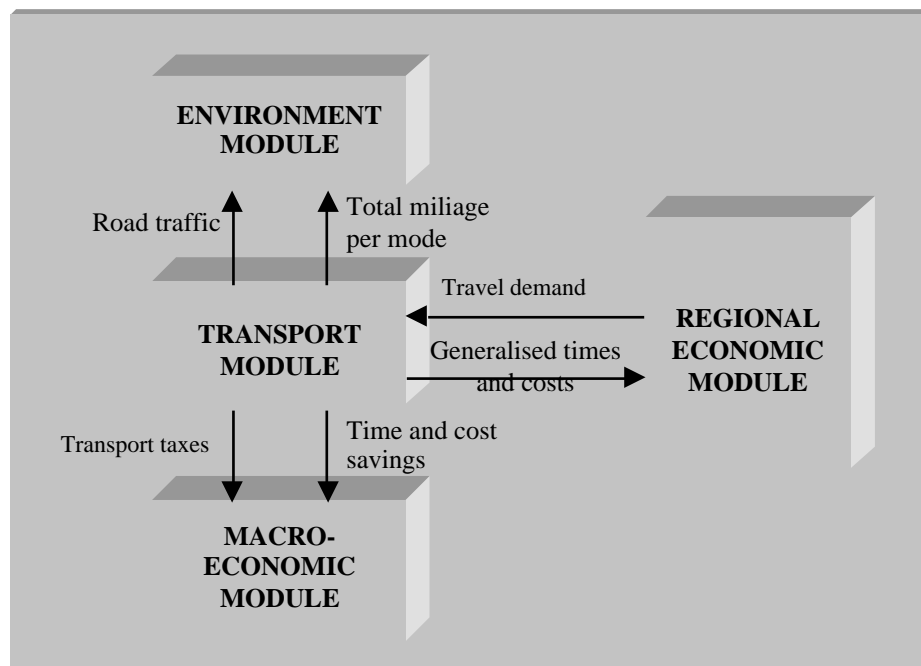


Figure 39: Interaction among the transport sub-module and the other sub-modules (aggiungere un link MAC-TRA)

6.3.5.1 Interface TRA MAC

Information handed over to the macroeconomic sub-module are total travel time savings, distinguishing between leisure and business time, and total travel costs savings, distinguishing between passenger and freight. Generalised time (and cost) savings are calculated as the "number of trips" x "change in duration of trip compared to previous dt ". In brief it might be said that these time (and cost) savings are calculated on the basis of trips that are actually undertaken at time dt and that have a shorter duration in comparison to the previous dt .

6.3.5.2 Interface TRA REM

The information passed to the regional economic sub-module consists of generalised times matrices differentiated by trip purpose and by distance band for passenger and generalised costs matrices by category for freight and by distance band. For each o/d pair, the generalised time (or generalised cost) is a value representing the composite time (or cost) using all modes of transport available between the two zones and is used by the regional economic sub-module to distribute passenger (or freight) traffic among the zones. In dimensional terms, this interface

is quite straightforward as the two sub-modules adopt the same functional zoning system respectively for passengers and freight.

6.3.5.3 Interface TRA ENV

The interface between the transport sub-module and the environment sub-module adds up the data by trip purposes and freight categories and provides the road vehicle traffic volume by distance bands and the total mileage by transport modes. Both variables are needed to calculate the transport activity related impacts.

6.4 Environment Sub-module (ENV)

6.4.1 Aim of the ENV Sub-module

The objective of the ASTRA environment sub-module is to calculate the environmental burdens caused by transport in the EU respectively in the macro regions or functional zones of the ASP and to provide information for the assessment of the effects of these burdens on the whole economy and the development of regions. For this purpose three kinds of environmental impacts should be treated by the environment sub-module:

- Global Impacts,
- Impacts on Human Health and
- Ecological Impacts.

Transport can cause environmental disturbance in two main ways. First there are the **transport activity related effects (TAR)**. E.g. noise or gaseous emissions from the combustion of fuel belong to this category. The second are the **product transformation related effects (PTR)**. This means burdens which occur during production, maintenance and disposal of transport infrastructure as well as of vehicles. E.g. the use of fresh water and platinum for the production of vehicles belong to this category. Together transport activity related effects and product transformation related effects form the **life cycle effects** of transport.

Different environmental burdens are affecting different spatial scales: global, regional and local. The estimations of global environmental impacts are simple to integrate in a system dynamics model, because there is no spatial dispersion for the effect to be quantified. But regional or even local effects will be more difficult to integrate them in a system dynamics model. Integrating these effects increases complexity of the model or needs simplification and therefore might decrease accuracy of the model.

6.4.2 Basic Structure and Future Expectations

The ENV consists of a set of more than 40 models. Most of the models are based on the macro regions zoning system. Only for passenger transport some models produce values for functional zones and for macro regions. The ENV provides data on a yearly time basis.

In the following a brief overview is given on the impacts of transport that are assessed within the ENV. The number of assessed impacts is restricted to the most important impacts, because of the size restrictions given by the software and the project scope. Most of the impacts can be directly quantified with indicators e.g. emission quantities for global impacts. But for some impacts only *potential risk indicators* can be applied, because the necessary variables for an accurate modelling approach can not be included within the model (e.g. accurate spatial representation). This type of indicators should give a hint on the potential environmental risk performed by a transport activity.

6.4.2.1 Global Impacts

The most important global impact is the greenhouse effect. Transport contributes according to different studies with a share of 20-40% to this effect. Most studies only tackle the transport activity related burdens, but also the product transformation related burdens contribute with a non-negligible share to this effect. The most important greenhouse gas, which is also emitted by transport, is carbon dioxide (CO₂). The emissions of CO₂ can be calculated as the sum of TAR, PTR of vehicles and PTR of fuel consumption. Therefore the emissions of CO₂ depend on the development of the traffic volume, the emission factors respectively the fuel consumption and the production factors²⁸. The Kyoto protocol stipulates the reduction of CO₂ emissions for the EU15. Most European nations aspire also to oblige transport to contribute to the CO₂ reductions of their country. However the expectations are that transport growth will overcompensate the technical improvements in efficiency such that CO₂ emissions from transport will keep on growing.

The second global impact is the resource consumption during the life-cycle of transport infrastructure and vehicles. Resources, which might be interesting for becoming an indicator, are steel, other metals and precious metals, energy consumption, fresh and waste water. E.g. in 1994 the production of one car in the German car industry consumed 322.000 litres of fresh water. At present there is no indicator for resource consumption integrated into the model. If the file size restrictions can be overcome fresh water consumption or use of precious metals would be adequate indicators for resource consumption.

Another global impact is the ozone depletion. Recent research results show that emissions of air transport probably have an effect on global stratospheric ozone depletion. If these findings become more plausible and the share is noticeable it should be integrated in the assessment of global impacts of transport. As for air transport a strong increase is expected the contribution to ozone depletion will increase, while for other relevant emissions production bans come into force during the next decade. So, the non-transport effects will decrease in the long-run, such that at least the share but probably also the absolute effect of transport will grow.

6.4.2.2 Impacts on Human Health

Human health is affected directly and indirectly by transport. The most important direct effect are the traffic accidents. They depend on the traffic volume, speed and infrastructure characteristics. In ASTRA they are estimated dependent on the characteristics of the different distance bands and on characteristics of the legal system within the macro regions. Expectations are that accident risk further decreases but with a decreasing rate.

Indirect effects on human health are processed via the impact path of gaseous emissions (emission, dispersion, concentration, effect). On regional scale nitrogen oxides (NO_x) are relevant, because they are precursors of photochemical ozone formation and also NO_x itself affects the human health. The emissions of NO_x are strongly reduced by catalytic converters, such that this problem will diminish significant in the next decades.

²⁸ Production factor means the quantity of emitted CO₂ during the construction process of one new vehicle.

The second indirect effect on human health to be considered is the impact of emissions of particulate matter. They have to be considered on a regional or even local scale, because they effect the local population. Estimations for Germany come to the conclusion that about 25.000 deaths per year were caused by particulate matter with a diameter of less than 10 μm (PM10) emitted from transport.²⁹ In case of PM10 not the absolute quantity of emissions is the relevant figure but the concentration and the number of people which are affected by these concentrations. The estimation of this impact should consider the background concentration in the examined functional zone. The real impacts will be difficult to estimate within ASTRA because the model does not include information on local distribution of the transport network and the population. Therefore a potential risk indicator, which considers the average population density has to be applied for impact assessment. The future development of this effect is uncertain. Currently it is argued by some experts that the available cleaning technology for particulates even enforces the problem as it reduces particles with greater diameter and increases the number of harmful particles with a diameter of 100 to 200 nanometers.

For estimating the noise emissions it is also necessary first to calculate the noise level with dependence to the traffic volume and the infrastructure characteristic. Second the relationship to the affected population has to be modelled. This can again be done by a potential risk indicator, which considers the population density in the examined region or region type. In the current version the noise model is not included. It should be considered in future attempts to improve the model. This is also valid for some other gaseous emissions, which have an effect on human health but are not as important as the aforementioned (e.g. VOC). Also there might be the necessity to invent new kinds of emissions into the model, which might become of major importance because of the technical development during the long-term forecasting period of ASTRA (e.g. emissions of platinum).

6.4.2.3 Ecological Impacts

The sealing of the surface by transport infrastructure leads to a total destruction of the ecological functions of the sealed ground e.g. the permeability for rain. Hence the floorspace of the infrastructure presents an appropriate indicator for this effect. It can be calculated by the length of the infrastructure multiplied by their specific width, which depends on the type of infrastructure. To calculate the length of infrastructure the infrastructure capacity variable of the transport sub-module has to be transformed into a length variable. The effect of sealing the ground also occurs because of constructing new business or private buildings. Both might in the long run also be affected by the changes in transport policy and therefore the indicator for the sealed surface should integrate both the floorspace of new infrastructure as well as the floorspace of new buildings.

Indicators that reflect the environmental sensibility of protected areas and of recreation areas should be implemented in the model. In both cases only potential risk indicators can be included within the model. They should consider the share of floorspace of the areas within certain functional zones and the transport variables like infrastructure length or traffic volume.

²⁹ UPI (1997)

Because of the project scope the described indicators for ecological impacts are not (yet) implemented in the ENV.

6.4.2.4 Impact Assessment

Given the described impacts and their corresponding indicators the following four methods of impact assessment can be applied:

- Quantitative comparison of indicator values between different scenarios. In principle, this can be done with every environmental indicator. But there may occur distortions in the assessment, because environmental damages mostly increase non-linear with increasing quantities.
- Comparison of indicator values with environmental goals e.g. reduction targets for CO₂ emissions. This method is appropriate for system dynamics models, because they automatically provide the necessary data: the value of the indicators and the time path of the values. One prerequisite is the existence of an agreed environmental goal like the 25% reduction target of CO₂ emissions between 1990 and 2010 in Germany.
- Evaluation of externalities e.g. by assigning cost values for environmental or health damages that are not performed with the inclusion of market transactions. In this case, the externalities can be compared with the benefits of transport or can be used to assess the changes in the welfare position of the EU member countries.
- Calculation of defensive costs. These are costs that are paid by the users of transport (e.g. material damages of road accidents) and therefore are included in market transactions. Eventually these costs do not increase welfare. They are paid to dispose of damages and to reach the same level of welfare as before the damage occurred.³⁰

6.4.3 Implementation of the Environment Sub-module (ENV)

The ENV is the only sub-module whose development is completely switched to the Vensim software. However, the Vensim-ENV is linked together with the core itthink ASTRA model to form the full ASTRA model in Vensim. For this purpose the equations of the core itthink 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) have to be implemented in Vensim manually.

The logical structure of the ENV described in the previous section 6.4.2 is implemented in the ASP by structuring it into several Vensim views. Each view represents a model of one of the following types:

- Vehicle fleet models for passenger cars (PC), buses, light duty vehicles (LDV), heavy duty vehicles (HDV).

³⁰ LEIPERT (1989)

- Purchase model of car fleet.
- Models for gaseous emissions of CO₂, NO_x, PM for the different transport modes PC, buses, freight road (LDV, HDV), train, ship and air.
- Detailed accidents models for road transport and rough accident models for other modes.
- Fuel consumption model respectively fuel tax model.
- Input of Cost Values.
- Model for estimation of externalities.
- Model for calculation of defensive costs.

The logical structure of the ENV is given in the following figure 40.

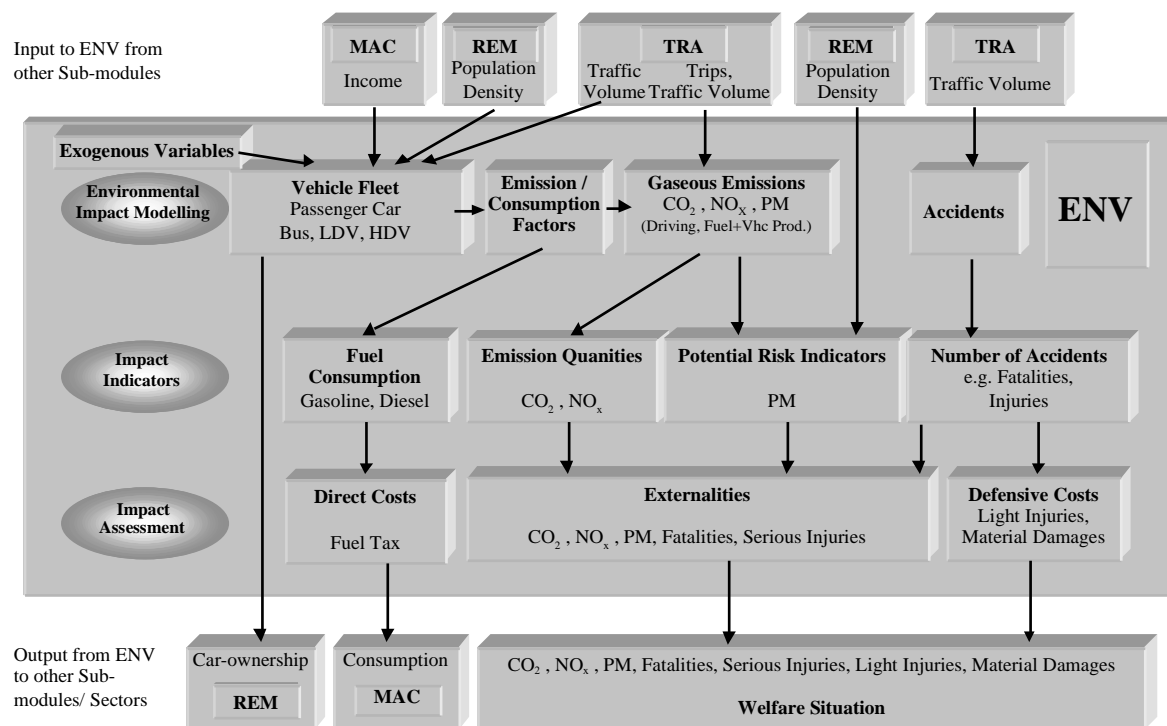


Figure 40: Structure of the Environment Sub-module (ENV)

6.4.3.1 Modelling Gaseous Emissions of Road Transport

The main input stream of information for the calculation of gaseous emissions within the ENV is transferred from the transport sub-module in terms of traffic volume respectively vehicle kilometres travelled and trips. At the first step in the ENV the information is used to model environmental burdens that are in the second step expressed by environmental indicators e.g. emission quantities. The third step is to assess the impacts of the burdens. This can be done by estimation of externalities. The fourth step is to pass the resulting indicators onto other sub-modules or to use them to adjust the levers of certain policy measures.

For the calculation of emission quantities four distinct sources of emissions are considered:

- Hot emissions (HOT) that occur because of the driving activity.
- Cold start emissions (CSE) that are emitted during the warm up phase of trips starting with cold engine.
- Fuel production emissions (FPE) that escape during extraction and production of the consumed fuel.
- Vehicle production emissions (VPE) that are emitted during the manufacturing process of the new vehicles.

The described structure of the model for gaseous emission is shown in figure 41. Similar structures are implemented for all road means.

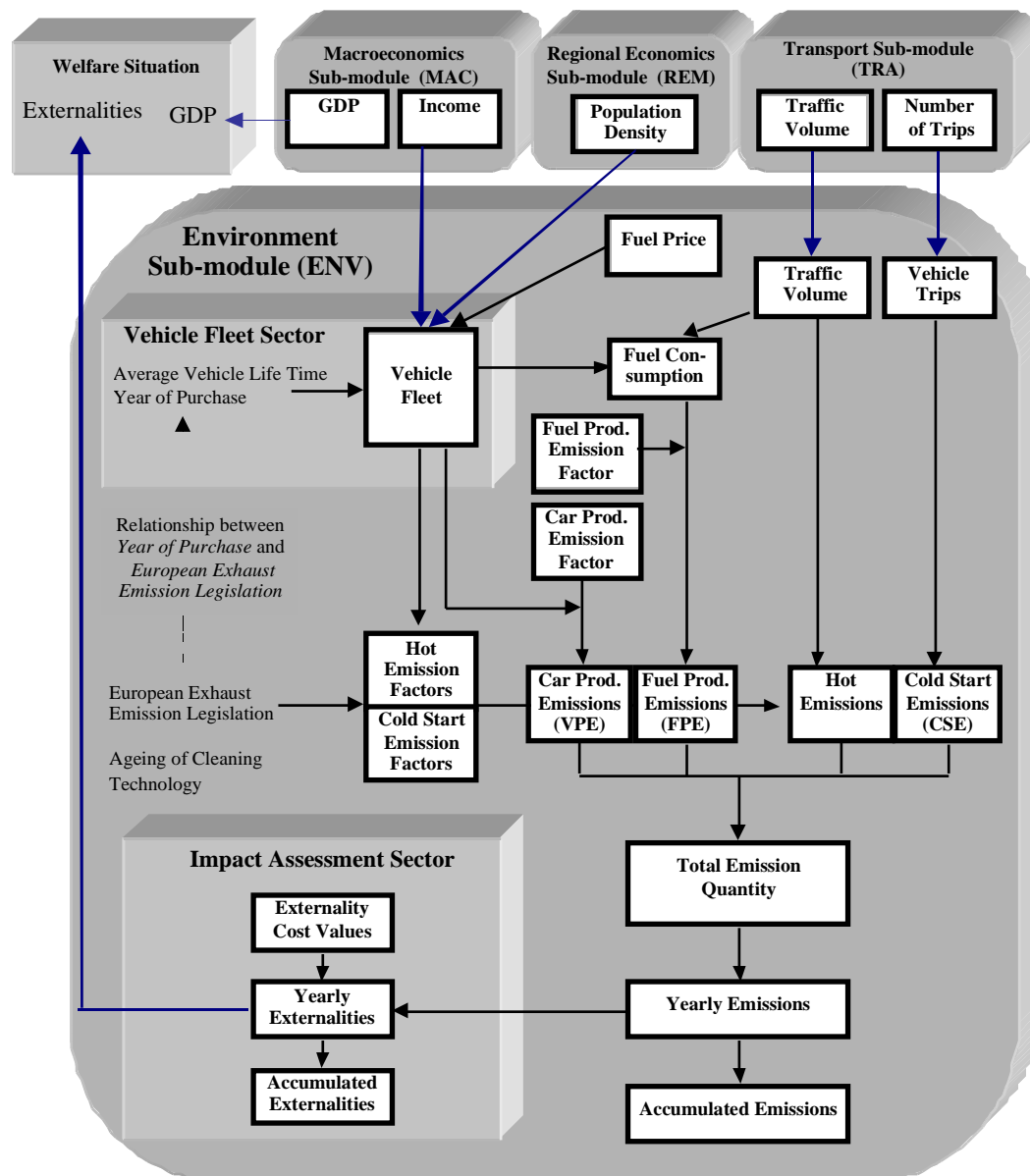


Figure 41: Structure of the Model for Gaseous Emissions of Cars in the ENV

(a) Vehicle Fleet Model

Emissions from road transport activities depend on the traffic volume and the composition of the vehicle fleet that is actually in use for driving the traffic volume. The traffic volume is calculated within the TRA. The development of the composition of the vehicle fleet is included within the ENV. The vehicle fleet is distinguished into vehicle categories with approximately homogenous emission patterns. For example, it is obvious that a small gasoline car with 1 litre of cubic capacity is emitting totally different quantities and also qualities of emissions than a diesel truck. To consider the different emission patterns there are introduced three levels of categorisation (for detailed description see annex 9.3).

The first level provides a differentiation into five vehicle types: gasoline passenger cars (GPC), diesel passenger cars (DPC), light duty vehicles (LDV), heavy duty vehicles (HDV) and buses. It has to be discussed if the share of emissions by mopeds or motorcycles is of such a relevant size that it is necessary to include these categories within the emission calculation. For example this might be the case in the local distance band of South European regions.

The second level is only relevant for passenger cars. It classifies GPC and DPC into classes with different cubic capacities. Gasoline cars are distinguished into three classes of cubic capacity (less than 1,4l; 1,4l to 2,0l; more than 2,0l) and diesel cars into two classes (<2,1; >2,0l). This classification corresponds to European exhaust emission legislation categories and is also applied in other EU projects e.g. MEET, COPERT, which makes it simple to apply results of these projects.³¹

On the third level the vehicles are distinguished by the emission legislation to which they belong. This is mainly indicated by the year in which a vehicle is purchased. Roughly spoken the relevant categories of emission legislation are Pre-Euro-Standards like ECE 15/03, EURO I, EURO II, EURO III and further future standards. For instance, a road vehicle is described by the three characteristics: *gasoline passenger car*, *cubic capacity less than 1,4 l* and *EURO I emission standard*. This categorisation determines that this vehicle emits 0,1845 g NO_x per km, while it is driving on the ASTRA local distance band. That means, the vehicle fleet model and the system of ASTRA distance bands determines the values of the emission factors, which are actually taken for emission calculation at a certain point of time.

The implementation of a vehicle fleet model in itthink is explained for the bus vehicle fleet.³² This fleet is only further categorised on the third level into five categories for different emission legislation (PreEuro, EURO1, EURO2, EURO3, EURO4). For the model of the bus vehicle fleet two different sets of input data are needed:

- New registration of buses in EU countries between 1973 and 1985 as initial values.
- Stock of buses in EU countries between 1986 and 1995 for calibration purposes.

The first step of the model development for the bus vehicle fleet is the calculation of the fleet for the base year, which is the year 1985. For this purpose the yearly number of new registered buses in a certain time period before the base year are needed. The length of the time period depends on the average life time of a new bus. For Germany the average life time in the period 1970 to 1985 was between 11,7 and 12,2 years.³³ That means, data of new bus registrations in the EU from at least 1974 until 1985 are needed.

The bus vehicle fleet is modelled as a so-called conveyor, which is a special kind of stock that is directly provided by the itthink software while in Vensim it has to be modelled explicitly.

³¹ HICKMAN et al. (1997), EEA (1997)

³² A similar approach is adopted for the fleets in the Vensim model.

³³ KBA (1996)

A conveyor behaves like a conveyor belt that is able to load a certain quantity of material at a certain point of time, to keep the material for a certain time period and afterwards to unload it into the environment or the next process step if the conveyor is part of a sequence of process steps. With such a conveyor the situation in the base year can be included in the model as a dataset of initial values, one for each slot of the conveyor. The values for the single slots are the numbers of new registered buses in the EU from the year 1973 to 1985. This is shown in figure 42:

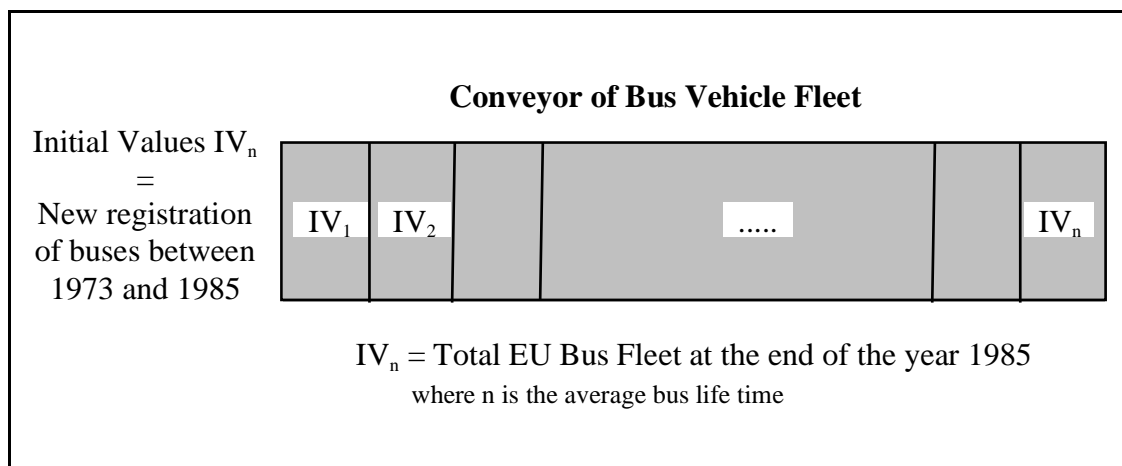


Figure 42: Conveyor for Bus Vehicle Fleet

The initial values for the bus vehicle fleet are derived from the bus stock in EU15 between 1973 and 1985 combined with the average life-time of a bus in Germany. For calibration purposes the number of the bus stock in the EU between 1986 and 1995 is used. Both can be taken from ECMT statistics.³⁴

The future development of the bus fleet in the model depends on two influences. The new registrations of buses and the average life time of a bus. If we treat both influences as exogenous then the model estimates the development of the fleet in the calibration period with a deviation of less than 3%. In the further development the new registration of buses is endogenized by linking it with the demand of bus trips respectively bus traffic volume, which is calculated within the TRA. The described interrelationships are presented in the effect diagram in figure 43.

³⁴ ECMT (1998)

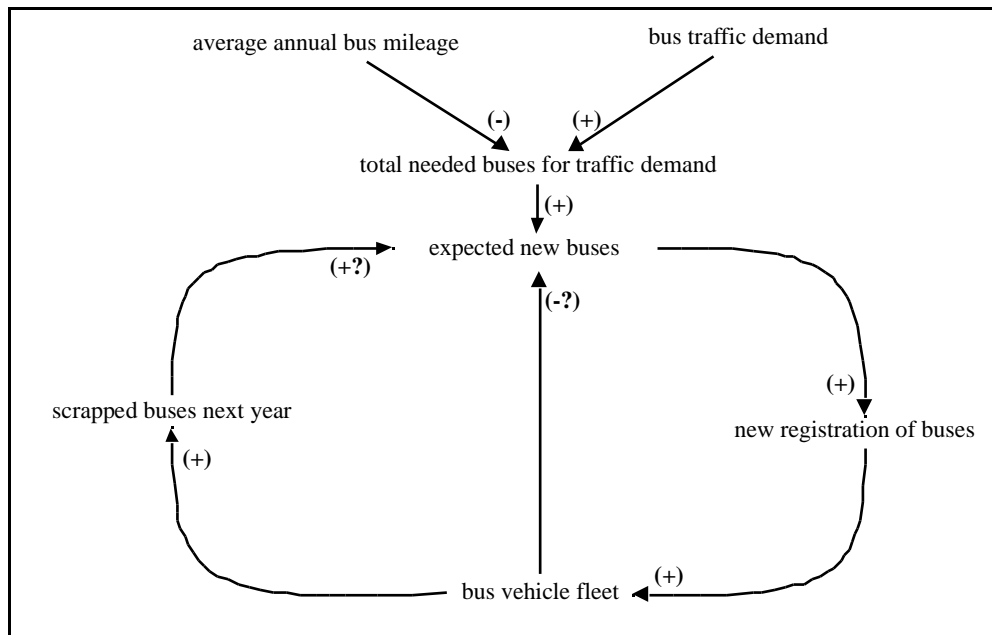


Figure 43: Effect Diagram for Calculation of New Registration of Buses

(b) Determination of Number of Cars in the Car Vehicle Fleet

In contrast to the other road vehicle fleets the car vehicle fleet is not driven by the demand for traffic, but by endogenous influences (income, population density) and exogenous influences (fuel price). The model consists of two main parts:

- a purchase model for the change of the number of cars in the fleet and
- a categorisation model for the distribution of new cars onto the five cubic capacity categories.

The model provides the linkage between the macroeconomic influences and the car-ownership in the REM. So, the vehicle fleet will drive respectively will influence the development of car-ownership. That means the following relationship holds for car-ownership:

$$\text{Car-ownership CO} = f(\text{vehicle fleet, population})$$

The models for the estimation of car-ownership and population are described within the REM (section 6.2).

[i] Purchase Model for Development of Passenger Car Vehicle Fleet

Actually it is not the whole vehicle fleet that is calculated by the model but it is the changes of the fleet between two time-steps that are caused by endogenous influences like personal income, population density and exogenous influences like fuel price. In the past growing disposable personal income was the major source for the increase of the car vehicle fleet.

While the increase in density has a counteractive effect. For regions with higher population the vehicle fleet is smaller than for low densely populated regions with the same population. This leads to the following basic equation:

$$VF = el_Inc * INC + el_PD * PD + el_FP * FP \quad (eq. 9)$$

where: VF = change of vehicle fleet
 el_Inc = fleet elasticity for income changes (>0)
 INC = change of income
 el_PD = fleet elasticity for changes of population density (<0)
 PD = change of population density
 el_FP = fleet elasticity for fuel price changes (<0)
 FP = change of fuel price

A first estimate for the applied elasticities is taken from the “best guess” of Johanssen/Schipper.³⁵ In fact they present a range for these fleet elasticities and it is a matter for calibration to figure out the elasticity values that produce the best fit compared to real values. For this purpose the Vensim optimizer can be applied which calculates specific elasticities for the four ASTRA macro regions (results are presented in Annex 9.3).

[ii] Composition of the Car Vehicle Fleet

The car vehicle fleet is categorised into 6 different emission legislation categories (only 5 for diesel cars) and 5 different cubic capacity categories such that finally 28 car categories are considered in the model. The assignment of new cars to the legislation categories depends on the point of time when the car is purchased. For the assignment of new cars to the cubic capacity categories the cubic capacity assignment model (CCAM) is applied. It consists of two levels.

On the first level 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, which mostly belong to this cubic capacity category.

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 (for more detailed description see Annex A 12.3).

³⁵ JOHANSSEN/SCHIPPER (1997)

(c) *Emission Factors and Transport Activity Related Emissions*

The main determinants for the quantity of hot emissions from transport activities are the traffic volume and the hot emission factors. The corresponding equation for calculating the emission quantity (EQ in kg) reads as follows:

$$EQ = (VKT * EF) / 1000 \quad (\text{eq. 10})$$

where: EQ = emission quantity [kg]
 VKT = vehicle kilometres travelled [vehicle-km]
 EF = emission factor [g/km]

The hot emission factors are depending on a complex set of characteristics e.g. speed, road characteristic, vehicle characteristic, altitude. As in ASTRA a functional transport network represented by distance bands and categorised network types is used a vehicle kinematics approach (bottom-up calculation) will not be feasible. Instead of a pure bottom-up approach an approach with emission factors differentiated by **driving patterns** according to the distance bands and by **vehicle categories** will be applied.

Integrating different driving patterns and different vehicle categories leads to equation 11, which is a more detailed specification of equation 10:

$$EQ = \sum_{DB} \sum_{VC} VKT_{DB} \times EF_{DB,VC} / 1000 \quad (\text{eq. 11})$$

where: EQ = emission quantity [kg]
 VKT = vehicle kilometres travelled [vehicle-km]
 EF = emission factors [g/km]
 DB = ASTRA distance band (5)
 VC = ASTRA vehicle category (28)

Basic data for calculating the actual emission factors will be taken from the Swiss/German Handbook of emission factors (HB-EFAC, see Annex A 12.3).³⁶ This handbook represents a database of emission factors differentiated into vehicle categories, vehicle cleaning technologies according to exhaust emission legislation, traffic situations, speed and slope. Data is available for the years 1980 to 2020. In case of passenger cars with catalytic converters it can be considered that the cleaning effects of the converters decrease during their lifetime. Data was derived from vehicles in Switzerland and Germany. But as the data corresponds to the European emission legislation it could also be applied to other countries if the country specific structure of the vehicle fleet is taken into account. Additional information about emission factors can be taken from the programme COPERT II (Computer Programme to Calculate Emissions from Road Transport).³⁷ Basically COPERT II proposes the same functional as

³⁶ BUWAL/UBA/infras (1995), BUWAL/UBA/infras (1999). The applied emission factors are shown in Annex A 12.3.

³⁷ EEA (1997)

given in equation 10. In addition, there are functionals given, which describe the dependency of the emission factors from the vehicle speed.

With the described vehicle categorisation the total number of 142 vehicle categories included in HB-EFAC will be reduced to 28 vehicle categories for cars, 5 each for buses, HDV, gasoline and diesel LDV, which will be modelled within ASTRA. So, 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.

The Combustion of fuel in vehicle engines depends on the conditions of the engine and on the ambient characteristics. If the engine works at a temperature below its normal working temperature additional emissions occur. These extra emissions are the so-called cold start emissions (CSE), which can be added upon the normal emissions of each trip. They depend on engine characteristics like fuel type of engine, cubic capacity and cleaning technology. Especially cars with catalytic converters are driving with higher emissions per km than when they are driving at their working temperature. All these characteristics are considered within the ASTRA environment sub-module. The cold start emissions depend also on trip characteristics, especially the speed during the cold start phase. This influence is not considered in the model. Ambient temperature and ambient humidity influence the cold start emissions. Both effects are not considered within the model. Therefore the applied equation to calculate the extra cold start emissions reads as follows:

$$EQ_{ColdStart} = \frac{PT}{VC} \times Share_{VC} \times EE_{ColdStart,VC} \quad (\text{eq.12})$$

where: PT = total number of passenger trips

EE = extra emissions per trip (for details see Annex A 12.3)

VC = ASTRA vehicle category (28)

For all emission quantities there are calculated yearly values and accumulated values. The accumulated values are especially important for irreversible impacts and for as it were irreversible impacts, because of very long residence times like for CO₂ emissions that stay in the atmosphere for about 100 years.

(d) *Production Factors and Production Emissions*

Production factors are used to calculate the environmental burdens that are caused by the production of fuel (FPE) and by the production of vehicles (VPE). The production of fuel causes gaseous emissions in several ways. Four of them are taken into account in the fuel production emission calculation within the environmental submodule. These are extraction of crude oil from the ground, transportation of crude oil to the refinery, refining process and transport of fuel (e.g. gasoline, diesel) to the end-user. Data for each of the emission sources as well as aggregated data over the four sources during the fuel production process can be taken from the MEET deliverable 2 “Fuel and Energy Production Emission Factors”³⁸. The

³⁸ LEWIS (1997)

emission factors can be transformed into quantity of emissions emitted by the combustion of one litre of fuel during transport activities. This leads to the following equation:

$$EQ_{FPE} = \left(VKT_{DB} \times FC_{DB} / 100 km \right) \times EF_{FPE} \quad (\text{eq. 13})$$

where: VKT = vehicle kilometres travelled [vehicle-km]

FC = Fuel Consumption per distance band

EF_{FPE} = Fuel Production Emission Factors

This calculation can be applied only for air pollutants with regional or global effects (NO_x, CO₂), because some of the emissions do not occur locally near populated areas or near nature protection areas.

The production of vehicles causes gaseous emissions mainly for the production of the energy, which is needed for the production process. Global values per vehicle can be calculated by using data from the German input-output tables and from the German environmental accounting tables both provided by the German federal statistical agency. On this basis it can be estimated that the production of one vehicle causes 7.710 kg CO₂ emissions and 17,9 kg NO_x emissions.³⁹

6.4.3.2 Modelling Emissions of other Transport Modes

For other transport modes than road a simplified approach for the calculation of emissions is implemented. The main difference is that no vehicle fleets are modelled and therefore the technical development of emission factors is taken exogenously. However the basic approach is similar as the emission calculation is mainly based on the vehicle kilometres travelled and the specific emission factors (see equation 10)

(a) Rail Emissions

The gaseous emissions from rail transport depend on a set of characteristics of which the most important are engine type (electric/diesel, age, version), train category (e.g. local train, intercity train), speed, train weight, number of train stops respectively train accelerations and topography. The relationships between these characteristics are given in figure 44.

³⁹ SCHADE (1997)

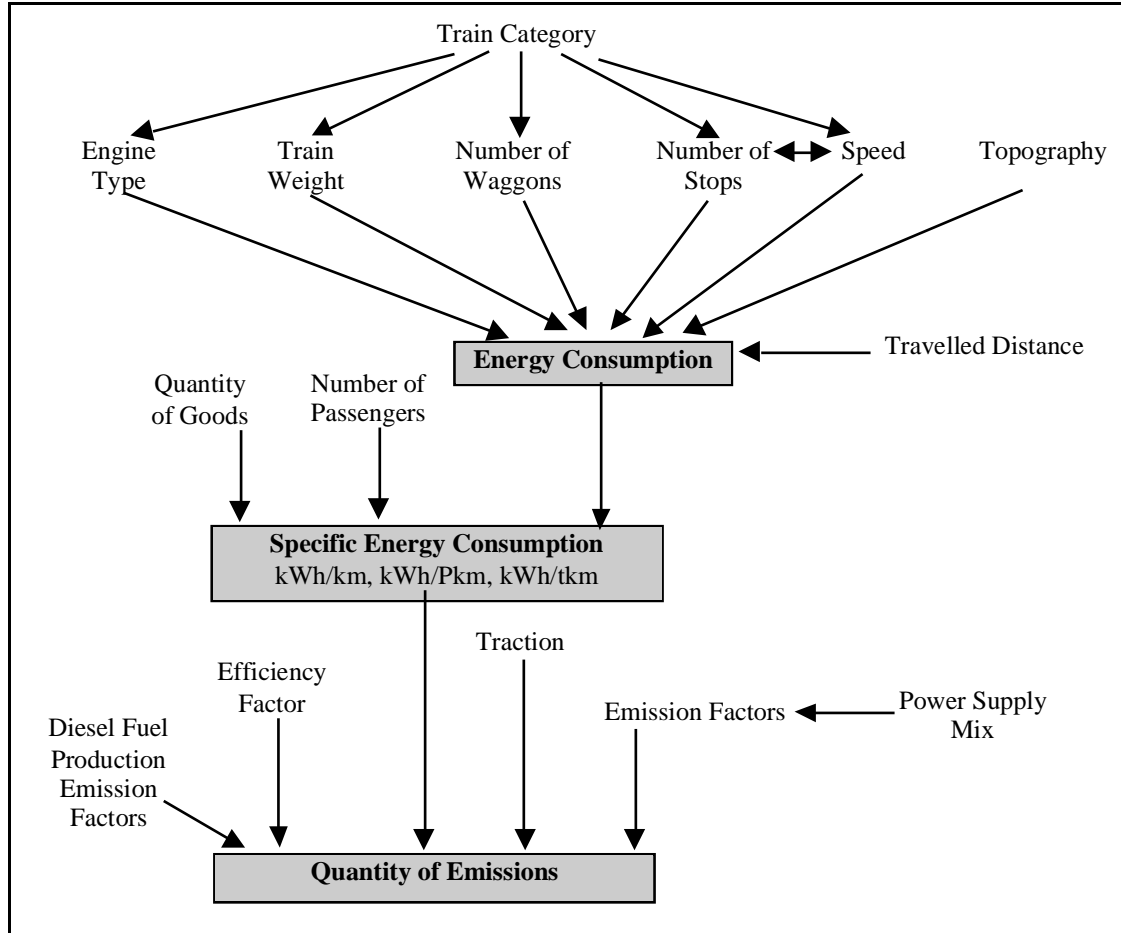


Figure 44: Influences on Emissions from Rail Transport

At present it is not possible to integrate all the characteristics into a europeanwide rail emissions model, because simply the data is not available. Secondly the model would be too detailed for the implementation within a system dynamics model. Therefore a simplified model that is based on the driven train distance, the train traction (electric/diesel) and a distance band specific emission factor is applied in the ASP.

The dependency of emission factors from train types and the correspondence between train types and ASTRA distance bands makes it possible to consider different train types, speeds and distances between stops by the use of distance band specific emission factors. That means, it is assumed that train types and therefore also emission factors are almost homogenous within one distance band but vary significantly for the five different ASTRA distance bands. This leads to equation 17:

$$EQ_{DB,Tr,ET} = TV_{DB,Tr} * EF_{DB,Tr,ET} \quad (\text{eq. 14})$$

where: EQ = emission quantity [g]
 TV = train traffic volume [train-km] (=Passenger-km / Train Occupancy)
 EF = emission factor [g/train-km]
 DB = ASTRA distance bands for trains (VST, SHT, MED, LON)
 Tr = train traction (electric, diesel)
 ET = emission type (CO₂, NO_x, PM)

The assignment of train categories to the different distance bands is as follows:

- 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

At present equation 17 is only applied for diesel trains. For passenger trains with electric traction a calculation based on the consumption of electric energy and emission factors of powerplants can be applied:

$$EQ = EN_{\text{spec}} * TV * EF \quad (\text{eq. 15})$$

Where: EQ = quantity of emissions (CO₂, NO_x or particulates) [g]
 EN_{spec} = specific energy consumption per km [kWh/train-km]
 TV = traffic volume [train-km]
 EF = emission factor of power plants [g / kWh]

(b) Air Emissions

Air transport emissions occur during five different stages of a plane flight: taxi out, take-off and climbing, cruise, descent and landing, taxi in. For modelling purposes these stages are grouped into a LTO-cycle (Landing-Take-Off) and the cruising stage. The LTO-cycle comprises taxi out, climbing, descent and taxi in. Fuel consumption and emissions during the LTO-cycle depend mainly on the aircraft type. Values for LTO-cycles of specific aircrafts are given in MEET D18.⁴⁰ Fuel consumption and emissions during the cruising stage are dependent on the cruising distance, the cruising altitude and also on the aircraft type. Aircraft specific values can be calculated with the aircraft emission index sheet given in MEET D18.

⁴⁰ KALIVODA/KUDRNA (1997)

The values in table 36 are calculated with an assumed cruising altitude of 9 km, while the flight cruising distance is taken distance band specific from the TRA. As average flight distances vary significantly between business air trips and tourism air trips different aircraft types are used for the emissions calculation. As representative for business flights, which in average are much shorter than tourism flights (see TRA values), the Boeing 737 is taken. This aircraft type covers about 20% of all air traffic in Europe (result of AERONOX project quoted in MEET D18). For the tourism flights, which cover longer distances in average, a combined value derived from Boeing 757 and Airbus A310 is used. This leads to the following values:

Table 36: Fuel Consumption and Emission Factors for Air Transport

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

Based on these values emission quantities are calculated with equation 16:

$$EQ_p = (spLTO_p * PF_p + \sum_{OD} spCEF_p * avFD_{p,OD}) / 1000 \quad (\text{eq. 16})$$

Where: EQ = quantity of emissions (CO₂, NO_x) [t]
 spLTO= specific LTO consumption or emission factor [kg/LTO]
 PF = number of plane flights
 spCEF = specific cruising consumption or emission factor [kg/Plane-km]
 avFD = average flight distance for OC/DC link [Plane-km]
 P = trip purpose (business, tourism)
 OD = index for origin destination links

The emission quantities are then used to calculate externalities in a similar way as for the other transport modes. However, as effects of air transport especially of NO_x emissions might be different than on ground level they are weighted with a factor of 3 in the externalities calculation.

(c) Ship Emissions

Ship transport is implemented only for the medium long and the long freight distance bands. It comprises coastal and ocean freight transport. So, only typical vessels for those two purposes

have to be considered in the ENV models. In addition, a specialisation of certain vessels for certain types of goods can be stated.⁴¹ This classification fits to the ASTRA goods classification such that for every ASTRA good category (bulk, semi-bulk, unitised) a group of corresponding categories of ships can be identified. For these categories the specific consumption factors and emission factors are estimated based on the findings of MEET deliverable 19. Since for MEET the emissions are given related to the fuel consumption but not specific to the travelled distances, they have to be reformulated as distance specific emission factors. For this purpose cruising speed, average fuel consumption per day and the specific emission factors per consumed unit of fuel are used. To consider also the additional emissions for manoeuvring, harbouring and hotelling a ship category specific surplus is applied. This leads to the following values for the ASTRA model:

Table 37: 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

6.4.3.3 Modelling Potential Risk Indicators for Soot Particles

Growing concern and also growing evidence on the detrimental health effects of soot particles or more general of particulate matter (PM) requires to model the environmental impacts of particles. In ASTRA the effect of soot particles from transport is calculated, where soot particles means a fraction of particulate matter. Growing knowledge about the human health impacts of PM shows that especiall PM with a diameter of less than 10 µm respectively 2.5 µm cause health damages. In this case PM includes PM from all source of air pollution with PM. However in ASTRA the focus is kept on soot particles from transport, as the databases (e.g. emission factors) and the health impacts (e.g. risk of cancer) can be quantified according to existing databases and studies.

The problem arises that the effects of soot particles have to be assessed on the local level where urban inhabitants are faced with a certain immission concentration of particulates. This can not be coped with directly in the ASTRA system dynamics model platform because the spatial resolution is not distinct enough. Therefore a concept of potential risk indicators is developed that estimates for certain common urban living locations and corresponding traffic situations the level of the resulting ambient air concentrations of soot particles.

The potential risk indicators can be used by examining a given local situation for its local characteristics of five major influencing variables:

- road type and housing situation along road,

⁴¹ Trozzi/Vaccaro (1997)

- traffic density linked to road type (average daily traffic = ADT),
- share of HDV, LDV, Buses at ADT,
- average wind velocity and
- angle between major wind direction and road direction.

Based on these characteristics and considering to which macro region and which functional zone the examined location belongs the immission concentration for soot particles is indicated by the ASTRA model. The following figure 45 shows the structure of the soot particles model.

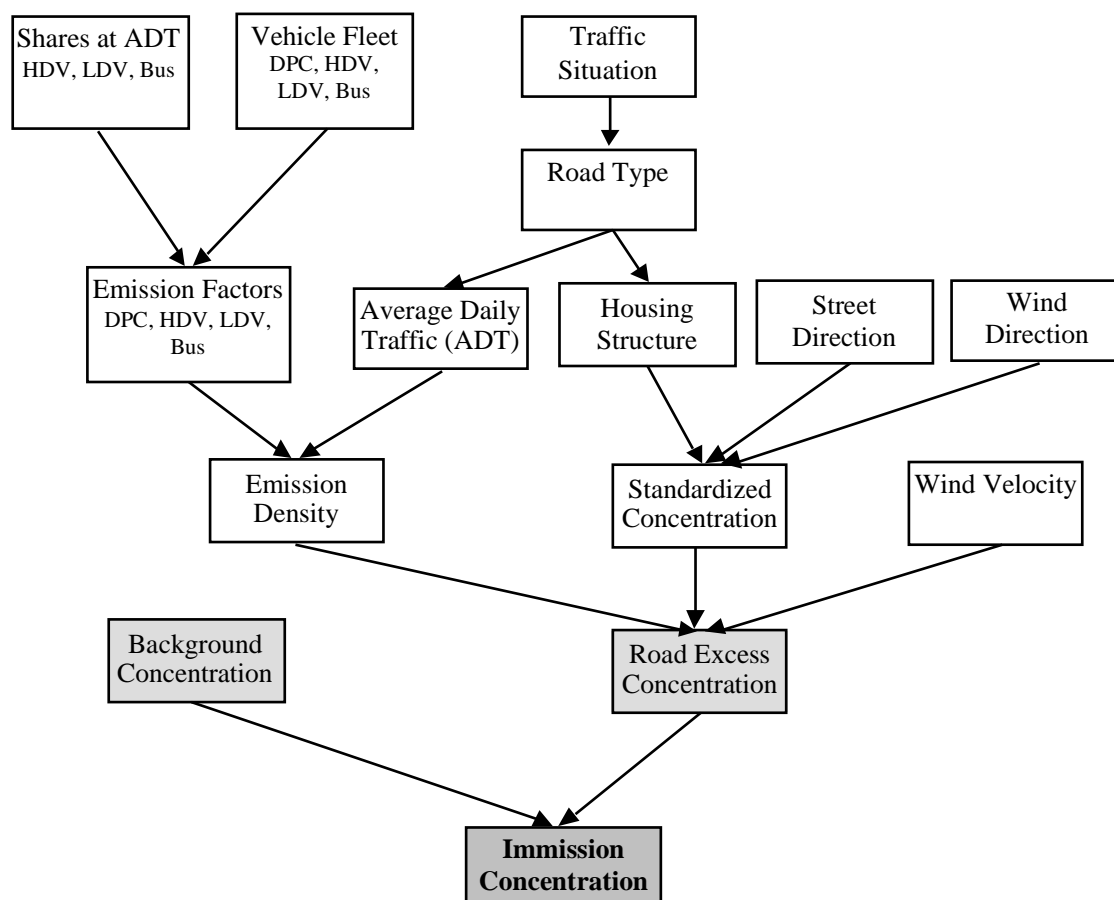


Figure 45: Model Structure for Calculation of Concentrations of Soot Particles

The model is only applied for the local road network and the corresponding distance bands (Local, Very Short and partially the Short distance band). The reason is that it is assumed that only transport in these distance bands is effecting urban population, which includes also village inhabitants in rural areas. For instance they are effected by their local traffic in the village, which is assigned to the ASTRA *local* distance band respectively the *very short*

distance band, but not by the motorway several kilometres away to which the short, medium and long distance bands are assigned.

The emission factors for the distance bands have been calculated by the composition of emission factors of four different urban traffic situations from HB-EFAC.⁴² The same traffic situations will also be used for the particulates model. For each traffic situation a typical road type with a specific housing structure can be identified. Traffic situations and road types are shown in table 38:

Table 38: Traffic situations and corresponding urban road types

Traffic Situation	Description of Road Types from HB-Efac
IO_Kern	Urban Road within City Centres
IO_Nebenstr_dicht	Urban Side Street with Both Sides Built up
IO_LSA2	Main Urban Road with disturbances by Traffic Lights or Crossings
IO_HVS1	Main Urban Road or Through Road without disturbances

Immission concentrations depend on a set of characteristics that the applied model should address. Important characteristics are the emission quantity per road distance unit, the wind velocity and wind direction to the street, regional background concentrations and the type of housing structure alongside the road. For the German Federal Infrastructure Plan LOHMEYER developed an approach for microscale immission concentration calculation based on the above parameters.⁴³ This approach was adjusted by GÜHNEMANN such that it better fits to assessments on strategic level respectively large scale estimations.⁴⁴ With little modifications the approach can be applied for ASTRA.

The model calculates the immission concentration in the vicinity of roads as the sum of an area specific background concentration and the excess concentration caused by transport on the infrastructure under investigation.

$$\mathbf{IC}_{P,RT} = \mathbf{BC}_{P,RT} + \mathbf{EC}_P * 1000 \quad (\text{eq. 17})$$

⁴² BUWAL et al. (1995, 1999)

⁴³ LOHMEYER (1996)

⁴⁴ GÜHNEMANN (1999)

where: IC = immission concentration [$\mu\text{g}/\text{m}^3$]
 BC = background concentration [$\mu\text{g}/\text{m}^3$]
 EC = excess concentration [mg/m^3]
 P = air pollutant e.g. soot particles
 RT = region type e.g. rural area

Background concentrations for different settlement types and area types presented in GÜHNEMANN (1999) can be assigned to the ASTRA functional zones. A second categorisation for background concentrations of different macro regions could be useful but is not applied, because the data was not yet available.⁴⁵ Table 39 presents the current background concentrations for the ASTRA functional zones.

Table 39: Background concentrations for soot particles

Background concentration	LSA	MPH	HDU	HDD	MDR	LDR
Soot particles [$\mu\text{g}/\text{m}^3$]	6,0	5,1	4,0	2,5	1,5	1,5

The excess concentration caused by transport is calculated with equation 18:

$$EC_{TS,PR,PW,ADT} = \frac{SC_{PR} * ED_{TS, ADT}}{WV_{PW}} \quad (\text{eq. 18})$$

where: EC = excess concentration [mg/m^3]
 SC = standardised concentration per housing structure [1/m]
 ED = annual averages for emission density [$\text{mg}/(\text{m}^*\text{s})$]
 WV = average wind velocity at 10m height [m/s]
 PR = potential risk for different wind directions (mean, max)
 TS = traffic situation (see table 38)
 ADT = typical average daily traffic for traffic situations and road types (see table 40)
 PW = potential wind velocities (low, medium/high)

For the wind velocity two values are assumed (2,5 and 4 m/s), which represent a region with low exchange of fresh air and with medium exchange of fresh air. The standardised concentrations are calculated by LOHMEYER (1996) with the MISKAM programm for nine typical housing structures alongside roads and for twelve different wind directions. In ASTRA every traffic situation is represented by a certain road type (see table 38) to which a specific composition of housing structures can be assigned. With the assigned housing structures a mean value reflecting the mean composition of housing structures along the road and a maximum value reflecting that the housing structure alongside a road is formed only by the

⁴⁵ However, in OECD (1997) data on concentrations of suspended particulates is provided, which would give a hint at the concentration of soot particles.

most unfavourable housing structure built at this road type are calculated. The latter immission concentration can be seen as highest possible concentration. The values for the mean and maximum standardised concentration are presented in table 40:

Table 40: Applied standardised concentrations and ADTs

Traffic Situation	Standardised Concentration		ADT [vehicles/24h]			Share on ADT [%]		
	Mean	Max	Medium	High	Very High	Buses	HDV	LDV
IO_Kern	0,5175	1,33	5000	10000	15000	4	0.5	6
IO_Nebenstr_dicht	0,5540	1,33	3000	6000	9000	2	0.1	2
IO_LSA2	0,2935	1,205	18000	24000	30000	5	1	8
IO_HVS1	0,1370	0,59	30000	40000	50000	2	2	6

The average annual emission densities are calculated with the vehicle fleet of the different road transport means (diesel cars, buses, LDV, HDV) differentiated into the macro regions, which means that the applied emission factors correspond to the vehicle fleet of the macro regions. The second parameter to describe the emission densities is the average daily traffic (ADT) on a certain road type. To calculate the potential risk performed by the traffic situations three different ADT values are used (see *table 40*). The applied values follow the precautionary principle in a sense that the very high ADT represents an extreme situation on a road. On the other hand, if already the potential immission concentration calculated with the medium ADT violates environmental quality standards the situations is even more grave because in this case there will be a lot of roads, where the potential immission concentration is realised. The third parameter is the share of the different road transport means on the ADT.

Equation 19 presents the calculation of emission densities:

$$\mathbf{ED_{TL}} = \frac{ADT_{TL}}{RM} * \frac{sTM_{RM}}{VC} * (SDC_{VC} * EF_{VC}) / \mathbf{86400} \quad (\text{eq. 19})$$

where: ED = emission density [mg/(m*s)]

ADT = average daily traffic [vhc/24h]

sTM = share transport mean [%/100]

SDC = share diesel cars

EF = emission factor [g/km]

VC = vehicle category

RM = road transport means (car, bus, HDV, LDV)

TL = traffic load categories (Medium, high, very high).

With the above categorisation 48 different excess concentrations and the same number of immission concentrations for soot particles caused by road transport in each of the four macro regions are calculated. The highest concentrations can be expected with the combination very high ADT, maximum standardised concentration and low wind velocity. A common safe minimum standard for soot particles would be $1,5 \mu\text{g}/\text{m}^3$, which is an environmental target based on a long-term horizon.⁴⁶ Considering that there is also a background concentration from other sources or smaller roads, a target for the excess concentration of transport could be $0,75 \mu\text{g}/\text{m}^3$.

6.4.3.4 Modelling Traffic Accidents

In general, the number of traffic accidents can be calculated in dependency of the traffic volume on a certain piece of transport infrastructure and with consideration of the corresponding accident risk. This is expressed in the following equation:

$$TA = \sum_i VKT_i * AR_i \quad (\text{eq. 20})$$

where: TA = total number of traffic accidents
 VKT = vehicle kilometres travelled [vehicle-km]
 AR = accident risk [accidents / vehicle-km]
 i = different types of infrastructure e. g. motorway, urban road

The number of accidents can be distinguished into different types of accidents that are differentiated by the most severe consequence of an accident. Common classifications distinguish between fatal accidents, accidents with serious or with light injuries and accidents that cause (severe) material damages. The accident risks vary according to these classes of consequences.

(a) Road Traffic Accident Risk

As the traffic volume is calculated within the TRA the ENV is modelling the development of the accident risk. For road traffic the accident risks depend on the road characteristic e.g. speed limit, occurrence of intersections. Therefore, the risk is different for different road types like motorways or urban roads. In the TRA the road network is distinguished into an urban network and a non-urban network. This categorisation is also used for the accident model that is divided into urban accidents and rural accidents. Examples for accident risks for these two categories are presented in table 41:

⁴⁶ LAI (1992), particulates in the sense of the LAI are soot particles from transport.

Table 41: Examples of Different Accident Risks

	Fatality	Serious Injuries	Light Injuries	Material Damages
Germany	[Accidents per 1 Million vehicle-km]			
Passenger Car (Urban)				
1988	0,040	0,761	2,184	5,700
1993	0,014	0,357	1,441	3,310
Passenger Car (Rural)				
1988	0,044	0,378	0,605	1,280
1993	0,016	0,165	0,343	0,920
Bus on Multi-Use Road Network				
1988	0,100	1,500	21,000	2,500
1993	0,032	0,655	12,900	1,560
Tram on Multi-Use Road Network				
1988	0,400	1,700	28,000	6,000
1993	0,140	0,798	14,784	3,480
United Kingdom	Fatality User	Fatality Pedestrian		
Passenger Car	0,007	0,004		
Bus Transport	0,004	0,018		
Heavy Lorry	0,002	0,005		

Sources: BMV quoted in FISCUS (1998), Hillman/Adams quoted in Litman (1998)

It can be stated from the table that the accident risks are not constant over time. Instead they decreased in the most European countries during the last years. This development has to be captured by the accident model, which will be applied in the ASTRA ENV. One possibility would be to use regression analysis to integrate the development over time into the model. For example, from the German accident data for the urban fatalities from 1980 until 1993 the following non-linear regression function can be derived:

$$AR = 40,54 * 0,912^t \quad (\text{eq. 21})$$

where: t = time after 1980

AR = accident risk for urban fatalities [fatalities / 1 Bio vehicle-km]

From the statistics point of view equation 21 would be sufficient. It fits with a coefficient of determination of 0,9513 to the real values. This is shown in figure 46:

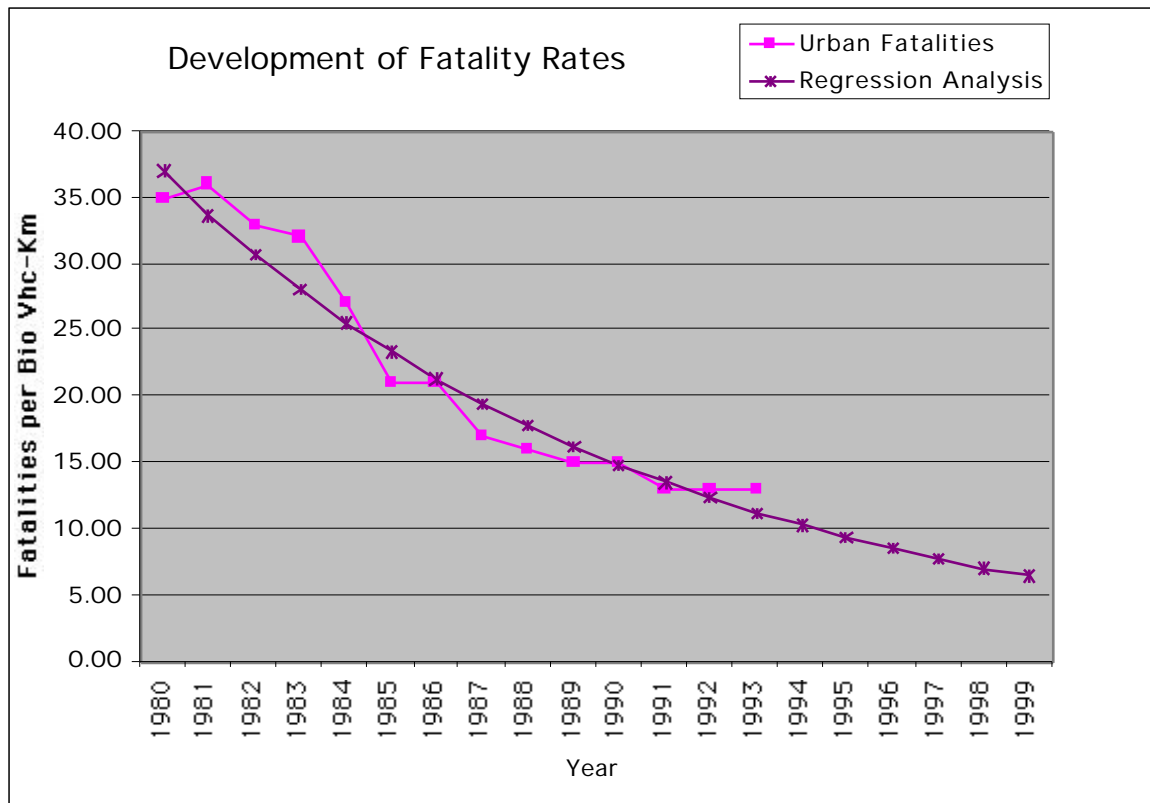


Figure 46: Development of Urban Fatality Accident Risks in Germany

But from the System Dynamics point of view this approach would be insufficient. It would imply that the development of accident risks is exogenous and only advancing by the development of time. Actually this is not the case. The accident risks change because of several more or less important influences e.g. change of speed limits, development of vehicle technology or implementation of safety features like airbag in vehicles. The regression analysis in figure 46 is not useful to capture future developments. Recently published values for accident risks indicate that they develop nearly on a constant level since 1996, while the regression curve still decreases during these years. The reason mainly seems to be that two safety features have been introduced for passenger road transport during the last 15 years. First in the beginning of the 80ies it was obliged to use the safety-belt. This decreased fatal accidents until the end of the 80ies by nearly half. Second the airbag was introduced in the vehicle fleet. Both safety features are nearly fully implemented and therefore will hardly further reduce the fatality accident risks.

That means, instead of applying a regression function that develops over time, an approach should be applied that is build on the causal relationships between accident risks and the underlying influences for changes of the accident risks. From literature surveys the following influences can be found. Applicable for ASTRA would be all influences, which can be quantified. However the model should only focus on the key influences.

- **Safety-belt.** Two policies that influence the safety effect of safety-belts can be distinguished. First an obligation to implement a safety-belt in the car and second an obligation to use this belt while driving.
- **Airbag.** The integration of airbags reduces the severity of the consequences of an accident.
- **Speed Limits.** An introduction of speed limits or more severe speed limits reduce the accident risks and may also reduce the severity of an accident.
- **Daytime Running Lights.** Often accidents happen because one of the participants did not see the other. This risk can be decreased by daytime running lights.
- **Ageing of Drivers.** Elderly drivers (65+ years) have a significant higher accident risk. This group will grow in the next decades and therefore this will have an influence on the overall accident risk.⁴⁷
- **Alcohol.** A high proportion of fatal accidents happens involving at least one driver with a non-negligible blood alcohol concentration.
- **Eyesight Problems.** Research results reveal that worse eyesight is also a cause for accidents, because most of the information needed for driving is captured visually.⁴⁸
- **Anti-Lock-Breaking-System (ABS).** The integration of ABS in passenger cars seems not to reduce accident risks, since drivers that are equipped with ABS tend to drive more hazardous and therefore compensate the positive effect of ABS.⁴⁹

In the following key developments and accident prevention measures are described that are of major importance for accident risks. The safety effect of these measures is quantified in a sense that the reduction rate on accident risks of a measure is estimated.

[i] Quantification of Safety Effect of Safety-Belts

A German study on national and international research results on the safety effect of safety-belts concluded that there is a major reduction of injury risk and only a very minor additional injury risk by the use of safety-belts.⁵⁰ The overall safety effect depends on the maximum theoretical injury reduction by the use of safety-belts and on the usage factor of safety-belts. This is shown in equation 22:

$$SE_{\text{safety-belt}} = TIR_{\text{safety-belt}} * UF_{\text{safety-belt}} \quad (\text{eq. 22})$$

where:

$SE_{\text{safety-belt}}$	= the overall safety effect of seat-belts [%]
$TIR_{\text{safety-belt}}$	= maximum of theoretical injury reduction [%]
$UF_{\text{safety-belt}}$	= usage factor of seat-belts while driving.

⁴⁷ ERSF (1998a), MANNAN et al. (1998)

⁴⁸ ERSF (1998c)

⁴⁹ BASt (1992)

⁵⁰ BASt (1978)

The theoretical injury reduction for fatalities and serious injuries is estimated to be about 55%. Combined with a usage factor of 60% the safety effect would be 33%. The maximum speed where the safety-belt reaches its safety optimum is 50 km/h. For higher speeds it can not protect for all injuries or even the belt itself may cause injuries.

In Germany the integration of a safety-belt in every car is obliged since 1974 and since 1976 front passengers are obliged to use it. Since August 1984 front passengers who do not use the safety-belt have to pay a fine. This policy measure caused a change of the usage factor from about 60% to about 92% in Germany. The fatalities are reduced by 22,8%, which is 13,8% higher than the decrease in the year before. The difference for the reduction of serious injuries is 15,9%. Despite this regulation the usage factor did never reach 100%. For instance in Germany the usage factor in 1996 was 92% and the maximum usage factor has been 96% in 1991.⁵¹ Recently a study from the federation of German Insurance Companies estimated that an improvement of the usage factor to 100% would avoid 800 fatalities per year in Germany.⁵²

Since 1986 also the back passengers of cars are obliged to use safety-belts. Since, the usage factor in the back of the cars lies between 40 and 65%. The BASt estimates that a usage factor of 100% in the back reduces fatalities by 250 deaths per year in Germany.⁵³ In the EU all car passengers are obliged to use safety-belts since 1993. For instance for back passengers the usage factor varies from 9% in Greece to 80% in Sweden.

[ii] Quantification of Safety Effect of Airbags

In Germany today every new car is equipped with airbags for the front passengers. The situation is similar in the United States where in 1997 one third of all cars in the fleet was already equipped with front passenger airbags. On the basis of accident statistics from the US it is estimated that driver fatalities are reduced by 11% and co-driver fatalities by 15%. Because only one third of the trips is undertaken with a co-driver the average reduction rate of fatalities by airbag is estimated to be 12%. In combination with the use of a safety-belt airbags reduce fatalities and serious injuries by about 65%. In total figures airbags avoided 1700 fatalities until 1996 but caused additional 55 fatalities in the US by causing injuries during their blow-up phase.⁵⁴ This leads to equation 23:

$$SE_{\text{airbag}} = TIR_{\text{airbag}} * IF_{\text{airbag}} \quad (\text{eq. 23})$$

where: SE_{airbag} = the overall safety effect of airbags [%]
 TIR_{airbags} = maximum of theoretical injury reduction by airbags [%]
 IF_{airbag} = implementation factor of airbags in vehicle fleet.

⁵¹ VDA (1985), VDA (1986b), BASt (1996)

⁵² GDV (1998)

⁵³ VDA (1986b)

⁵⁴ VDA (1997) S.191

The implementation factor can be estimated with the vehicle fleet of passenger cars by considering that from a certain point of time a growing share of new cars is equipped with an airbag.

[iii] Quantification of Safety Effect of Speed Limits

At the beginning of the 70ies a big research program about the effect of a general speed limit of 100 km/h on rural roads was carried out in Germany. For nearly two years a speed limit of 100 km/h was introduced on rural roads and the effects are investigated. Fatalities decreased by 25,8% and Injuries by 20,7% within a two years period on rural roads. Considering the safety effect of other measures during this time (e.g. safety-belt) a reduction of 10% is due to the speed limit. This includes also the effect that on urban roads accident risks are also effected by the speed limit on rural roads because people drive slower when they reach a village.⁵⁵

In 1985 a big research study was carried out on German motorways to test the effect on emission of a speed limit of 100km/h on motorways. In parallel to this research the development of accident risks are investigated. The overall reduction of the accident risk was 28,8% on the investigated motorways while the reduction was 12,8% on a control group of motorways. With statistical significance a reduction effect caused by the speed limit is estimated to be 24%. Accidents with injuries and with fatalities are reduced by about 30%, a result which can only be based on a low statistical significance.⁵⁶

In the US 12 federal countries rose their speed limit on highways from 88 km/h to 115 km/h in the year 1996. This caused an increase of fatalities of 6% taking into consideration that traffic volume also increased. For instance in Texas 455 persons died in 1995 on the highways while in 1996 this number increased to 566.⁵⁷

[iv] Quantification of Safety Effect of Daytime Running Lights

A meta-study on behalf of DGVII on international accident research results revealed that a cheap but very effective measure to reduce fatal accidents of transport is to drive with daytime running light. This would decrease fatalities as well as all accidents in the EU by 25%.⁵⁸

[v] Quantification of Safety Effect of Measures against Alcoholic Driving

In Germany every fourth fatality or serious injury happens under alcoholic influences. In the US about 30% of fatally injured drivers had blood alcohol concentrations of more than 0,1 percent. According to a German study a reduction of the blood alcohol limit from 0,8 percent to 0,5 percent reduced fatalities and serious injuries by about 5%.⁵⁹

⁵⁵ BASt (1975)

⁵⁶ BASt (1986)

⁵⁷ ERSF (1998b)

⁵⁸ Koornstra et al. (1997)

⁵⁹ GDV (1998)

(b) Modelling Road Accidents

The influences on the total number of accidents can be distinguished into two categories. The first category changes the number of all accidents expressed by the overall base accident risk. These are called *influences on accident risk*. The second category changes the number of certain consequences of an accident e.g. fatalities. This is expressed by the *influences on injury risk*. For the model it is assumed that changes caused by influences on accident risks are evenly distributed on all injury risks. The accident model is differentiated into macro regions, such that for the following equations different calculations are performed for each of the four macro regions. The consideration of a separate influence for accident risk and injury risk leads to the following equation:

$$TA_j = TV * AR_{Base} * iAR_j * iIR_j \quad (\text{eq. 24})$$

where: TA_j = total number of traffic accidents with damage j
 TV = traffic volume [vehicle-km]
 AR_{Base} = base accident risk [accidents / vehicle-km]
 iAR_j = influences on accident risk for damage j
 iIR_j = influences on injury risk for damage j
 j = type of damage e.g. fatality

The following *table 42* shows the changes in accident risk and injury risk by certain influences, which can also be seen as policy measures.

Table 42: Influences on Car Passenger Risks

Influencing Factor	Accident Risk	Injury Risk			
		Fatality	Serious Injury	Light Injury	Material Damage
Safety-Belt	---	-55%	-55%		
Airbag	---	-12%	(-12%)		
Safety-Belt + Airbag	---	-65%	-65%		
Speed Limit 100km/h instead of no limit	-24%	(-30%)	(-30%)		
Speed Limit 88 instead of 115km/h	-6%				
Daytime Running Lights	-25%				
Blood Alcohol Limit 0,5 instead of 0,8	(-5%)	-5%	-5%		

Based on these influences the following effect diagram describes the relationships in the accident model.

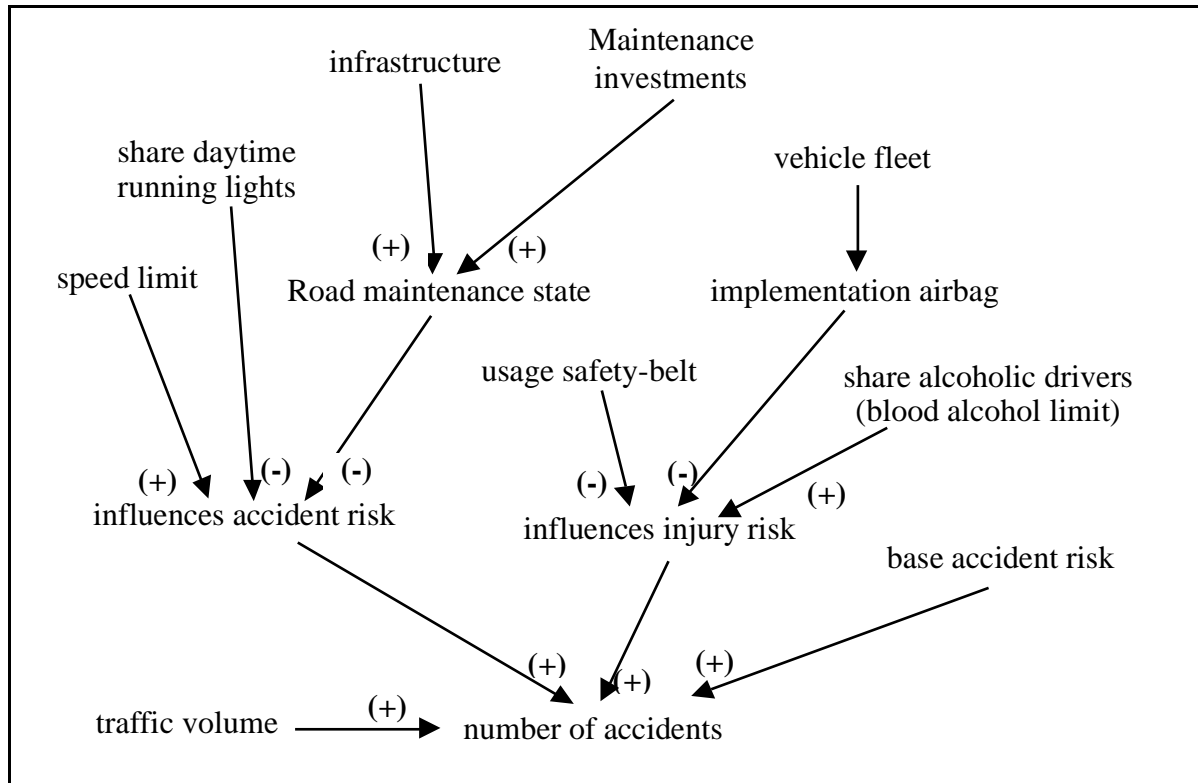


Figure 47: Effect Diagram of Road Accident Model

[i] *Estimation of Light Injuries and Material Damages*

Light injuries and material damages of accidents mainly depend on the accident risks. Therefore they can be estimated based only on the base accident risk and the influences on this accident risk. The baseline of the estimation is the accident risk without the application of all policy measures.

$$TA_j = TV * AR_{Base,j} * iAR_j$$

$$TA_j = TV * AR_{Base,j} * (1 - SE_{SL}) * (1 - SE_{max,drl} * sDRL) \quad (\text{eq. 25})$$

where:	TA_j =	total number of traffic accidents with damage j
	TV =	traffic volume [vehicle-km]
	$AR_{Base,j}$ =	base accident risk [accidents / vehicle-km]
	iAR_j =	influences on accident risks
	j =	light injuries, material damages
	SE_{SL} =	safety effect of speed limit
	$SE_{max,drl}$ =	safety effect of daytime running light
	$sDRL$ =	share of vehicles driving with daytime running light

The policy measure speed limit is only applied for rural roads. The policy to require daytime running light while driving is mainly applied in macro region 4. The calculation in equation 25

might be completed by an autonomous decrease of accidents because of not considered developments in traffic safety (e.g. improvements in traffic organization).

[ii] Estimation of Fatalities and Serious Injuries

Fatalities and serious injuries can be estimated by the completion of equation 25 with the influences on the injury risks. These are safety-belts, airbags and changes in blood alcohol limit.

$$TA_j = TV * AR_{Base} * iAR_j * iIR_j$$

$$TA_j = TV * AR_{Base} * iAR_j * (1 - TIR_{SB} * UF_{SB}) * (1 - TIR_{AB} * IF_{AB}) * (1 - SE_{BAL}) \quad (\text{eq. 26})$$

where:	TA_j =	total number of traffic accidents with damage j
	TV =	traffic volume [vehicle-km]
	AR_{Base} =	base accident risk
	iAR_j =	influences on accident risk
	iIR_j =	influences on injury risk
	j =	fatality, serious injury
	TIR_{SB} =	maximum of theoretical injury reduction by safety-belts [%]
	UF_{SB} =	usage factor of safety-belts while driving
	TIR_{AB} =	maximum of theoretical injury reduction by airbags [%]
	IF_{AB} =	implementation factor of airbags in vehicle fleet
	SE_{BAL} =	safety effect of blood alcohol limit

The effect of using safety-belts and airbags can be treated different for urban and non-urban roads. For improvements of the model the estimation in equation 26 can be completed by an autonomous development of the injury risk because of new technologies (e.g. electronic distance keeping systems) or organisational measures.

(c) Modelling other Accidents

The models for the calculation of accidents of bus, HDV and LDV transport, of slow mode transport and of rail transport are implemented as relatively simple models that are based on the following calculation:

$$NoA_{m,d} = TV_m * spAR_{m,d} / 1000000 \quad (\text{eq. 27})$$

Where:	NoA =	number of accidents
	TV =	traffic volume [pkm], [vhc-km]
	$spAR$ =	specific accident rate [case per 1 Mio km]
	m =	transport mode
	d =	type of damage (fatality, serious injury, light injury, material damage)

The development of accident rates is driven exogenously (see annex B). It should be based on trend forecasts or on trends for safety improvement investments.

6.4.3.5 Modelling Fuel Prices and Taxes

The fuel price and tax model is a very important element of the ASP as it integrates policy levers e.g. fuel taxes as well as drivers of some sub-modules e.g. fuel cost for TRA, tax revenues for MAC. It is allocated to the ENV as this sub-module deals with the fuel consumption though other arguments could be found to allocate it to the MAC. The total fuel price in ASTRA is composed of five elements:

- Historic pure fuel prices until 1996 taken from energy statistics. Pure fuel price means the fuel price net of all fuel tax and all VAT.
- Assumption about the development of pure fuel prices after 1996.
- Historic fuel taxes until 1996 taken from energy statistics.
- Assumption about fuel tax development after 1996 and levers for policy changes of fuel taxes.
- Historic development of VAT until 1998 and assumed constancy of VAT after 1998.

The sum of these five elements produces the total fuel price such that policies can either be introduced on the pure fuel price, the fuel tax or the VAT. This structure is implemented for gasoline, diesel and kerosene.

6.4.3.6 Modelling Impact Assessment: Welfare Indicators

For the first two assessment approaches that are described in chapter 6.4.2.4 - scenario comparison and comparison against reduction targets - there is no need to develop special models. But the calculation of defensive costs and the estimation of externalities has to be modelled.

The ENV calculates defensive costs for material damages and light injuries of accidents. These costs are paid by the transport users respectively their insurance companies. But defensive costs are integrated in GDP with the wrong sign if one considers GDP as a welfare measure. Instead of adding up to GDP they should be subtracted, because they are paid to restore the welfare situation before the damage happened. The defensive costs depend on the number of accidents causing material damages and light injuries and the average cost values applied for calculation. At present the cost values are taken from the German Federal Infrastructure Plan (BVWP92).⁶⁰ This leads to equation 28:

⁶⁰ BMV (1993)

$$DC_i = NoA_i * dCV_i \quad (\text{eq. 28})$$

where: DC = defensive costs [EURO]
 NoA = number of accidents
 dCV = defensive cost value [EURO]
 i = light injuries, material damages

The estimation of externalities for CO₂- and NO_x-emissions, fatalities and serious injuries by accidents follows a similar approach that also depends on a quantitative environmental indicator e.g. CO₂ emissions and an externality cost value e.g. expressed as EURO per ton emitted CO₂. The externality cost values are taken from national or European estimates (see annex 9.3). Both assessment models calculate values for two different time scales. First yearly values are calculated and second the defensive costs respectively the externalities are accumulated over the whole simulation period.

For soot particles the fatality risk of cancer caused by these particles is also included within the calculation of externalities. However other adverse health effects of particulate matter e.g. (chronic) bronchitis, asthma attacks, respirators hospital admissions for which it can be assumed that they are in parts caused by soot particles are not considered. The reason is that studies on these effects are always based on P10 or PM2.5

For the calculation of externalities the problem has to be solved to relate the local concentration to the local population. For this purpose estimates have to be made for:

- share of transport on background concentration of soot particles,
- share of settlement areas located in areas with concentration levels at background concentration,
- share of settlement areas located besides or near to each of the road categories.

Based on these shares an average immission concentration is calculated for macro regions and functional zones. Relating this concentration with the effected population and considering the unit risk for cancer of soot particles the yearly number of fatalities can be calculated with the following equation :

$$\mathbf{FSP}_{MR,OC} = \mathbf{avIC}_{MR,OC} * \mathbf{POP}_{MR,OC} * \mathbf{UR} \quad (\text{eq. 29})$$

where: FSP = yearly fatalities caused by soot particles from transport
 avIC = average immission concentration of soot particles [$\mu\text{g}/\text{m}^3$]
 POP = affected population [Mio*Pers]
 UR = unit risk for cancer by soot particles [cases/(Mio*Pers*($\mu\text{g}/\text{m}^3$)*year)]
 MR = macro regions
 OC = functional zones

The unit risk value is taken from the German LAI study.⁶¹ It is a measure for the number of fatalities over a period of 70 years when a certain number of people (100.000) are effected with a concentration of 1 $\mu\text{g}/\text{m}^3$ of a harmful substance. For soot particles the LAI estimates a unit risk of 70 fatalities per million persons per $\mu\text{g}/\text{m}^3$ per 70 years. The number of fatalities is the evaluated with a cost value taken from a study for the WHO.⁶² This value is below the value used for accident fatalities as different age groups are affected by the impacts.

As the cost values for fatality and serious injury externalities are derived with willingness-to-pay (WTP) approaches, the cost values are increased corresponding to the increase in GDP.⁶³

Based on the externality indicators and on economic indicators further welfare indicators can be constructed. For instance the fraction of externalities on GDP can be calculated. This new indicator gives a hint on the quality of economic growth in a sense that if this fraction of externalities would increase over time the growth would at least partially be driven by a deterioration of environmental quality.

Finally it has to be reminded that the considered externalities do not represent the complete range of externalities of transport. Further effects especially noise and impacts on nature and landscape should be considered to get a complete picture of transport externalities, which is important for policy assessment. In this sense the externalities calculated in the ASTRA project stand for a minimum level of externalities that is performed by CO₂- and NO_x-emissions, carcinogenic effects of soot particles and accidents.

6.4.4 Calibration approach for the ENV

In ASTRA deliverable 2 the steps in the development of a system dynamics model are described.⁶⁴ The description includes several development tasks that support the calibration of a model. In general the very thorough system dynamics modelling procedure based on wordmodels and effect diagrams support the calibration process.

The first development task that is explicitly used for calibration is the validity check of the model structure. This is done in three ways. First the ENV is based on valid existing models

⁶¹ LAI (1992). The exact value of the unit risk is still a matter of research and discussion. However, the LAI value seems to present a widely agreed result.

⁶² WHO et al. (1999)

⁶³ It would also be possible to link the increase to the income development.

⁶⁴ ASTRA (1998)

e.g. from the MEET project or the IWW/UBA project.⁶⁵ Second, the model structure is described in ASTRA project notes and discussed in the ASTRA expert group.⁶⁶ Third, the values for indicators that are produced by the model without any calibration should reflect the development and the values of the real data. Without calibration means only the pure functional relationships are included in the model, without any correction terms for not considered influences. The second and main calibration task is carried out on the 3rd basic development step with the check of behavioural and empirical validity. For this purpose correction terms are implemented in the functional relationships such that average deviations are decreased to an acceptable level.

Based on the described modelling tasks the environmental sub-module (ENV) is calibrated with two different approaches. The first approach applies a stand-alone system dynamics model for Germany (SASDyG) and the second approach uses aggregated environmental indicators for the EU15 countries. The calibration period in both cases starts with the year 1986 and lasts until 1995.

6.4.4.1 Validation results with the stand-alone model for Germany

The stand-alone system dynamics model for Germany (SASDyG) covers the same environmental aspects as the ENV. It is feeded exogenously with the real values of the traffic volume and the real vehicle fleet of Germany. That means it is guaranteed that the input values of the model are met fairly well. Therefore the SASDyG can be used for tests of structural validity with a higher degree of precision than if the input values stem from interfaces of other sub-modules as the latter might imply that input values already include deviations from the real values. The following table 43 presents some of the model results for indicators of the ENV calculated with the pure functional uncalibrated model. As the results show deviations of less than 25% from the real data the structure of the ENV seems to be valid. With calibration the values should be reduced to deviations of less than 10%.

Table 43: Results of Comparison between Real Indicators and not calibrated SASDyG Model Indicators

Indicator	Time Period	Average Deviation [%]
Passenger Car Fleet	1986 - 1994	3
Yearly CO ₂ emissions of Cars	1987 - 1994	24
Yearly NO _x emissions of Cars	1986 - 1994	23
Yearly Fatalities of Car Transport	1986 - 1995	25
Yearly Serious Injuries of Car Transport	1986 - 1995	14

⁶⁵ HASSEL/WEBER (1997), HICKMAN et al. (1997), IWW et al. (1998)

⁶⁶ IWW (1998), IWW (1999)

6.4.4.2 Calibration of the ENV within the ASP

The main calibration approach is based on the indicators within the ENV in the ASP. Main indicators like CO₂ emissions from transport are aggregated over all modes and all distance bands. The resulting indicator values can be compared with “real” data. This second type of calibration is needed because of the change of the models scope from German data to European data that influences e.g. the composition of the vehicle fleet.

There are two reasons for uncertainty by this comparison. First, the sub-module might be able to calculate the real values, but the input from other sub-modules include already a deviation, which produce deviation in the ENV even if the whole structure of the sub-module would produce reality very well. To test and avoid this problem calibration runs are carried out with a stand-alone model of the ENV for EU15. The second reason is that especially on European level the “real” data for environmental indicators often also stems from model estimations like emission indicators that are e.g. calculated in the Corinair project. These modelled “real” data may itself include deviations. E.g. two data sources for German car transport emissions present values that are different by 20% deviation. That means a comparison with UBA data might lead to a deviation of 5% while with BMV data the deviation reaches 25%.⁶⁷ Similar results can be revealed from the vehicle fleet if one compares data from the MEET project with real data from the German KBA.⁶⁸ For these reasons an average deviation of 10% for environmental indicators seem to be appropriate for calibration of the ASP. At this point it has to be emphasised again that the purpose of socio-economic system dynamics models is not to make a point-to-point forecast of a certain future value with a high precision but to show the long-term trends of indicators. This problem could be formulated as the questions whether the slope of an indicators development is positive or negative, whether an increase by 10% or by 20% occurs, whether the indicator reaches maximum or minimum values or how long it takes to double the value of an indicator.

The ENV consists of more than 40 models, of which some of them are subdivided into several sub-models like the passenger car CO₂-emission model, which is subdivided into sub-models for hot emissions, cold start emissions (both differentiated into gasoline and diesel cars), vehicle production emissions, gasoline and diesel fuel production emissions.

On the European level it is often not possible to calibrate each of the sub-models (e.g. vehicle production emissions) or the aggregate models (e.g. CO₂ emissions of all modes for the applied part of the life-cycle approach) because no data or only incomplete data for the period 1985 to 1995 is available. Therefore calibration data is collected and compiled from different data sources to calibrate or at least to get an idea for the right order of magnitude of the following variables of the ENV:

- PC Fleet,
- LDV and HDV Fleet,

⁶⁷ UBA (1997), BMV (1994)

⁶⁸ HICKMAN ET AL. (1997), KBA (1995)

- Bus Fleet,
- Road Fuel Consumption,
- Car, Bus, LDV&HDV Traffic Volume,
- Hot NO_x-emissions of Road Transport and Total Transport,
- Hot NO_x-emissions of Car, LDV, HDV, Railway Transport for 1994,
- Hot CO₂-emissions of Road Transport and Total Transport for 1980, 1990, 1994, 1995 and
- Fatalities and Injuries of Road Accidents and Slow Mode Accidents.

It can be stated that the aggregate fuel consumption, the aggregate fleet numbers and the aggregate fatalities are the best documented and most reliable figures. Less reliable data or lacking data is the case for the different cubic capacities in the fleet or the fleet emission legislation categories, for the vehicle kilometres travelled, for light injuries and material damages of accidents and for historic emission data.

Summarising the status of calibration, the best fit to real data is currently given for aggregated fuel consumption (petrol -3% to -9% deviation, diesel -30 to -20% deviation) and Car Fleet (-4% to -18% deviation). For fatalities the deviations are in the range of -10% to +20% depending on the regions. The deviations for NO_x emissions of road transport are in a range of -15% to 20% and for all CO₂ emissions from transport in the range of -3% to 11%.

6.4.5 Interfaces to other Sub-modules

There have been intensive discussions among the partners to identify possibilities to implement feedbacks of whatever kind of environmental quality indicator into other sub-modules. At the present state of the underlying conventional models this seems not to be feasible. The reason is that the conventional models often realise that environmental concerns are important, but they are not integrated into the models. For instance, regional planners discuss about soft factors, which influence location choices, but functional relationships for this influence are missing. Also, macroeconomic models often only include capital and labour within their production function, while the environment (e.g. natural resources) are treated as they would not influence the production output. However, from the viewpoint of research disciplines like ecological economics, the models can be improved to reflect these influences.

Therefore two ways of feeding back output from the ENV concerning environmental quality can be seen. The first way is to drive and to adjust the levers of policy measures. For instance, if a fuel tax is imposed to reduce CO₂ emissions to achieve a reduction target the height of the tax can be adjusted over the time path of the simulation in dependency of the deviation from the target. This can be realised within the demonstration examples. The second way that is

already implemented in the model is to transfer aggregated welfare indicators from the ENV e.g. externalities and from the MAC e.g. GDP to a sector that then presents the development of the welfare situation over time.

Besides environmental and welfare indicators the ENV creates three further types of output. The first one are fiscal indicators that depend mainly on consumption of natural resources. One example would be the fuel tax revenues that are transferred from the ENV to the MAC. The second type of output concerns information related to the vehicle fleet. With the car fleet model the total change of the car stock is estimated. This information of changes is transferred to the REM, where it influences the development of car-ownership. Also, within the vehicle fleet models the purchase of new cars is calculated. Considering average vehicle prices the purchase expenditures for road vehicles are transferred to the MAC. The third type of output are total fuel prices including pure fuel price, fuel tax and VAT on fuel that are transferred to the TRA where they influence the transport costs.

7 ASTRA Demonstration Examples

In this chapter the general framework of European transport policy is presented which is the background for the ASTRA demonstration examples. The advantages of applying a system dynamics model for policy testing will be explained and finally the definition and results of the base run and six policy packages will be presented.

7.1 The ASTRA Policy Assessment Framework

One of the premier objectives of the ASTRA project is to develop a model for strategic policy assessment. Of particular importance in this respect is the provision of an assessment tool, capable of identifying and analysing the long term impacts of European policy decisions, notably those related to the Common Transport Policy (CTP) and the Trans-European Networks (TENS).

The goal of CTP (1992) is to close gaps in the European transnational networks of both rail and road infrastructure and this has been justified largely in economic terms; investment in new and improved infrastructure is viewed as a way of generating economic growth and stimulating regional economic development. With this goal very much in sight, most of the objectives of the CTP (see below) address the traditional transport problem of how to move passengers and goods from one place to another, within the context of reinforcement of the internal market.

7.1.1 Objectives of the Common Transport Policy

The objectives of the CTP can be listed as follows:

- the continued reinforcement and proper functioning of the internal market, facilitating the free movement of goods and persons throughout the Community,
- the transition from the elimination of artificial regulatory obstacles towards the adoption of the right balance of policies favouring the development of coherent, integrated transport systems for the Community as a whole using the best available technology,
- the strengthening of economic and social cohesion through the contribution which the development of transport infrastructure can make to reducing disparities between the regions and linking island, land-locked and peripheral regions with the central regions of the Community,
- measures to ensure that the development of transport systems contributes to a sustainable pattern of development by respecting the environment and, in particular, by contributing to the solution of major environmental problems such as the limitation of CO₂,
- safety measures,
- social welfare measures and
- the development of appropriate relations with third countries, where necessary giving priority to those for which the transport of goods or persons is important for the Community as a whole.

Improvement of the environment, social welfare and safety clearly are also important objectives of the CTP and together with mobility aims, these have been promoted through the Common Transport Policy Action Programme (CTAP) introduced in 1995. The CTAP outlines current and planned initiatives, aiming in particular to deliver transport systems which offer improved competitiveness and safety plus reduced environmental impact. CTAP also aims to actively promote efficiency and choice in order to improve the functioning of the Single Market and to improve links with third countries.

More recently the European Commission has considered ways in which transport prices can better reflect the costs to society of pollution, congestion and accidents. The 1998 Transport White Paper on Fair Payment for Infrastructure Use represents an important step forward in the development of policies, which particularly address the problems caused by congestion. Again the main justification underlying the policy proposals set out in the White Paper is economic growth and regional economic development. This time, however, the ultimate goal is to achieve fair payment for transport infrastructure use through the gradual and progressive harmonisation of charging principles for all commercial transport modes.

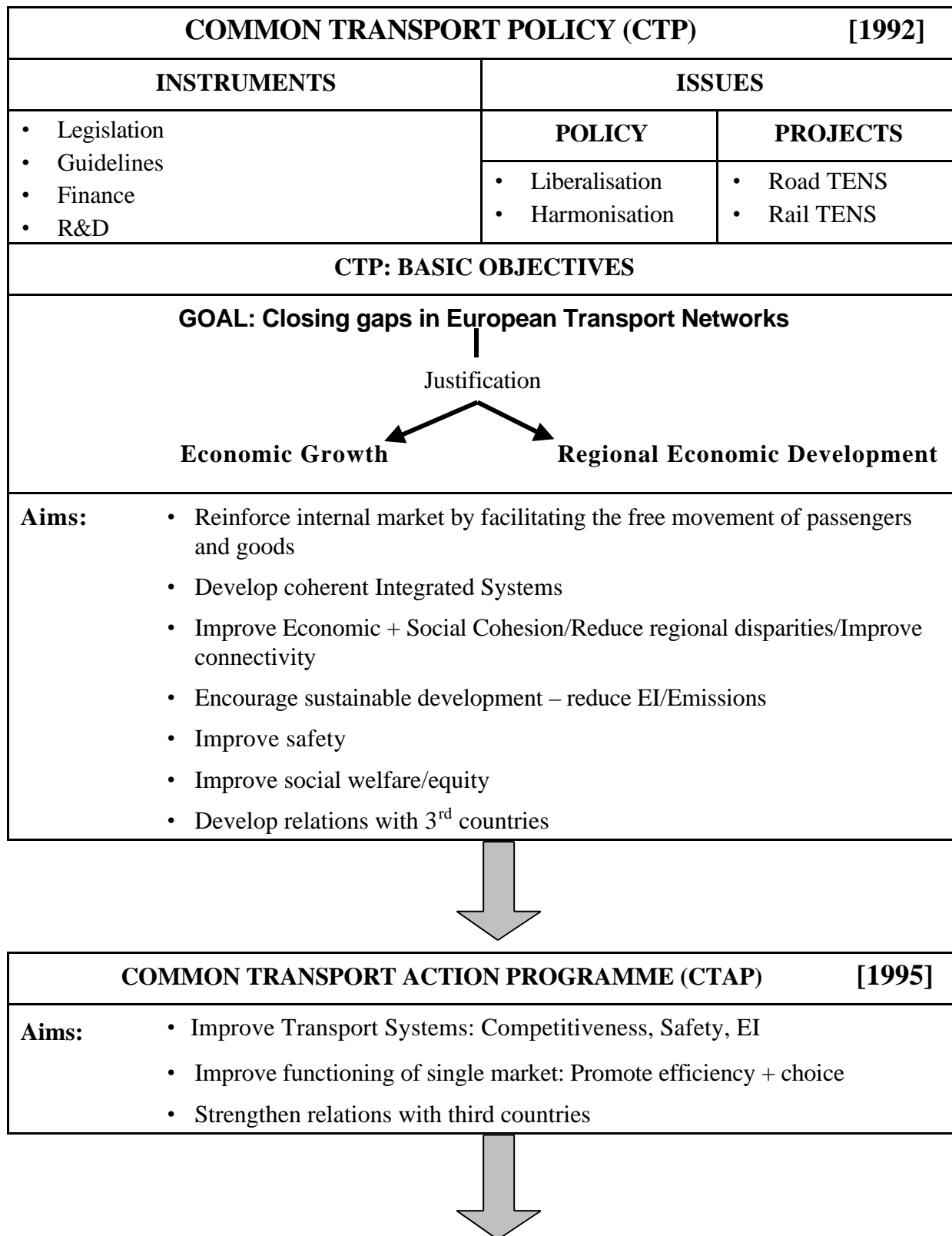
Key amongst the principles on which the White Paper is based is the premise that the **user pays**, ie, all users of transport infrastructure should pay for the costs they impose at or close to the point of use. This in turn gives rise to the principle that transport prices should reflect the costs of pollution, congestion and accidents.

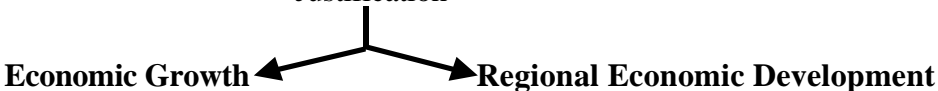
The 1998 White Paper outlines a step by step, phased approach to implementation of what promises to be a far-reaching policy and project development framework. It also sets out the essential criteria for transport scheme selection with net social benefits to be estimated through a comprehensive physical evaluation and economic cost-benefit analysis. This takes into account land use/economic impacts, cross-state effects and accessibility as well as:

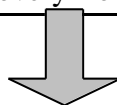
- integration
- economic and social impacts
- environmental safety
- safety
- equity
- external trade
- competitiveness
- efficiency
- cost recovery

The following section identifies the main, relevant components of European transport policy and traces its development through the 1990's. This provides the basic framework for the development and assessment of the ASTRA Demonstration Examples, which are then considered in the subsequent sections.

7.1.2 Components of European Transport Policy



FAIR PAYMENT FOR INFRASTRUCTURE (FPI)		[1998]
OBJECTIVES		
<p>GOAL: Fair payment through gradual and progressive harmonisation of charging principles for all commercial modes of transport</p> <p style="text-align: center;">Justification</p> <p style="text-align: center;">  </p>		
Principles:	<ul style="list-style-type: none"> • User Pays (all users of infrastructure pay for the costs they impose at/close to point of use) • Transport prices should reflect costs of pollution, congestion, accidents • Member states specify charging levels – subsidiarity principle maintained 	
Aims:	<ul style="list-style-type: none"> • Improve technical efficiency of transport systems (use) • Improve efficiency of provision • Remove distortion in competition (intra + inter-modal) • Improve incentives to cut environmental costs • Raise levels of cost recovery from users (via marginal social cost charging) 	



FPI: IMPLEMENTATION
<p>Step by step approach</p> <p>Phase 1 (1998-2000)</p> <ul style="list-style-type: none"> • Introduce charging systems for rail and airports to complement road haulage • External costs charged per agreed EU framework capped by average infrastructure costs <p>Phase 2 (2001-2004)</p> <ul style="list-style-type: none"> • Better harmonisation/adaptation of charging system • HGV and Rail – per km charges differentiated by vehicle type + geographical area – introduce ports charges • Marginal infrastructure + local + community wide external costs <p>Phase 3 (2004 +)</p> <ul style="list-style-type: none"> • Continued implementation of harmonised charging • Update framework with benefit of hindsight
FPI: CRITERIA FOR SCHEME SELECTION
<p>Net Social Benefits estimated through comprehensive Cost Benefit Analysis incorporating</p> <ul style="list-style-type: none"> • Cross State effects • Land use/Economic Impacts • Accessibility

7.2 Advantages of Policy Testing with ASTRA

The use of the system dynamics (SD) methodology and of standard SD software packages provides several advantages against most other forecasting and assessment approaches like qualitative, point-to-point or partial model forecasts. These can be summarised under the headings:

- consistency,
- verifiability,
- stepwise policy implementation,
- multiple policy implementation,
- time-path indicators,
- intensity indicators and
- linking backcasting and forecasting.

7.2.1 Consistency of Policy Results

The major task in modelling a SD model consists of the identification, mathematical formulation and quantification of the key-relationships of the investigated real system. Presupposing that this process is reasonably carried out a model with inherent consistency for assumptions and all model variables is created. For instance, demand forecasts e.g. of energy use or transport performance sometimes neglect also to consider the technological or social possibilities of the development on the supply side. Also if the same exogenous variable is influencing several model elements e.g. fuel tax influences fuel prices, vehicle purchase, or tax revenues it can be assured in the framework of a SD model that all model elements are driven by the same development of this variable. This also contributes to the consistency of a model.

7.2.2 Verifiability of SD Models

As most standard SD software packages provide similar easy-to-use graphical user interfaces (GUI) the possibility for users (e.g. decision-makers, other expert users) exist to review the structure of the complete model and to verify implemented functional relationships or the underlying assumptions consisting of the exogenous variables. The scope of this verification opportunities depends on the users equipment and the technical possibilities of the software to create executable or interpretable files. The broadest position for verification is given, if users dispose about the same standard software. However, this might imply an additional investment in the purchase of the software package. So, the most practicable solution is to provide users with runtime versions, which should provide the necessary capabilities for comprehensive verification but limits the ability to make changes at the model. In the case of executable files the users can only run the model and receive the results.

7.2.3 Stepwise Policy Implementation

SD models provide data for all included model variables over the full simulation period. Also policy variables can be introduced at any point of time during the simulation. They can be changed for any time-step during the simulation. The changes at policy variables can be implemented in three ways. If only at one or two points of time a certain variable is changed, this can be done within the equation with the use of an if-then-else statement. For a policy with several changes in intensity at different points of time these can be realised with graphs (ithink) or lookups (Vensim). Also policies can be fed from exogenous data files like spreadsheets (e.g. EXCEL) or software specific files. An example for stepwise policy implementation with a graph/lookup is given in figure 48:

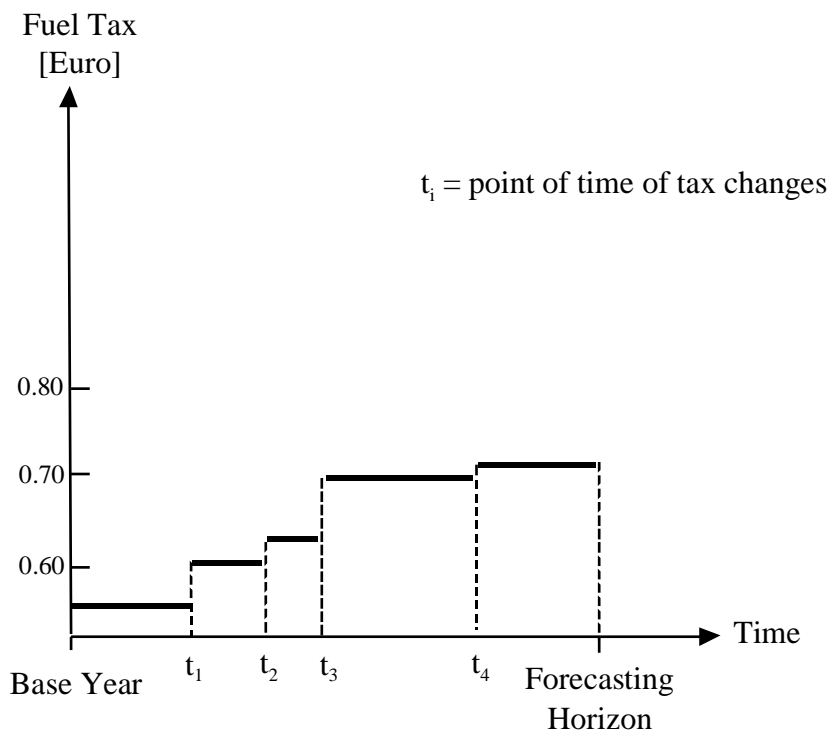


Figure 48: Example of Stepwise Policy Implementation

However, for the demonstration examples it should not be necessary to vary the policies within the model variables or graphs itself, as these are implemented with control tools on the ASTRA Steering Panel.

7.2.4 Multiple Policy Implementation

The ability for multiple policy implementation means to apply more than one policy measure during one simulation run. Each policy might be implemented stepwise. This enables to check if synergies or countereffects between the policies exist. With the knowledge on synergies different policy measures can be grouped to more effective and reasonable policy packages.

7.2.5 Time-path Indicators

The values of each variable are calculated for every point of time during the simulation period. This enables to present the development of indicator variables during the complete time path of the simulation, which is a big step ahead compared to point-to-point analysis where the results consist of a base year value and a forecast year value. Also for some variables a policy can cause important different effects even when the values at the forecasting horizon are the same. This happens when the aggregate values would be different. Considering for instance CO₂-emissions it makes a big difference if the aggregated CO₂-emissions of two policies differ significantly. This is shown in figure 49:

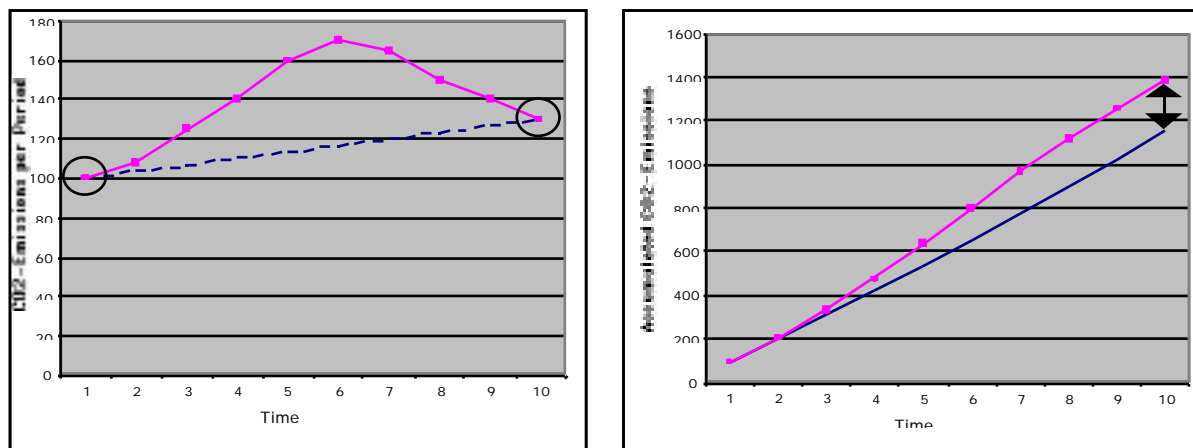


Figure 49: Different Results with Point-to-Point-Indicators and Time-path-Indicators

The difference of the curve in the right diagram of figure 49 can only be detected from time-path indicators.

7.2.6 Intensity Indicators

SD models require the quantification of all included variables. Therefore new indicators can be constructed by relating two or more variables with each other. In principle, this can be done with each combination of variables and any mathematical function. A reasonable approach would be to calculate intensity indicators by dividing one variable with another one. For instance CO₂-emissions from transport divided by GDP provides an important information about the CO₂-emission intensity per GDP of different policies.

7.2.7 Linking Backcasting and Forecasting

Backcasting techniques have been successfully used to draw images of the future and to think qualitatively about the development paths towards these images. This approach can be improved if one aspires to quantify these development paths with an integrated model. This can successfully be done with a system dynamics model as it has been shown by the ESCOT model within the OECD-EST project. On the European research agenda a combination of results from the POSSUM and ASTRA project could lead to a promising approach linking backcasting and forecasting techniques for a profound long-term policy assessment.

7.3 ASTRA Scenarios, Simulation Runs and Policies

The ASTRA demonstration examples cover a reference scenario and several policy scenarios. Each scenario is described by a corresponding simulation run with specific changes of exogenous variables. Changes can be applied on constants or graph variables in the model. Experts who dispose about the software capabilities might create individual scenarios. However the creation of individual scenarios is only recommended for sensitivity analysis and not yet for individual forecasts.

The content of results of simulation runs with the ASTRA system dynamics model platform (ASP) is twofold. Firstly, regarding the mere simulation results the development of indicator variables in terms of increases, decreases, fluctuating behaviour or even breaks in developments are presented graphically and by quantities. Secondly, the development of indicator values over time can be compared with their development in the reference scenario. This approach is shown in figure 50:

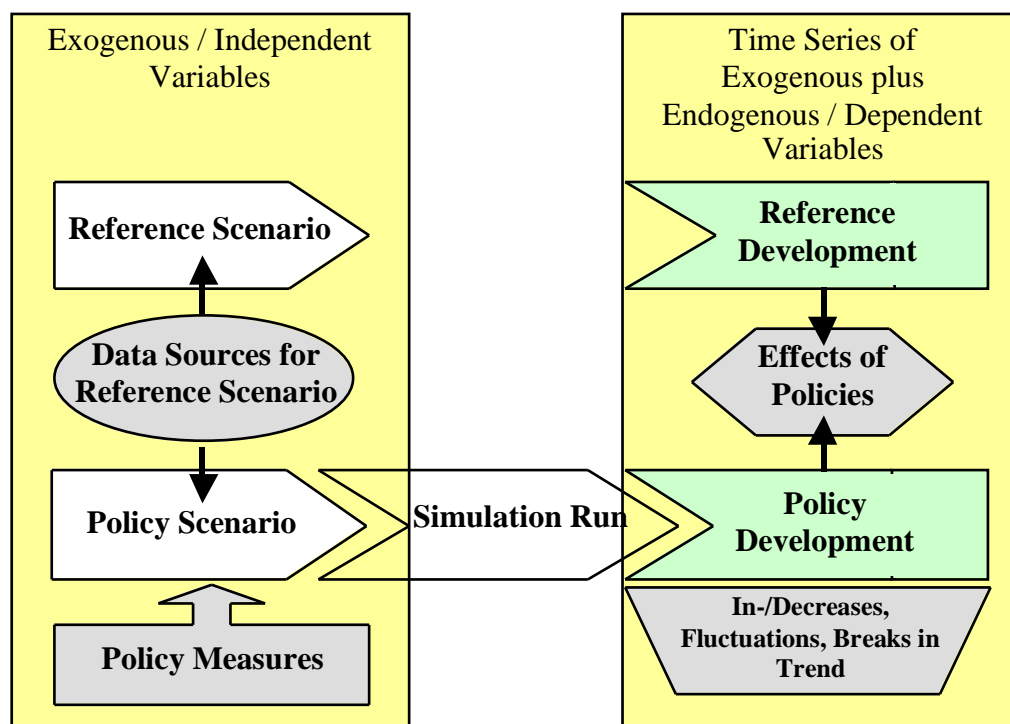


Figure 50: Connection between Reference and Policy Scenarios

This approach raises the problem to define a so-called base scenario or reference scenario, which is discussed in the next section. In the subsequent sections the tested ASTRA policy packages are described. The final section of this chapter presents results for some sensitivity tests. Looking at the results one should have in mind that the ASTRA model goes beyond the common notion of direct and indirect effects in transport research. Direct effects of policies could be re-routing, short-term changes in modal-split, destination and trip length, which can be observed with ASTRA. Usually indirect effects of transport policies are change of

locations (either private or industrial), changes of settlement structure or logistics. This is covered to a certain extent (e.g. by looking at long-term changes of trip length), but there is no local or map-based investigation. However, other indirect effects are in the focus of ASTRA, which e.g. can be provided by the economic effects of changes in transport that might change private consumption and subsequently influence the investment patterns of the economic sectors leading to economic effects that finally effect transport, which was initially the cause of the effect.

7.3.1 ASTRA Reference Scenario

One of the major objectives of the SCENARIOS project is the definition of a reference scenario especially with regard to transport research. In SCENARIOS it is stated that in general a reference scenario can be constructed with a projection of past and current trends of key variables to the desired time horizon. This approach implies that no trend breaks for the key variables are occurring during the period of investigation. *“In this way the reference scenario can provide a standard against which other contrasting hypotheses can be compared. However this does not imply that the reference scenario is the most probable future position.”*⁶⁹

The construction of the ASTRA reference scenario follows the approach of the SCENARIOS project. That means for the ASTRA reference scenario it is also assumed that during the simulation period until 2026 no break in trends occurs. So, it is aspired that the development of key variables in the SCENARIOS reference scenario and the ASTRA reference scenario correspond to each other. However, in SCENARIOS not all variables of the ASP are covered. Therefore, further sources for the definition of the ASTRA reference scenario are used. One major source is the data set that is produced by the STREAMS model reference run, which defines reference developments for several variables in REM and TRA. Other sources are EUROSTAT statistics and results of research projects like MEET⁷⁰ and EUFRANET⁷¹, the Swiss/German handbook on emission factors (HB-EFAC)⁷² and OECD projections. Finally, the simulation run with the reference scenario produces the reference values for the remaining variables such that for each of the variables in the ASP a reference development is existing that later on can be compared with the values produced by the various policy simulation runs.

In the following, reference developments of key variables in the reference scenario are presented. The annex contains further information and the most comprehensive view of the reference scenario is provided with the ASP, where each variable can be reviewed. To compare the reference developments with results of the model it is necessary for most of the variables to aggregate them into the four macro regions. For variables within the passenger model of REM and TRA an aggregation into the six functional zones is needed. This is shown in the following population projection for the reference scenario:

⁶⁹ SCENARIOS (1998)

⁷⁰ HICKMAN ET AL. (1997)

⁷¹ EUFRANET (1999)

⁷² BUWAL ET AL. (1995), BUWAL ET AL. (1999)

Table 44: Development of Population in ASTRA Reference Scenario (EUROSTAT 1999)

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
H DU	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 Madeira

One has to mention that here again the difference between a discrete time series given for the reference scenario (values for seven points of time) and a quasi-continuous time series produced by the ASP (values for every integration period = 120 values) has to be considered. That means, the curve in the first case is assumed to be a straight line between the points of time, while in the second case the system dynamics models might change the slope of the curve for every integration period. It is obvious, that it is not reasonable to fit the dynamic curve exactly to the straight line, even if it would be possible. This argument is enforced as the dynamics are one of the issues we are looking for.

The following graph presents the reference development of GDP in 1992 values as it is provided by the SCENARIOS project.

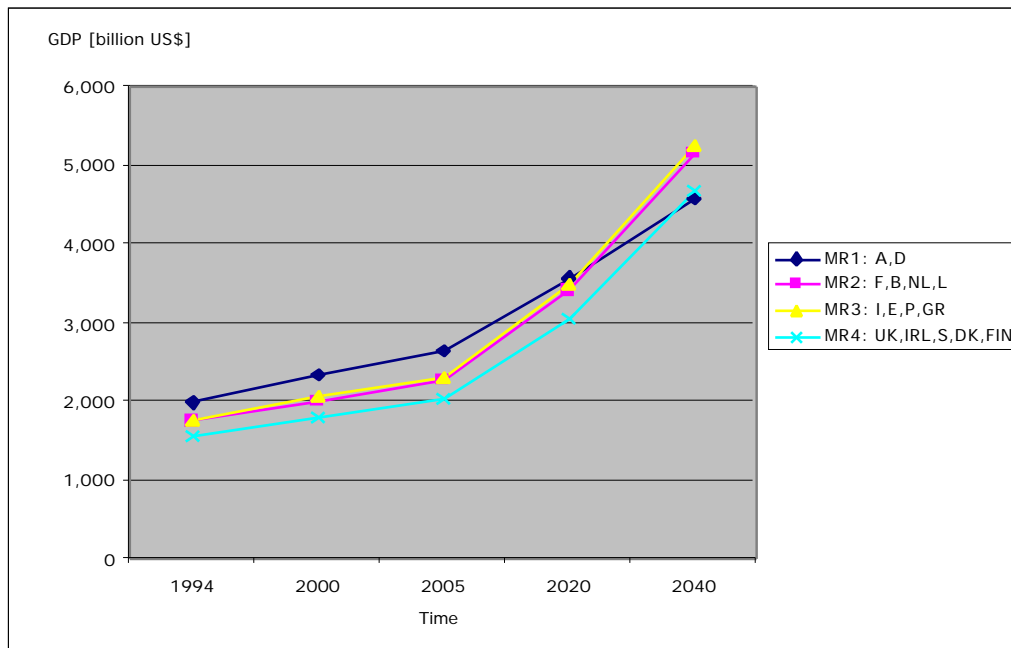


Figure 51: Development of GDP in the Reference Scenario (SCENARIOS 1998)

The next figure demonstrates the reference development for employment in the MAC taken also from SCENARIOS reference scenario.

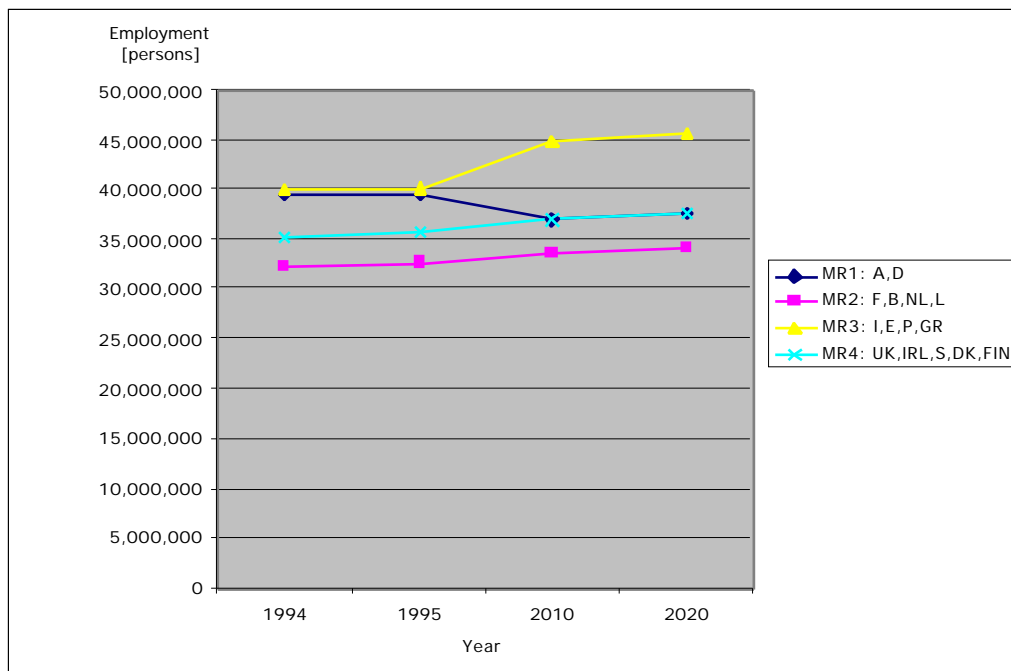


Figure 52: Development of Employment in the MAC in the Reference Scenario (SCENARIOS 1998)

Table 45 summarises the aspects of the reference scenario belonging to the REM. Some examples of data for the reference developments are presented in this section, while the full details are presented in the annex B. 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 45: Summary of Trends in REM Sub-module for Reference Scenario (1996-2026)

REM Model	Future trend	Exogenous inputs	Reference Development (Endogenous Variables)
<i>Passenger model</i>			
Demographic	Change in structure and size of population over time	<ul style="list-style-type: none"> • Birth rates • Life expectancy • Death rates 	<ul style="list-style-type: none"> • Population growth rate slows down 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	<ul style="list-style-type: none"> • Activity rates 	<ul style="list-style-type: none"> • Working age population begins to fall • Labour force growth rate slows and starts to decline
Car ownership	Car ownership changes over time	<ul style="list-style-type: none"> • Calibrated parameters 	<ul style="list-style-type: none"> • More people in car owning cohorts
Passenger trips/ trip length	Trip rates per person remain relatively stable whilst trip lengths increase	<ul style="list-style-type: none"> • Trip rates 	<ul style="list-style-type: none"> • Number of trips per person remain relatively stable • Trip lengths tend to increase with falling unit transport costs
<i>Freight model</i>			
Industrial production	Stronger growth in high technology sectors	<ul style="list-style-type: none"> • Industrial sector growth rates 	<ul style="list-style-type: none"> • Changing industrial structure
Freight volumes/ length of haul	Trends in volume densities of different industrial production	<ul style="list-style-type: none"> • Value to volume ratios 	<ul style="list-style-type: none"> • Changing levels and mix of freight volumes to be moved • Length of haul tend to increase with falling unit transport costs

The reference scenario for the car vehicle fleet, that is influencing the car-ownership (REM) and the emission factors, can be taken from MEET and OECD projections. However, the projections provide the clue for the scenario as developments of influencing factors (e.g. income, fuel prices) are not fully consistent between the projections and ASTRA. Also, it is stated for the MEET project, that if the composition of the fleet is of importance, then own control on the fleet should be exercised. The MEET projection is shown in figure 53:

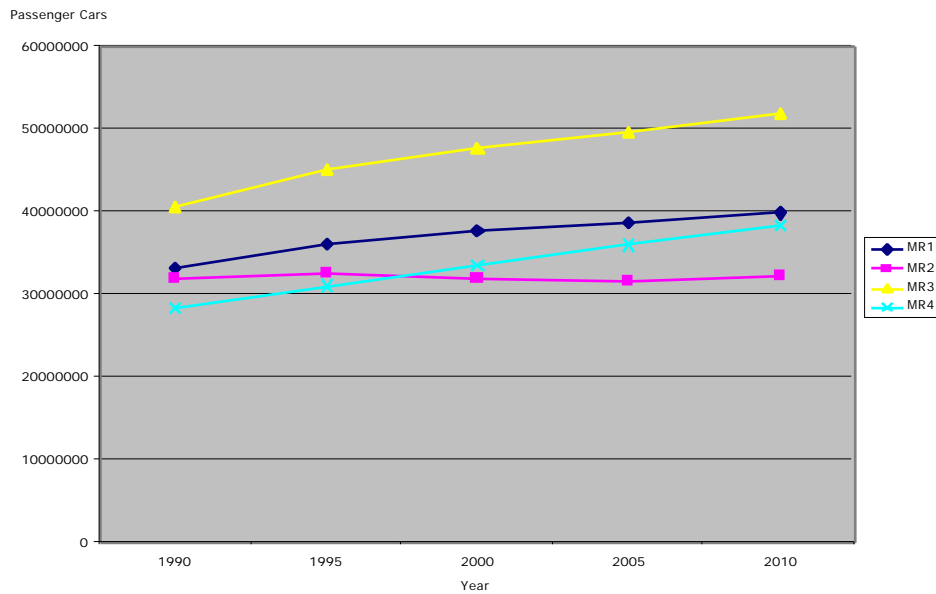


Figure 53: Development of PC Vehicle Fleet (MEET D4, TRENDS-Project)⁷³

The time series showing ASTRA reference developments presented in the previous table and graphs stem from the reference scenario of the SCENARIOS project and the EUROSTAT projections. In the following, developments for indicators in the ASTRA base scenario produced by the complete ASP are presented. Figure 54 presents the development of GDP for all regions.

⁷³ HICKMAN ET AL. (1997)

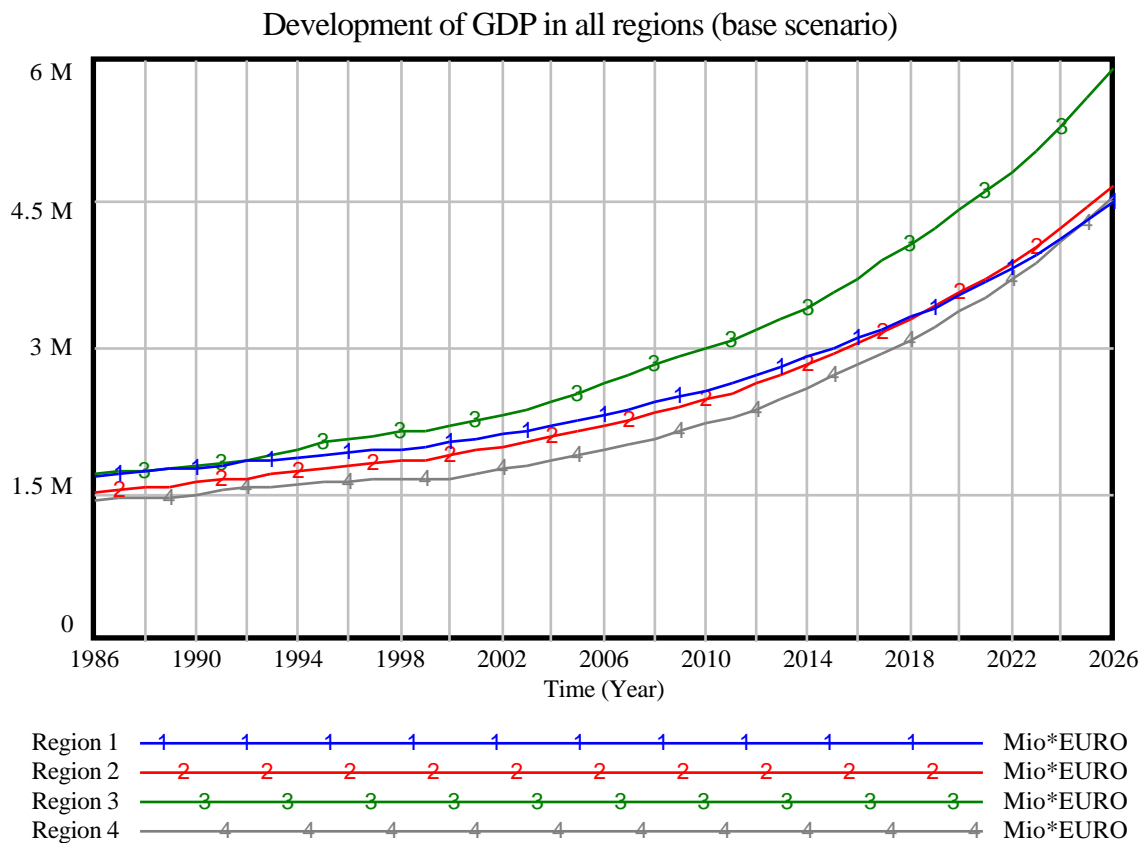


Figure 54: GDP in Base Scenario for Region 1 (A, D), Region 2 (B, F, NL, L), Region 3 (E, GR, I, P) and Region 4 (DK, FIN, IRL, S, UK)

As can be seen from the curves in figure 54 the model is not designed to reflect oscillations caused by short-term business cycles. Instead the long-term economic trends should be indicated by the model. The resulting development of real GDP is in line with the forecasts of long-term yearly average growth rates until 2020 in the SCENES project (see table 46).

Table 46: Comparison of long-term growth rates for real GDP between ASTRA and SCENES

[%]	Region 1	Region 2	Region 3	Region 4
SCENES	1.9	2.56	2.6	2.38
ASTRA	2.1	2.4	2.7	2.4

These high growth rates can be justified beyond others by the accelerated technical progress that fosters productivity caused by the new information technologies and growing market entanglement. However, as population will start to decline between the years 2004 to 2010 in the different European regions the risk of shortages of employees at least shortages of qualified employees arises. In this case a reduction in growth of productivity will hamper the economic growth because of a lack of labour force. That would imply that the optimistic forecasts can not be realized. Considering this background the development of employment is given in figure 54.

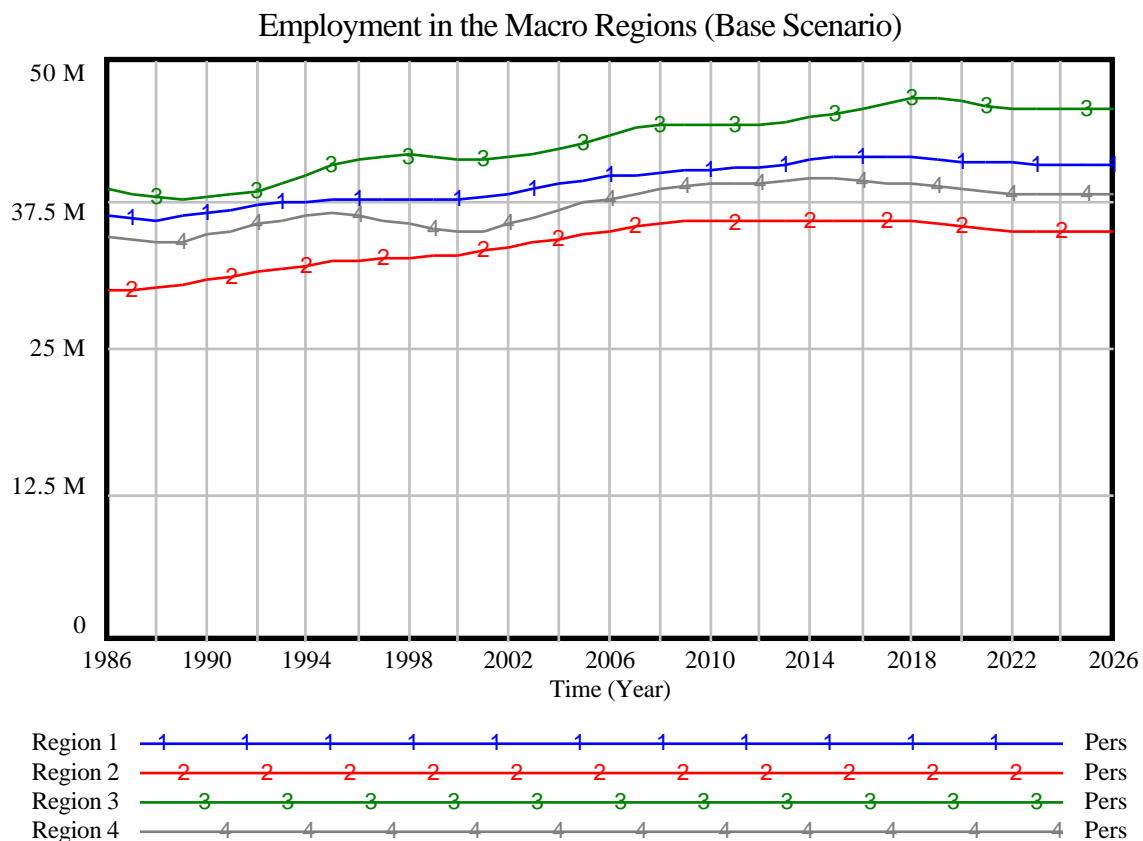


Figure 55: Employment in Base Scenario for Region 1 (A, D), Region 2 (B, F, NL, L), Region 3 (E, GR, I, P) and Region 4 (DK, FIN, IRL, S, UK)

The curves for employment show a slow but continuous growth for all regions until around 2016. Then there seems to be a turnaround for the development of employment, which is mainly due to the fact that population in all regions declines. In parallel also the labour productivity implemented in the model as ratio of employees per gross value added within the 12 economic sectors increases, which is shown in figure 56.

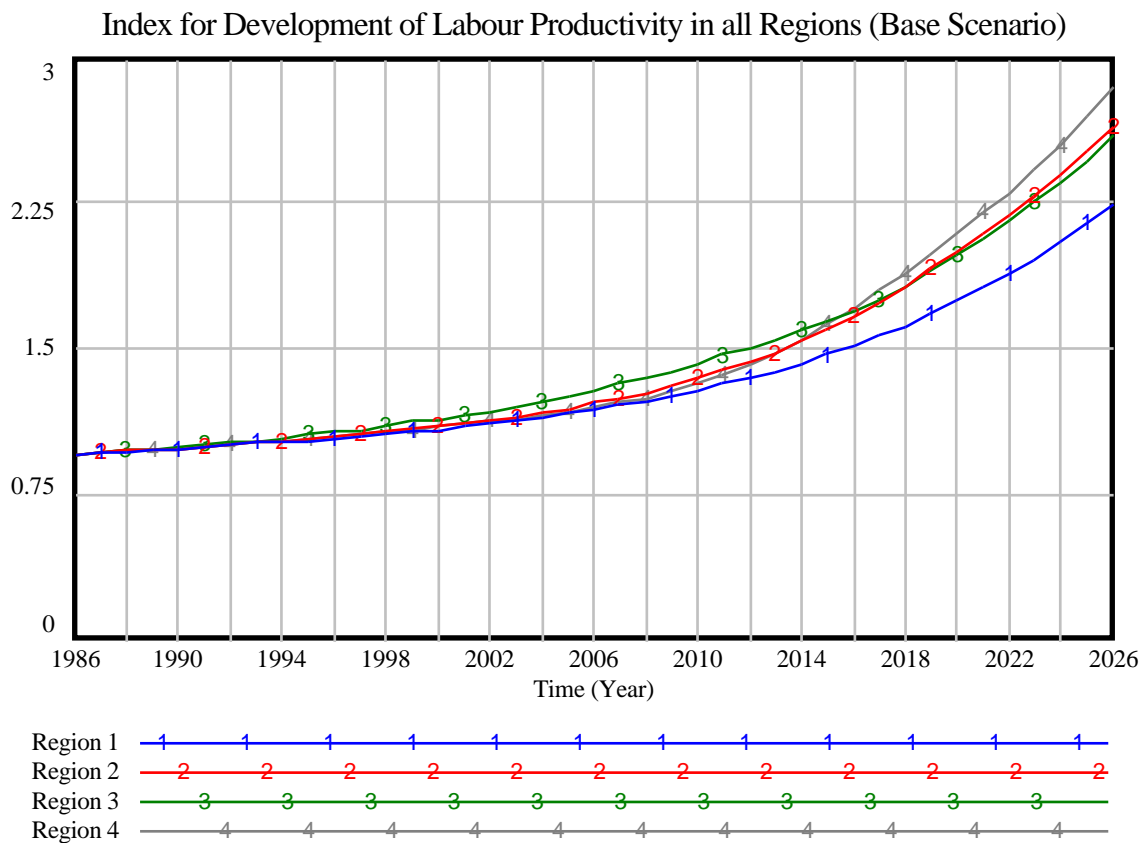


Figure 56: Index for the Development of Labour Productivity in Base Scenario for Region 1 (A, D), Region 2 (B, F, NL, L), Region 3 (E, GR, I, P) and Region 4 (DK, FIN, IRL, S, UK)

The previous indicators all belong to the MAC. In the next section major indicators of the REM are presented. As the REM is structured into macro regions for freight and into functional zones for passenger transport some of the following indicators are given for the zones scheme. In figure 57 the development of European population is presented based on the structure of the functional zones. Despite for HDD regions the population in the zones starts to decline between around 2006 and 2010. In total the decline leads to a slight decrease of European population after around 2006.

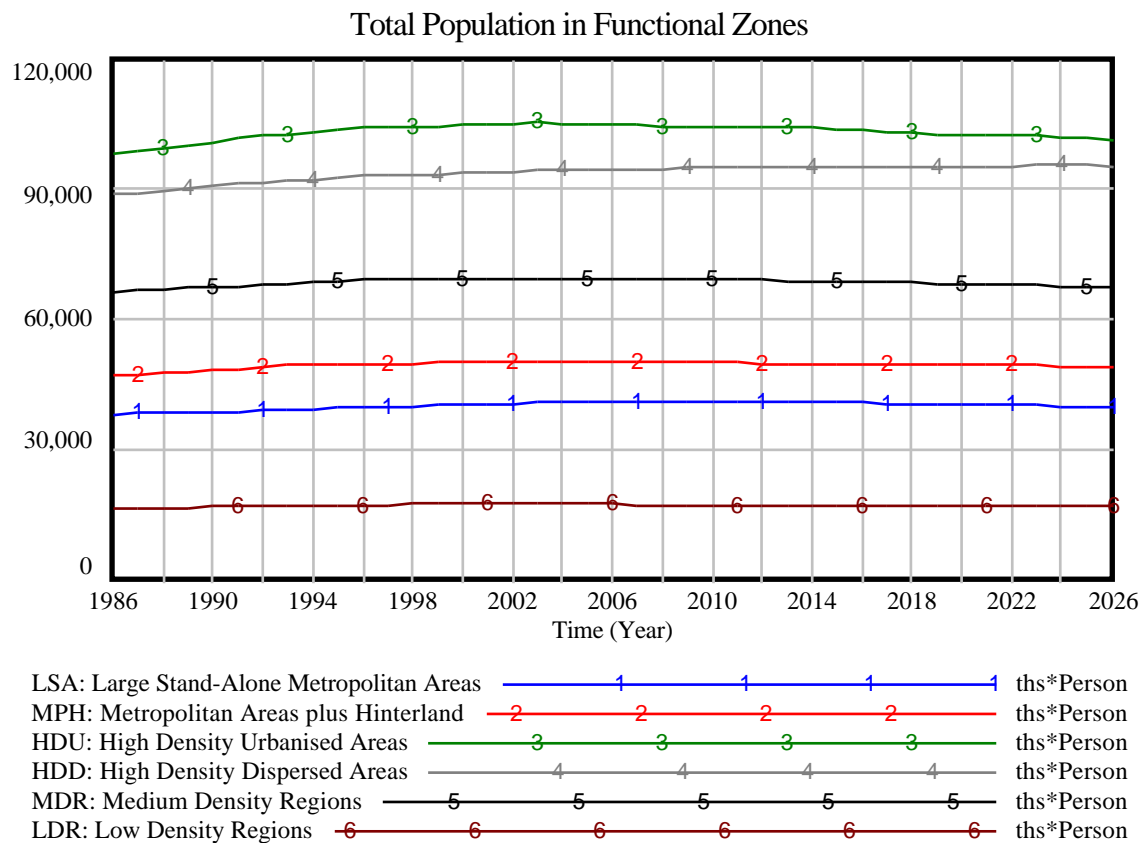


Figure 57: Total Population per Functional Zone

The depicted development of population is the major influencing variable for the demand of passenger trips shown in the following figure 58. Until about 1998 the total trip demand increases by 0.7% per year. After this period the demand is nearly stable, which corresponds to the stable respectively declining population. About 75% of all trips are private trips with a slightly decreasing trend. The share of business trips is around 20% with a slightly increasing trend. Tourism trips count for about 2.5% of all trips and are also slightly increasing.

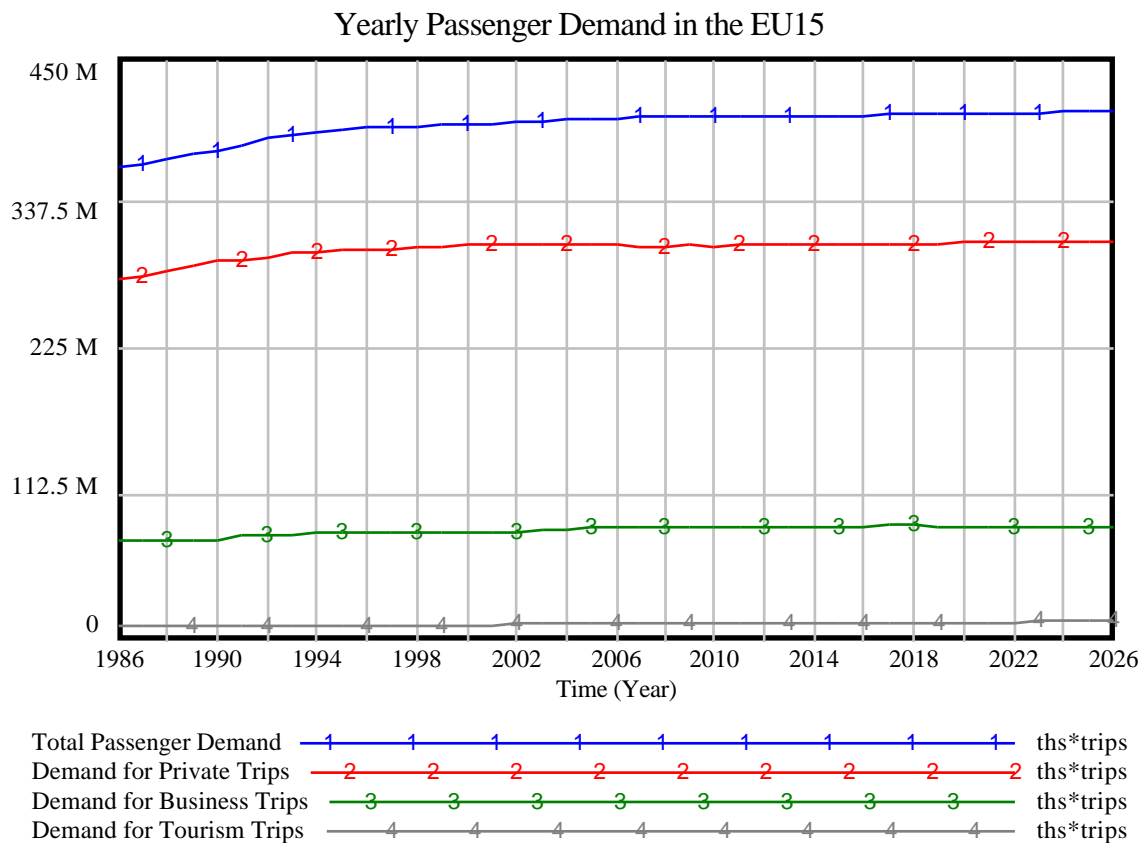


Figure 58: European Demand for Passenger Trips

The distribution of trip demand on the five distance bands is shown in figure 59. For the demand share of the two distance bands below 8km (local and very short distance band) a decreasing tendency can be observed. In the initial years the share of the local distance band amounts to 40% and of the very short distance band to 24%. For the other three distance bands increasing shares are discernible with the strongest growth for medium distance trips (40-160km) and only a minor growth for short distance trips.

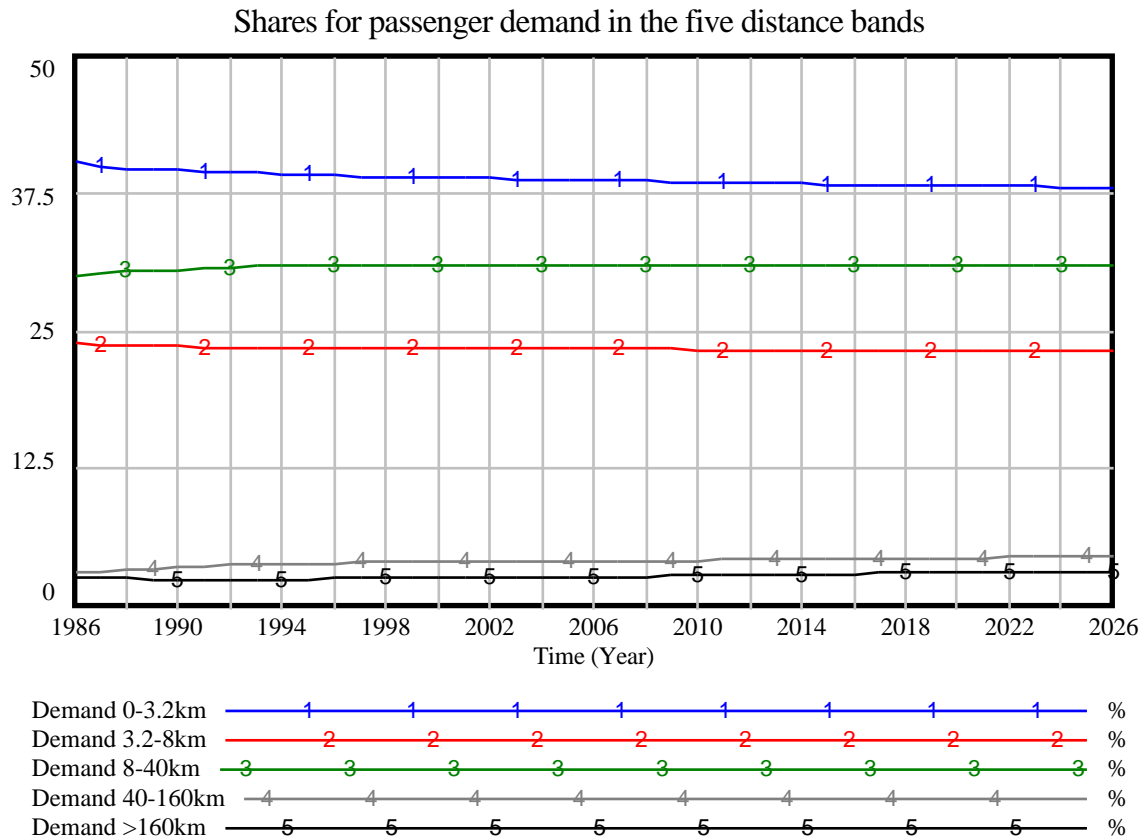


Figure 59: Split of Trip Demand between the five Distance Bands for Passenger Transport

In the following indicators of the TRA in the base scenario are shown. In figure 60 the passenger modal-split related to transport performance (pkm) is depicted. It can be observed that the split of car transport is relatively stable with a plateau of 74% in the years before 2000. For bus transport the share is decreasing strongly and the share of rail transport is declining slightly. A very strong increase can be observed for the share of air transport, which is nearly doubling between 1986 and 2026. Slow mode is stable with a share of around 1%. The next figure 61 below figure 60 presents the modal-split related to trip volumes for the interurban trips (> 40km). The shape of the curves are very similar, however the levels are different. Especially the share of air mode is about 50% higher, which is due to the consideration only of interurban trips in the latter figure.

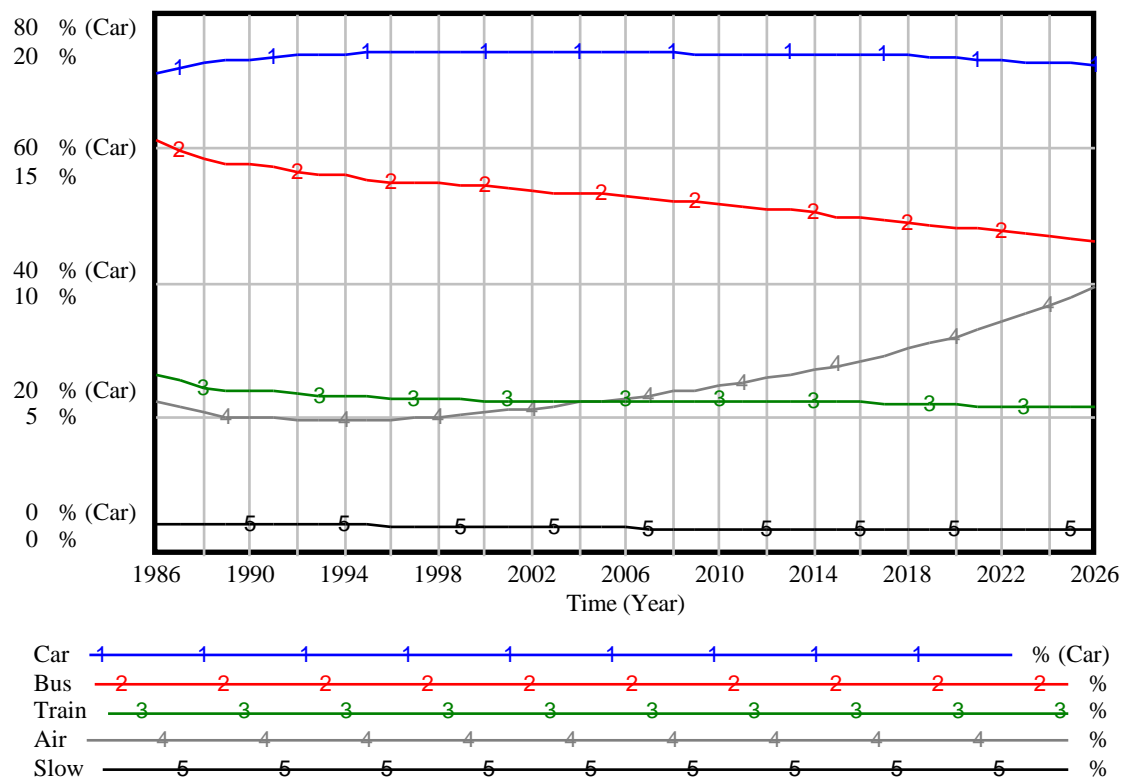


Figure 60: Passenger Modal Split related to Transport Performance in EU15 Countries

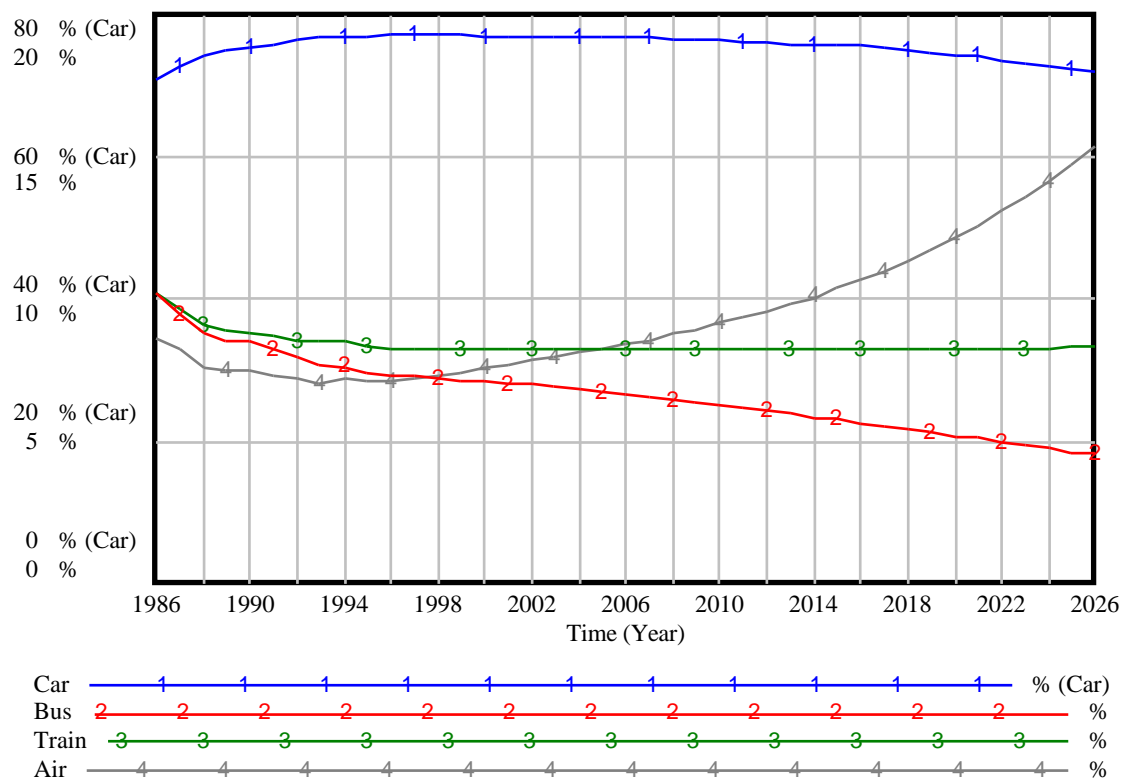


Figure 61: Passenger Modal Split for Interurban Trips in EU15 Countries based on Trip Volumes

The following figure 62 shows the origin passenger transport performance (pkm) in the long distance band over 700km for the zone covering the metropolitan areas plus hinterland (MPH). The notion origin stands for all trips starting in the MPH zone e.g. a trip from MPH zone to HDD zone would count for MPH zone. The most interesting curve is obviously curve 4 representing air transport, which in the initial years is at the same level as bus and train mode. But around 2024 air mode has more than doubled and has even overtaken car transport. Rail mode is nearly stable, while bus mode is strongly decreasing. Car mode is increasing but it seems that around 2015 the maximum level is reached.

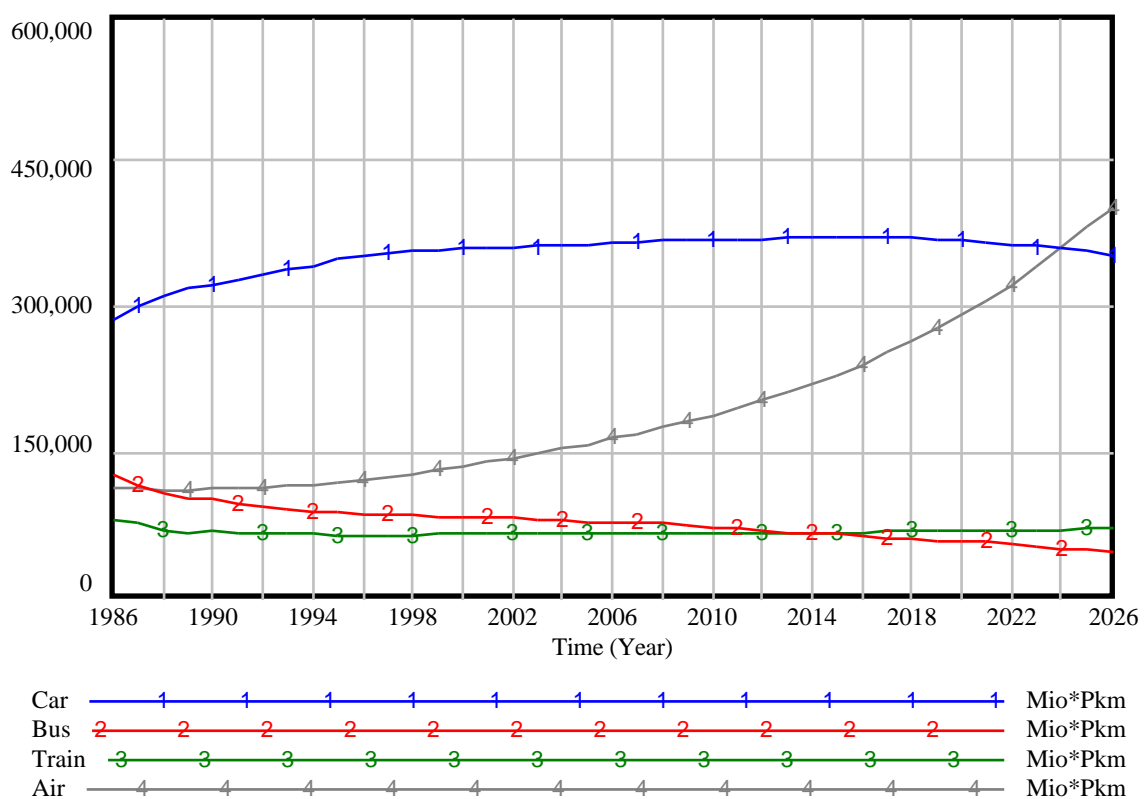


Figure 62: Yearly Origin Passenger Kilometres per Mode for Metropolitan Areas plus Hinterland (MPH zone) in the long distance band (>700km)

The following figure 63 presents the freight origin modal split in the medium long distance band (150-700km) related to transport performance (tkm) for region 1 (A, D) and region 4 (DK, FIN, IRL, S, UK). Origin modal split stands for the view on all trips starting in this region. E.g. a long distance haul from region 1 to region 4 by train would count for the modal split in region 1 as this is the origin of the trip. It can be seen that the structure of the modal split is similar in both regions with truck carrying most of the haul followed by train and then by ship. However, differences can be identified as in region 4 the share of ship transport is more than double compared to region 1, which is explained by the fact that in and between UK and IRL as well as between DK, S, and FIN ship transport over these distances is possible, whereas the opportunities for A and D for ship transport are fewer. Also the share of train transport is higher in region 4 than in region 1. Consequently in region 1 the share of truck transport is higher than in region 4.

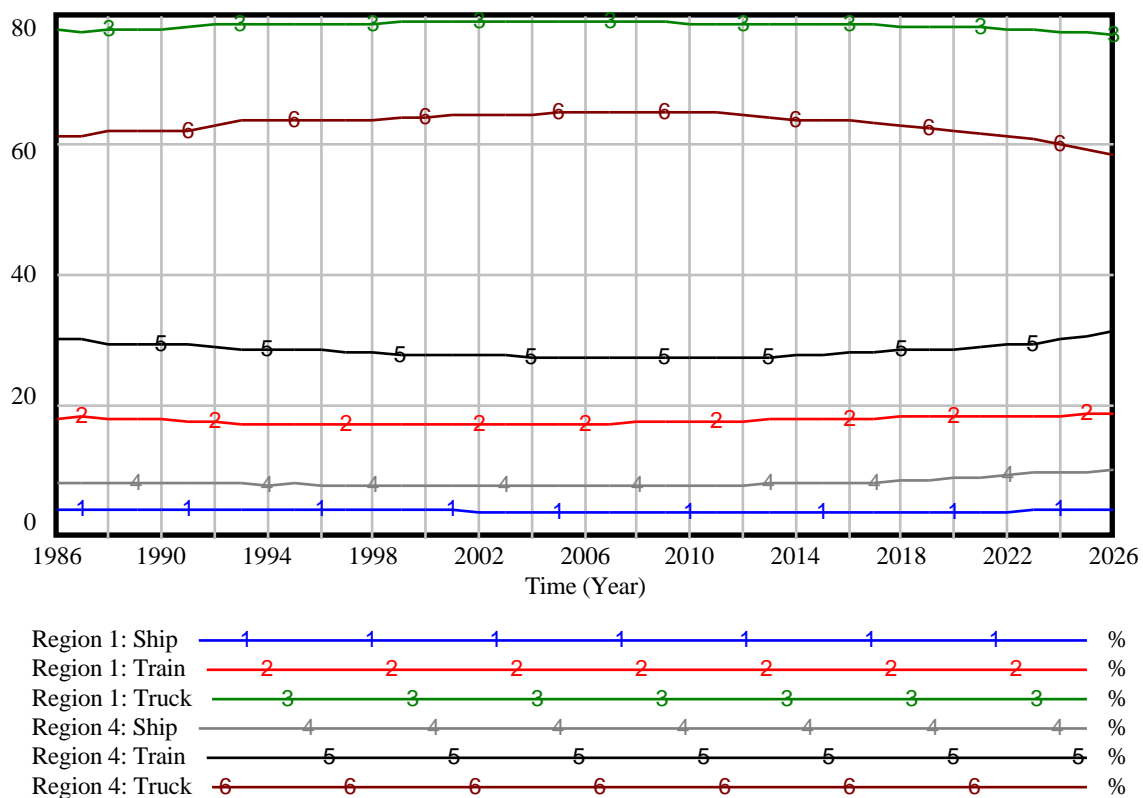


Figure 63: Freight Modal Split related to Transport Performance for Region 1 (A, D) and Region 4 (DK, FIN, IRL, S, UK)

In figure 64 truck transport performance and truck vehicle kilometres travelled are presented for region 2 (B, F, L, NL) and region 4 (DK, FIN, IRL, S, UK). For the calculation of regional transport performance for the ML and LG distance bands (>150km) again the origin principle is applied. That means a trip from one to another region is assigned to the origin region. For the calculation of truck vehicle kilometres travelled for those two distance bands (>150km) the sharing principle is applied. That means for the interregional trips half of the travelling distance is assigned to the origin region and the other half to the destination region. All curves indicate about a doubling of truck tkm respectively vhc-km between 1986 and 2026.

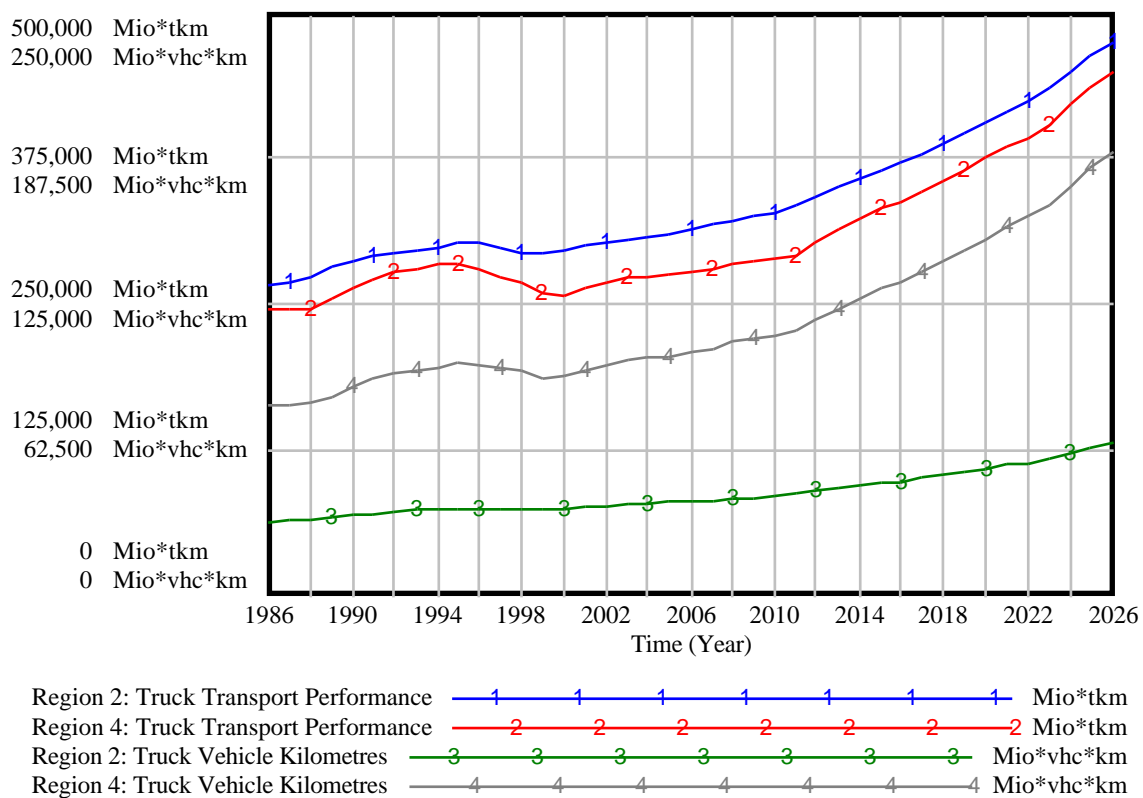


Figure 64: Transport Performance and Vehicle Kilometres for Trucks in Region 2 and Region 4

One of the major influencing variables for the transport model are the transport cost per km. A set of these specific costs for business passenger transport in the base scenario is shown in figure 65. It can be observed that except for air transport the cost are increasing over time. Considering the local distance band car mode costs grow stronger than costs for bus mode. Also for the long distance band car mode in the long run is increasing stronger than costs for rail transport.

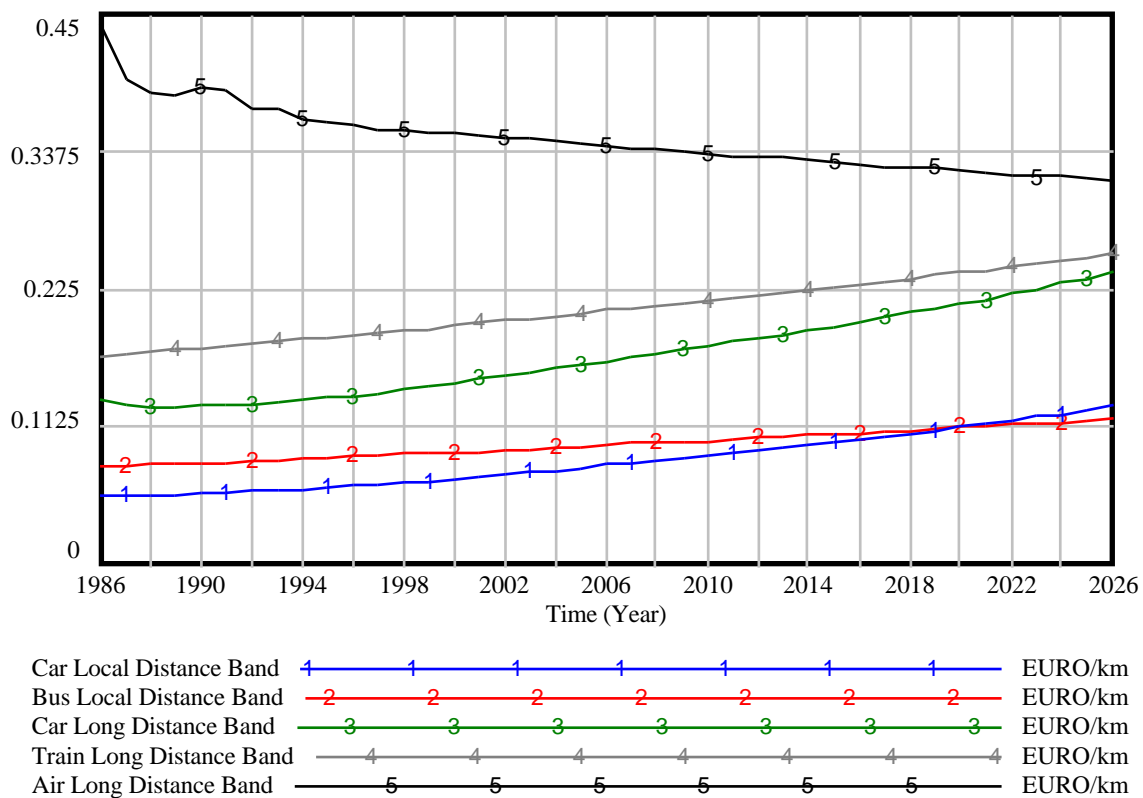
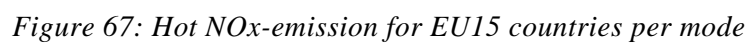
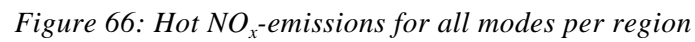


Figure 65: Cost per km for a set of passenger modes for business transport in local and long distance band

Based on the previously described indicators especially the vehicle kilometres travelled the indicators of the ENV are calculated of which a set is presented in the following. The following figures present the yearly hot NO_x-emissions per region (figure 66) and per mode (figure 67). For all regions a strong decline of NO_x-emissions between 1992 and 2004 can be observed, which is due to the introduction of the EURO emission legislation. After 2004 minor decreases occur, which after around 2016 are followed by minor growth. In the latter figure it can be seen that mainly car transport contributes to the strong reduction of NO_x-emissions, while the final increase is caused by an increase of air transport and a remaining high level of truck transport.



Average NOx emission factor in local distance band

Average NOx emission factor in medium distance band

Region 1 g NOx/km
Region 2 g NOx/km
Region 3 g NOx/km
Region 4 g NOx/km

Page: 168

Additionally to the hot CO₂-emissions other quantities of CO₂ emissions are related to transport. For two of them the emissions caused during road vehicle production and during fuel production are shown in figure 70. These production related emissions amount to about one third of the hot CO₂-emissions. The oscillations in the curves are mainly due to the purchases made for the fleets that are modelled in dependency of demand and age structure (LDV, HDV, bus). Especially the age structure that itself shows similar oscillating patterns is triggering such oscillations.

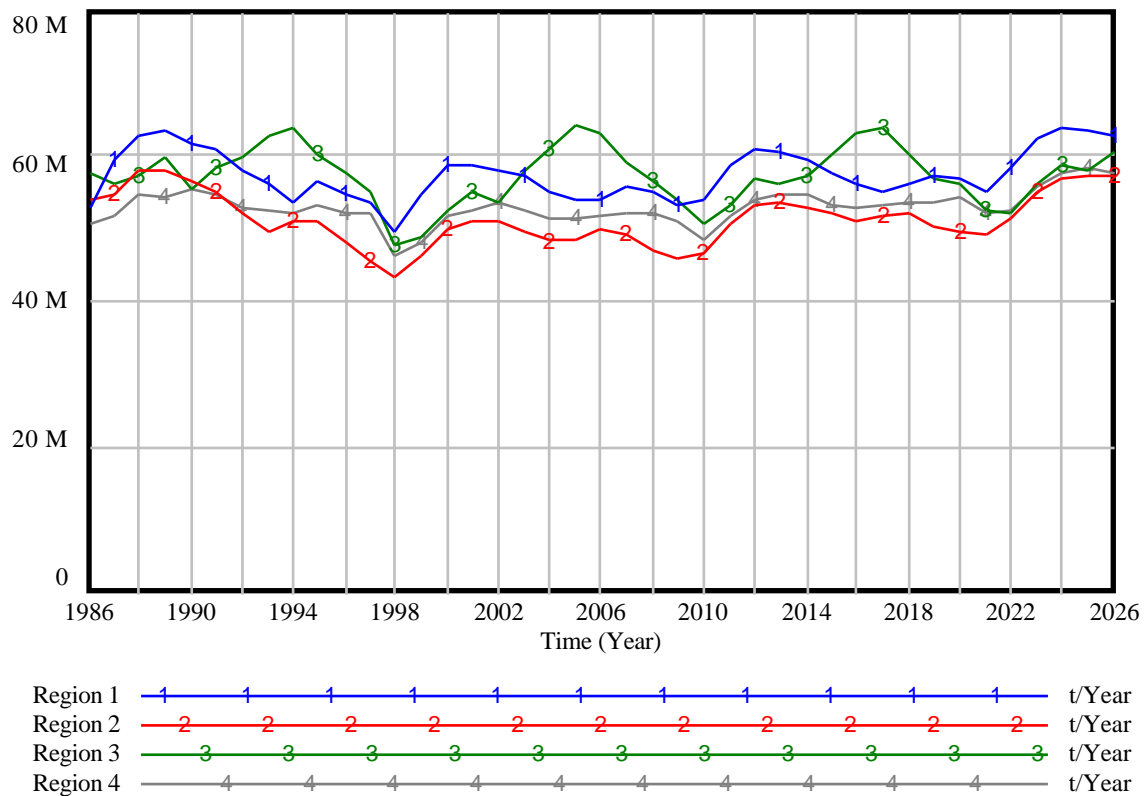


Figure 70: CO₂ emissions from road vehicle production and fuel production

Figure 71 presents an overview on the development of the externalities caused by the considered set of transport emissions (CO_2 , NO_x , PM) and by transport accidents. It can be observed that both kinds of externalities are in a similar order of magnitude at the beginning of the simulation. However, the externalities from accidents grow over time while the ones for emissions are nearly stable. It should be remembered that for both the externality cost values are not constants as they are based on literature values for a certain year, which then develop over time according to the changes of GDP.

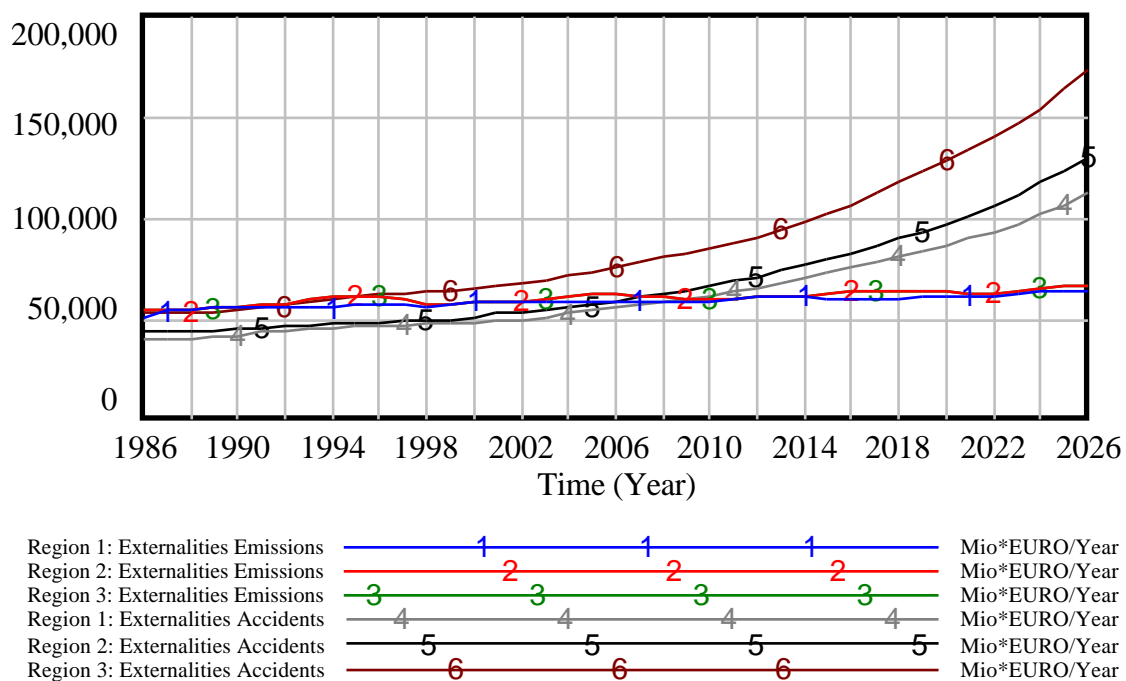


Figure 71: Yearly Externalities of Emissions and Accidents in Regions 1, 2 and 3

In the next figure 72 the reference development of the passenger car fleet is given. It can be seen that for all regions a further growth of the vehicle fleet is expected. As the development of disposable income is the strongest influencing factor for the fleet in the model the shape of the two curves are similar.

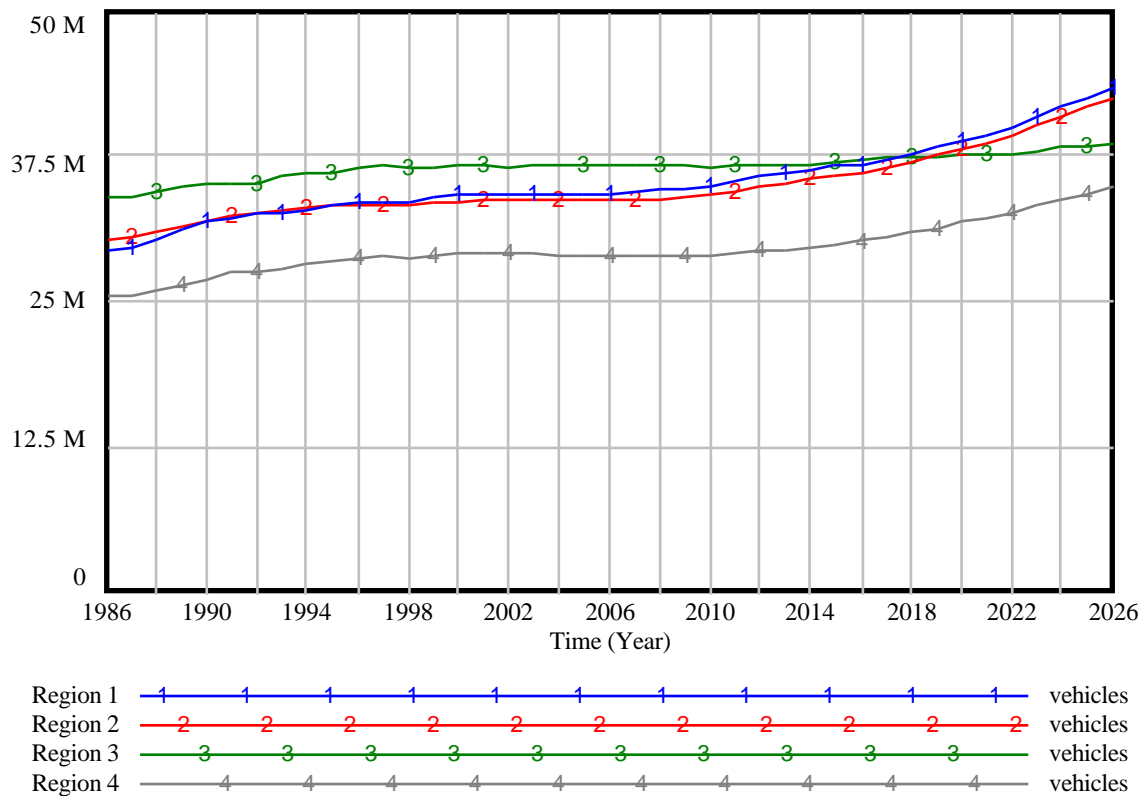


Figure 72: Development of Passenger Car Fleet per Region

Figure 73 as the final figure for the presentation of the reference developments shows private expenditures for fuel consumption excluding all taxes in the curves 1, 3 and 5. It can be observed that the highest level of these expenditures was in the mid of the 80ies where the oil prices have been at a very high level, which is reduced until mid of the 90ies. The reduction of expenditures is enforced by slightly decreasing fuel consumption of cars. From 1996 on the oil prices are assumed to increase moderate. The price shocks in the year 2000 are not considered in the reference scenario.

The development of yearly fuel tax revenues shown in curves 2, 4 and 6 is formed by two superimposing influences. On the one hand the slight decrease in private fuel consumption reduces the revenues, while on the other hand between 1985 and 1995 in the most regions tax rates have been increased, which increases the revenues. Also even with a constant tax rate the calculation in 1995 prices having positive inflation rates from 1985 to 1995 leads to the effect that the real tax rate in 1985 is higher than in 1995, which also effects the revenues. For the future years a slow but steady increase in tax rates is expected. In total increasing fuel tax revenues are expected for the future.

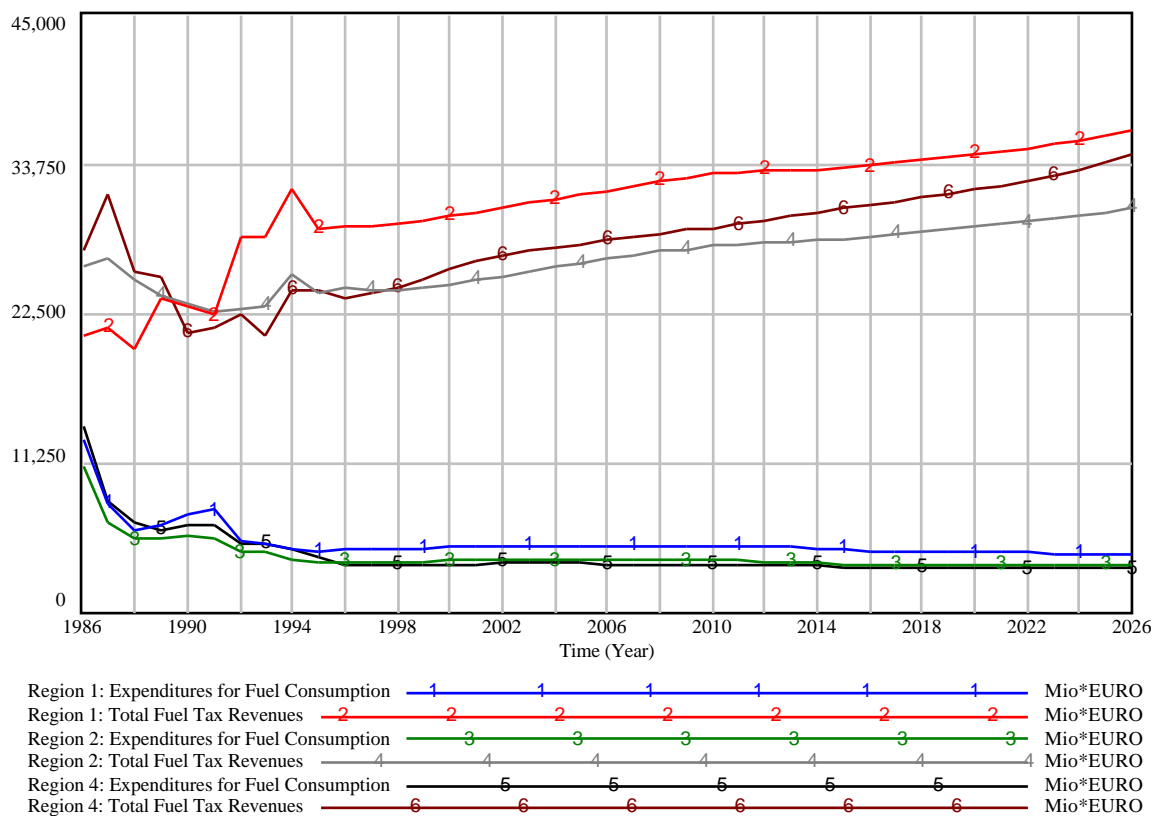


Figure 73: Development of Expenditure for Private Fuel Consumption in Comparison with Total Fuel Tax Revenues in Regions 1,2 and 4

7.3.2 Structure of the ASTRA demonstration examples

The description of the ASTRA demonstration examples has to be introduced by an explanation of the used notions for policies. Three notions are distinguished:

- Policy measure means a single measure like changing speed limit, increasing gasoline fuel tax that could either be taken at one point of time or with a time schedule over a longer time period e.g. as yearly percentage increase of the fuel tax.
- Policy package describes a set of policy measures that are combined to fulfill the goals of a certain strategy e.g. green tax strategy with increase of energy cost and decrease of labour cost.
- Policy programme comprises a set of policy packages, which comes closest to real policy situation, where each single policy measure is embedded in a whole policy framework. The goal of such a programme would be to find out between which policy packages synergies or contradictions exist.

The ASTRA demonstration examples cover five policy packages consisting of several policy measures and one integrated policy programme including mainly four of the policy packages. This is shown in figure 74.

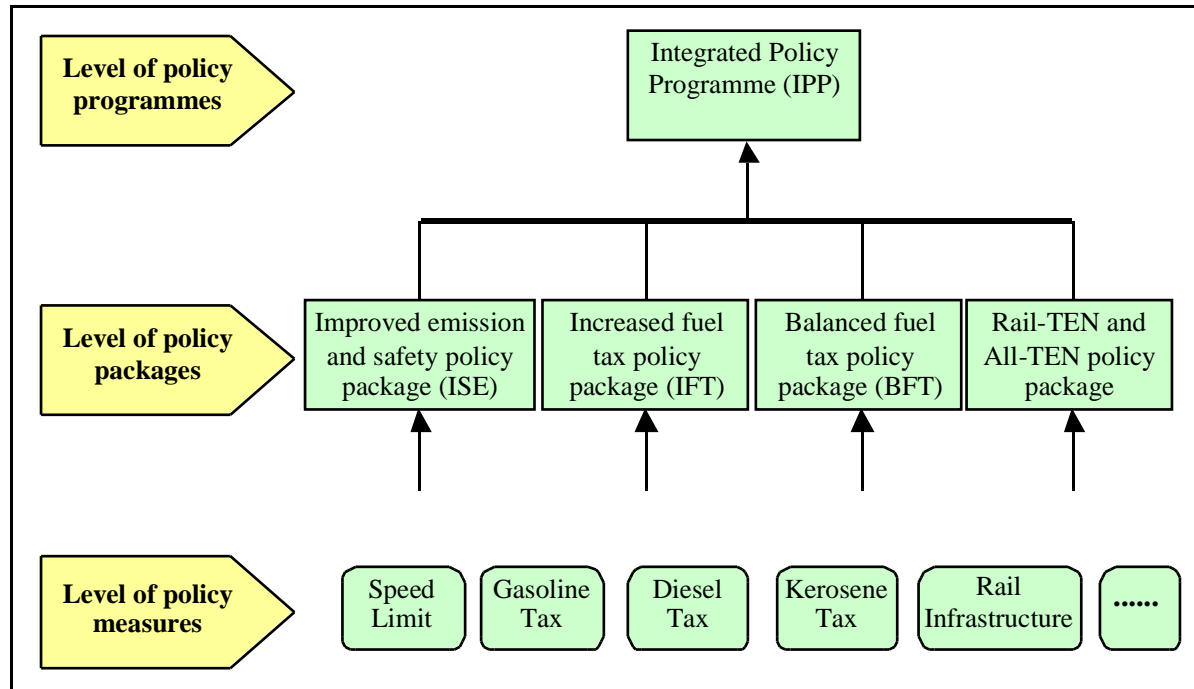


Figure 74: Structure and notion of the ASTRA demonstration examples

7.3.2 Policy Package 1: Improving Safety and Emissions Situation (ISE)

This policy package combines three measures effecting safety and air pollution. The baseline for the safety measures comprises an enforced speed limit for the long distance road network, an increased usage of safety-belts and concerning emissions an enforced emission legislation by a movement of the point of time when new emission standards for passenger cars come into force. In addition the reduced speed limit also effects the emissions.

For the reference scenario speed limits are kept constant at the 1995 levels, while for the policies it is aspired to introduce a maximum level of 110 km/h on motorways (90 km/h on other rural roads) for cars. Limits that are already below these values are not changed. For trucks the speed level of 80 km/h should be actually the maximum, which is severely controlled such that no violations occur. For instance, on German motorways where the speed limit is 80 km/h for trucks the actual average truck speed today is around 90 km/h. It can be assumed that the situation is similar in other European countries.

The safety-belt usage in the reference scenario increases only by 1% from 1996 to 2026, while it is increased from 1996 by 1% per year to reach a maximum of 98% in all four macro regions (front passengers).

Emission standards for cars in the reference scenario are introduced according to the proposed dates of the EURO I-IV emission legislation. From the years 2010 to 2026 additional reductions of emission factors are considered, because further legislation and technological development will improve the emission factors. The emission legislation will be enforced by moving all points of time when a new standard comes into force three years earlier. This is started with the EURO II legislation. Also, additional reductions of the emission factors from 2010 to 2026 are introduced. For NO_x this reduction amounts to 10% and for CO₂ it amounts to 30%.

7.3.2.1 Implementation in the Model

The changes for the implementation of this policy package concern the TRA and the ENV. For the changes of speed limit the road driving times in the TRA, the speed limit in the accident model and the emission factors in the emission model have to be changed. For trucks the driving time is increased by 7% as a consequence of the observance of the 80 km/h speed limit. For cars the changed speed limit leads to the weighted speed limits for long distance transport given in table 47.

Table 47: Changes of weighted speed limit for emission & safety policy

	MR1	MR2	MR3	MR4
Base Scenario [km/h]	117.36	99.83	102.30	98.82
Emission & Safety Policy [km/h]	96.00	94.85	96.00	95.05
Reduction [%]	18	5	6	4

Safety-belt usage has to be altered also in the accident model such that the level of 98%-usage for interurban trips is reached in MR1 in 1998, MR2 in 2000, MR3 in 2005 and MR4 in 1999 and for local trips is reached in MR1 in 2001, MR2 in 2003, MR3 in 2017 and MR4 in 2001. The enforcement of the emission standard belongs to the vehicle fleet model of passenger cars, where the first year and the final year in which a certain legislation is in force are altered. The change of the emission factors is then endogenously produced by the developing shares of cars in the fleet that are equipped with different engines and a certain type of cleaning technology. Only the additional reductions after 2010 are directly implemented with a change of emission factors.

7.3.2.2 Results of Emission & Safety Policy (ISE)

This policy provides a broad range of direct and secondary effects. Direct effects in the transport system are performed by the strengthened speed limit that changes travel times. This leads to changed trip distribution and modal-split in the passenger and freight model. Secondary effects then occur e.g. because the overall demand per mode is altered with the consequence that expenditures and investments per mode are different compared to the base scenario. Also the reduced speed decreases the specific emission factors in the interurban distance bands, which decreases overall emissions. This reduction of emissions is increased by the enforced emission legislation as future emissions legislation categories reduce the specific emission factors for the relevant gaseous emissions. This effect occurs in all distance bands.

Strengthened speed limit and increased safety-belt usage reduce the number of fatalities and the other adverse impacts of road accidents. More precise, the accident rate for all road modes is reduced by the strengthened speed limit while additionally the injury risk for passenger cars is reduced by the increased safety-belt usage.

In the following selected detailed results of the emission & safety policy are presented. Figure 75 shows three sources of NO_x emissions from the base scenario (curve 1,4,5) and two sources of NO_x emissions from the emission & safety policy.

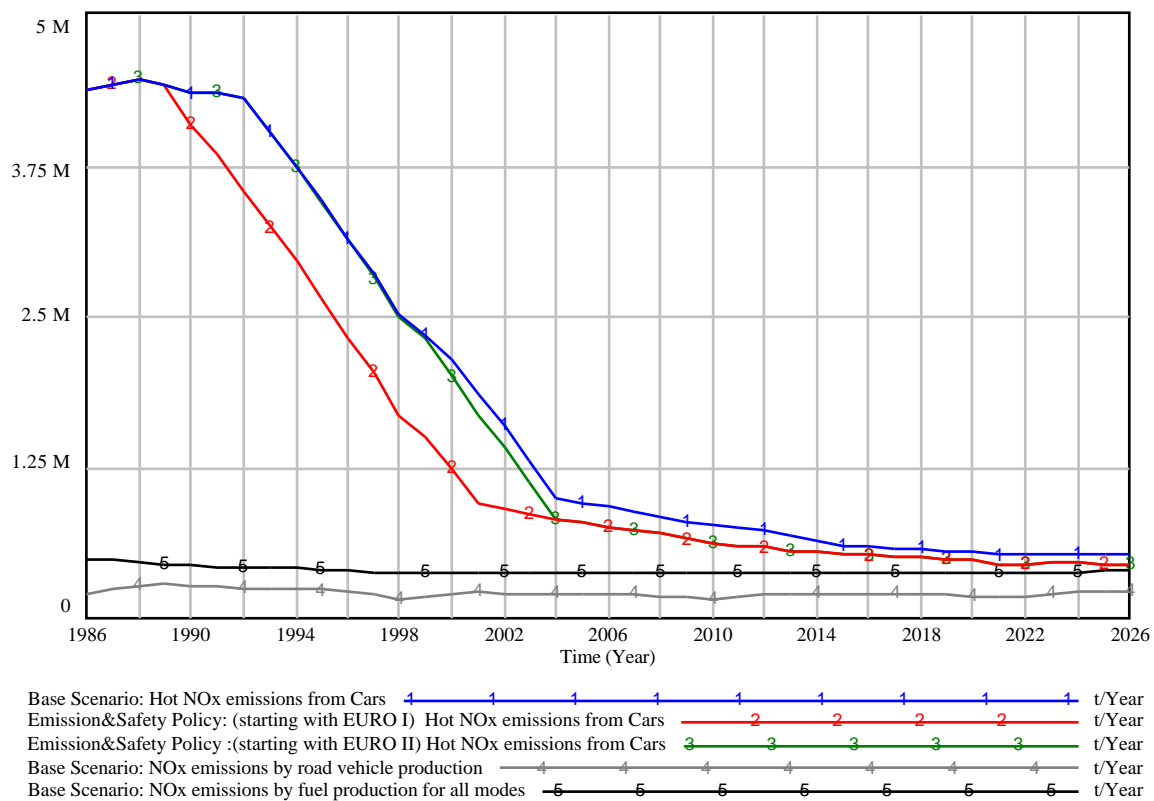


Figure 75: Comparison of different sources and policy results for NO_x emissions⁷³

Curve 1 indicates the development of hot NO_x emissions from passenger cars in the base scenario for the EU15 countries. It can be clearly identified that from the year 1992, when EURO I cars start to replace ECE 1503 cars the NO_x emissions strongly decrease until about 2004, when finally the last ECE 1504 cars are scrapped. The level of hot NO_x emissions in 2004 amounts only to 15% of the 1992 level. After 2004 further minor reductions occur as for the future car categories further reductions of the specific emission factors are expected.

Curve 2 and 3 indicate two options of the emission & safety policy. Both consider a movement of the point of time when new EURO emission legislation comes into force. The former curve starts the shift with EURO I legislation while the latter starts the shift with EURO II legislation. It can be clearly realised that to advance EURO I legislation to 1989 would have reduced hot NO_x emissions from cars by about 35% from 1989 to 2001. To advance EURO II to 1993 would have provided only a minor reduction effect. It should be mentioned that a reduction of NO_x does not necessarily cause a similar reduction of impacts as e.g. for the formation of ozone, for which NO_x is one of the precursors, non-linear relationships are known.

Curve 4 and 5 indicate NO_x emissions emitted during road vehicle production and during the fuel production process for all modes. It should be noticed that after about 2010 the hot NO_x

⁷³ This and some of the following graphs indicate the numbers on the y-axis followed by a notion for the order of magnitude e.g. M for Million, B for Billion.

emissions from car transport will be in a similar order of magnitude as these upstream emissions.

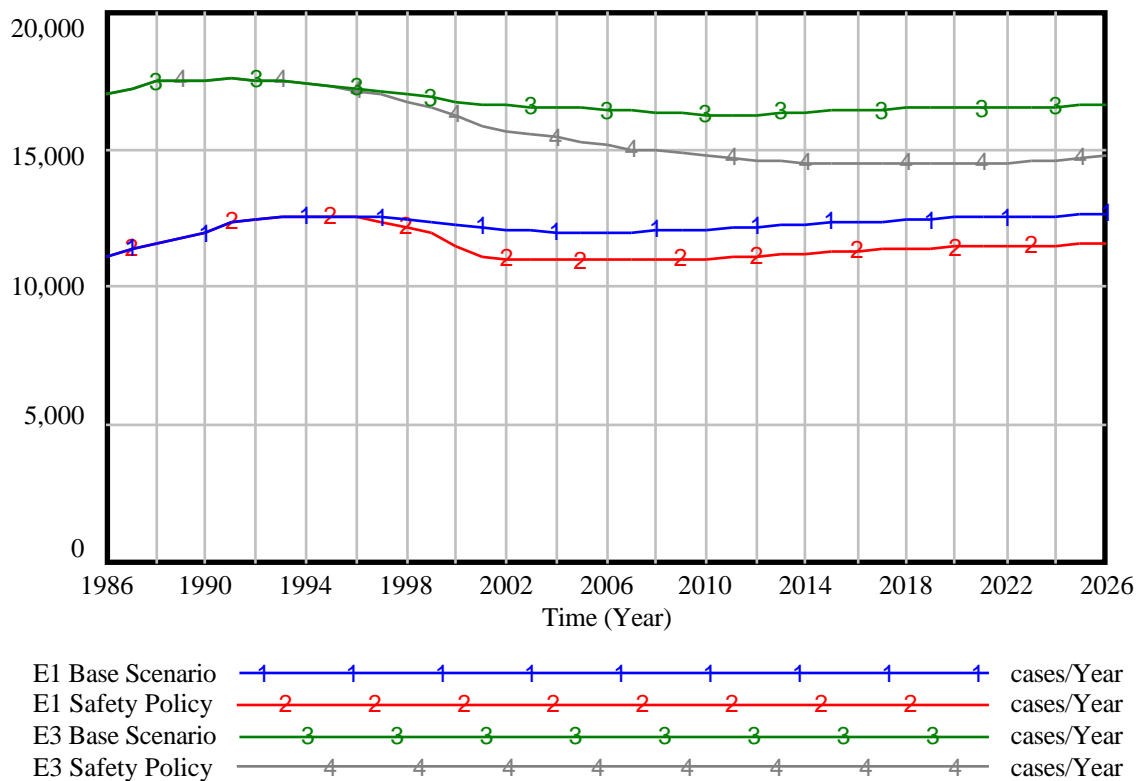


Figure 76: Yearly Road Fatalities in Region E1 (A, D) and Region E3 (E, GR, I, P)

In figure 76 the yearly fatalities for all road modes including slow mode for region 1 (A, D) in curve 1 and 2 and region 3 (E, GR, I, P) in curve 3 and 4 are given. It can be realized that from the year 1996 the increased safety-belt usage diminishes the number of fatalities slightly compared to the base scenario. Around 2000 the speed limit is introduced, which has a strong reduction effect in region 1 and a minor effect in region 3. After 2001 in region 1 the difference between base scenario and emission & safety policy is stable with about 10% reduction by the policy measures. For region 3 after 2001 still an increasing reduction of at maximum 12% compared to the base scenario can be observed until 2017, which is due to the improvements of safety-belt usage until 2005 for interurban and until 2017 for local transport.

The reduction effects for fatalities in figure 76 are also influenced by trade-offs between the modes. As the speed limit also has an effect on modal-split producing less car transport and more transport with competing modes the number of accidents for the latter increases slightly while the reduction for car transport in 2017 reaches nearly 15%.

In general, the development of road fatalities is seen not very optimistic. The model aspires to consider the current and future safety technology. However, the safety-belt usage, which is the most effective measure, is already quite high in all regions besides region 3. Implementation of airbags is growing (e.g. in 2000 55% of cars in region 1 and 34% of cars in

region 3) but the additional reduction effect of airbags is smaller considering that people already use safety-belts. Some effective measures like reduced blood alcohol limit are in discussion on the political agenda, while other effective measures like daytime-running lights or speed limit of 30 km/h in urban roads seem not to be realistic and feasible within the current political agenda.

An influence of investments in maintenance for safety is considered. However, its impact is negative as these investments are below the needed amount to keep a constant maintenance level. Actually this influence increases the curves between 1985 and 1990 as the model followed the idealistic assumption that in the base year 1985 the investment level is high enough to conserve the safety level, which is not the case for the following years such that the road network starts to deteriorate. So, the two open questions concerning the model results and a major reduction of fatalities are if there will be developed a future technology (e.g. like electronic distance controls) or a kind of exogenous road safety standard improvement e.g. by new construction guidelines that will further reduce fatalities by noticeable numbers. For serious injuries similar results as for fatalities can be obtained.

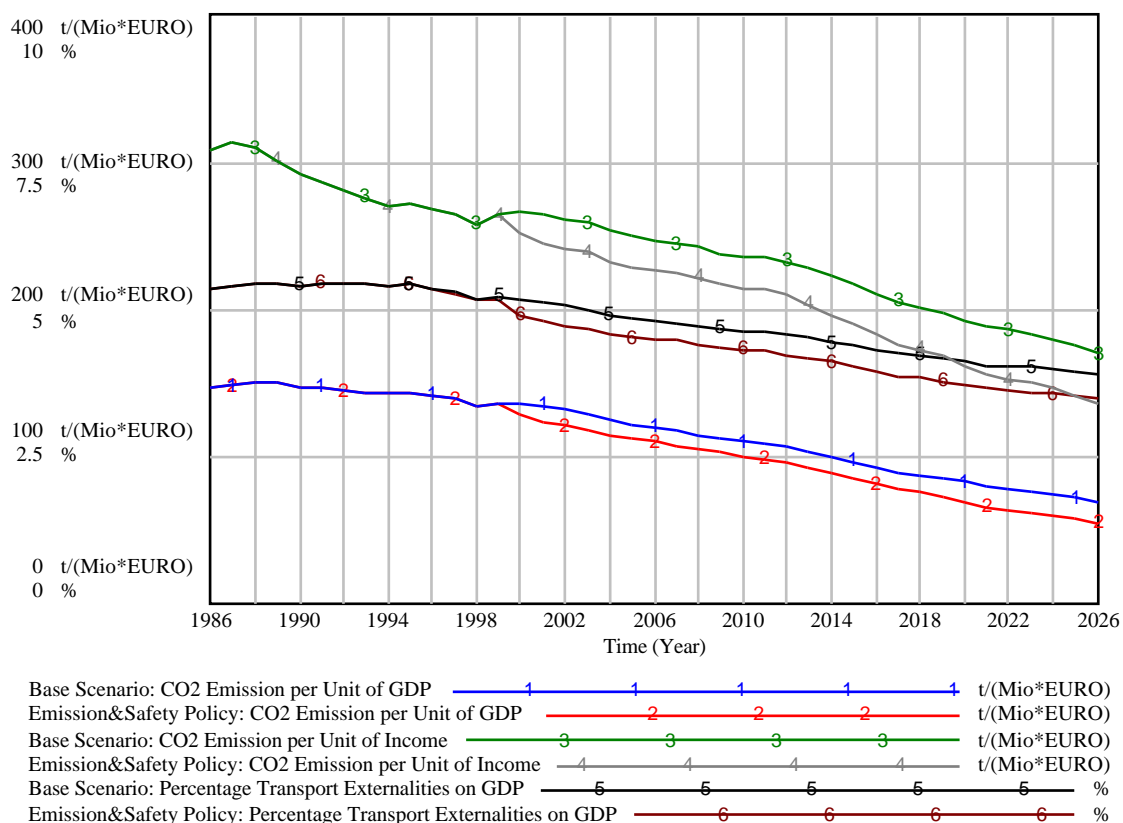


Figure 77: Combined Environment and Welfare Indicators for Region 1 (A, D)

In figure 77 environmental indicators for region 1 (A, D) are related to economic indicators for the base scenario and the emission & safety policy. Curve 1 and 2 present CO₂ emissions from transport per unit of GDP. In the second half of the 80ies the highest level is reached with about 150 tons CO₂ per 1 Mio EURO of GDP. This decreases until 2026 to less than 70

tons CO₂ per 1 Mio EURO of GDP and the emission & safety policy would reduce it by 20% related to the 2026 level.

Curve 3 and 4 reveal a similar development for the relationship between transport CO₂ emission and unit of disposable income starting from about 300 tons CO₂ per 1 Mio EURO of income and decreasing to 300 tons CO₂ per 1 Mio EURO of income. The curves 5 and 6 present the percentage of the modelled transport externalities (accidents, CO₂, NO_x, PM) on the overall GDP. This share decreases from 5.4 % to 3.8 % in the base scenario. It would be further reduced by 0.4% by the policy.

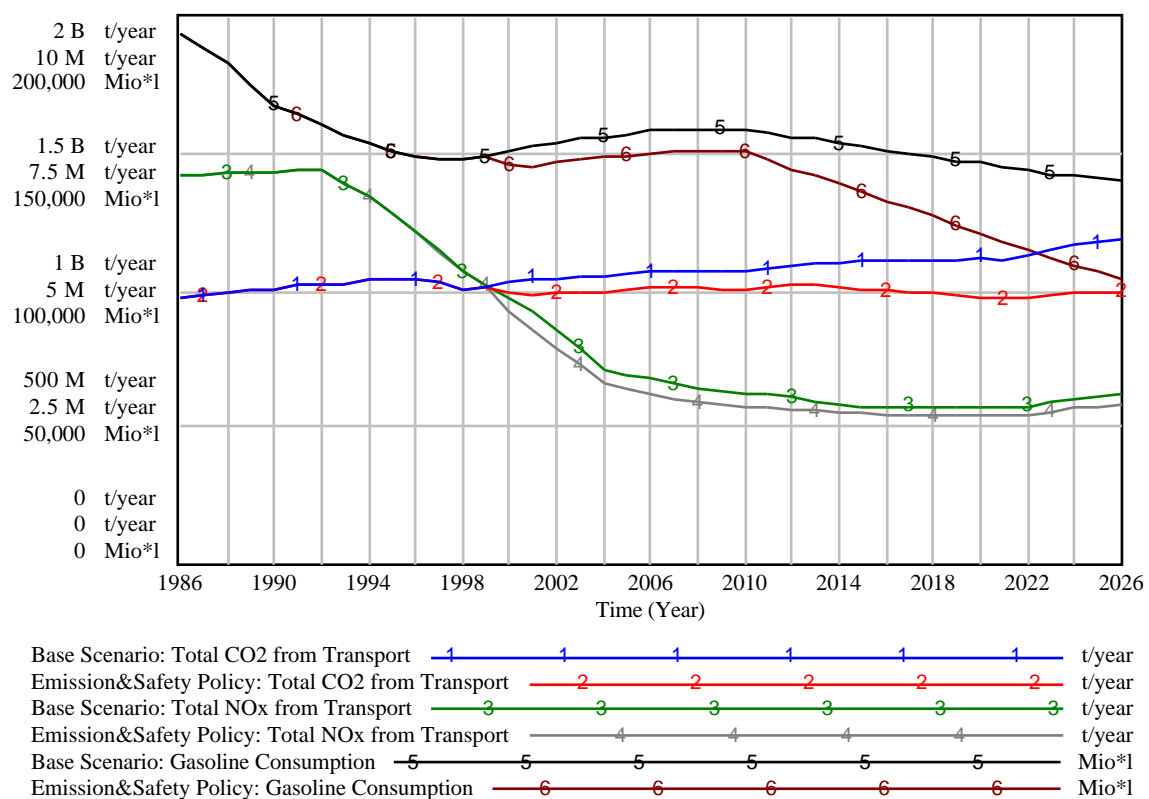


Figure 78: Transport CO₂-, NO_x- emissions and Gasoline Consumption in the EU15 countries

In Figure 78 the development of aggregated environmental indicators for the EU15 is presented. The total CO₂ emissions from transport that include hot emissions, cold start emissions, vehicle and fuel production emissions are given in curve 1 and 2. For the base scenario these amount to about 1 billion tons in 1986 with a nearly linear increase to about 1.2 Bio tons of CO₂ emissions in 2026. With the emission & safety policy the total CO₂ emissions more or less stabilise around the 1990 level.

The comparable indicator for NO_x emissions from transport presented in figure 3 and 4 reveals a different development. Between 1986 and 1992 the NO_x emissions are stable at 7.1 Mio tons. With the introduction of the EURO emission legislation for road transport modes these emissions were more than halved until 2004. After 2004 they are nearly stable, with the

indication of a slight increase in the final years of the simulation that is driven by heavy duty road mode and by air mode.

The curves 5 and 6 show the consumption of gasoline fuel for transport. In the first five years there is a slight overestimation of the gasoline consumption but afterwards the curves fit well to actual data. In the base scenario a period with increasing consumption between 1998 and 2010 can be observed. This depends on an increase in vehicle kilometres travelled by car and to small decreases in specific fuel consumption for the new cars in the fleet. After 2010 the increase in demand is weakened and the fuel consumption factors for cars are reduced exogenously by 20% between 2010 and 2030. The emission & safety policy leads more or less to a stabilisation of gasoline consumption from 1998 to 2010 and then the consumption factors are reduced by 45% until 2030, which causes the stronger decrease compared to the base scenario.

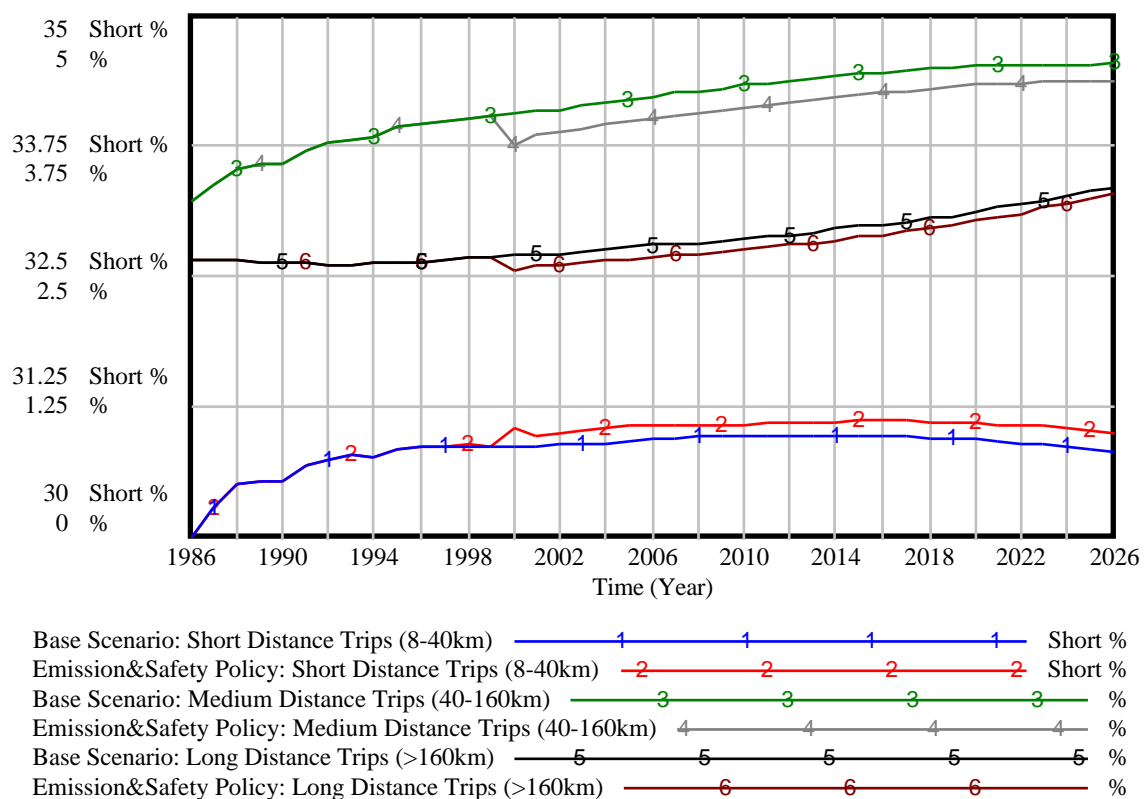


Figure 79: Passenger Demand Split between Distance Bands

In figure 79 and figure 80 the split between the five distance bands for passenger trip demand is shown. In the former figure the effect of the emission & safety policy can be identified, which is a shift from the longer distance bands (over 40km) towards the shorter distances. In this case mainly the short distance band share is increasing, while medium and long distance band are decreasing. The reason can be seen in the increased travel time for the interurban road network, because of the strengthened speed limit. A similar effect can be observed for freight transport, for which also the share of the short distance band (0-50km) is growing, while mainly the share of medium long distance band (150-700km) is declining.

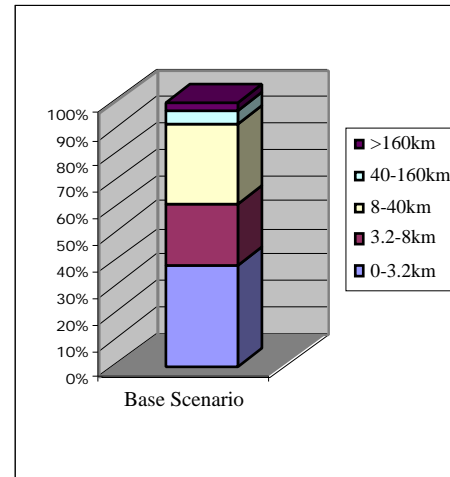


Figure 80: Trip Distance Split

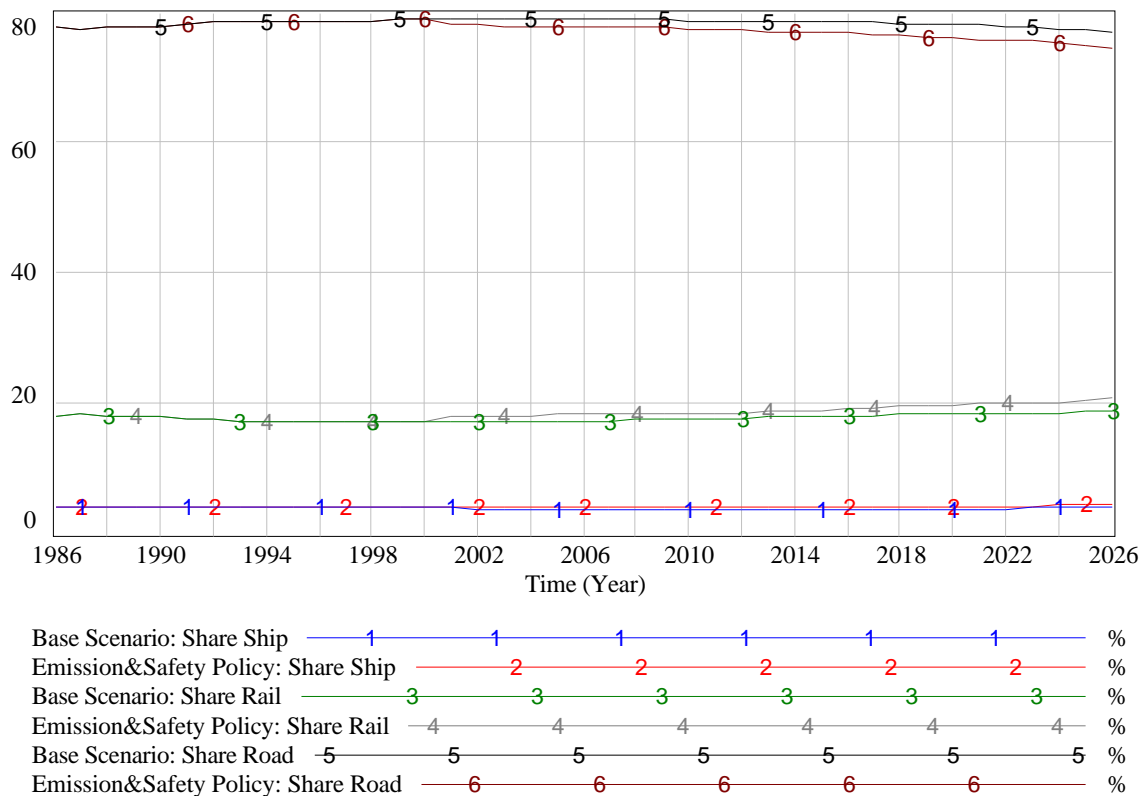


Figure 81: Freight Modal Split for Medium Long Distance Band (150-700km) in Region 1 (A, D)

Figure 81 presents the modal split in terms of tkm between the three competing freight modes in the medium long distance band. Curves 5 and 6 for road mode indicate that the emission & safety policy shifts freight transport slightly away from road mode with a reduction of road share by about 2.5% in the year 2026. Most of this decline is gained by rail mode with nearly 2 % increase in 2026 (curve 3 and 4). For the long distance band also road mode share is declining but in this distance band the more successful competitor is ship mode.

Though the taken policy measures in the emission & safety policy package are focussed on transport specific measures, they also provide effects on the economic side. Changing passenger modal-split effects the consumption expenditures for fuel, for car purchase, for transport services and considering the budget constraint also the non-transport consumption expenditures. That means the consumption patterns can be changed. For freight transport the changes in modal split, which most often also imply a change in demand, have an effect on investments. In both cases the tax revenues from fuel can also be altered.

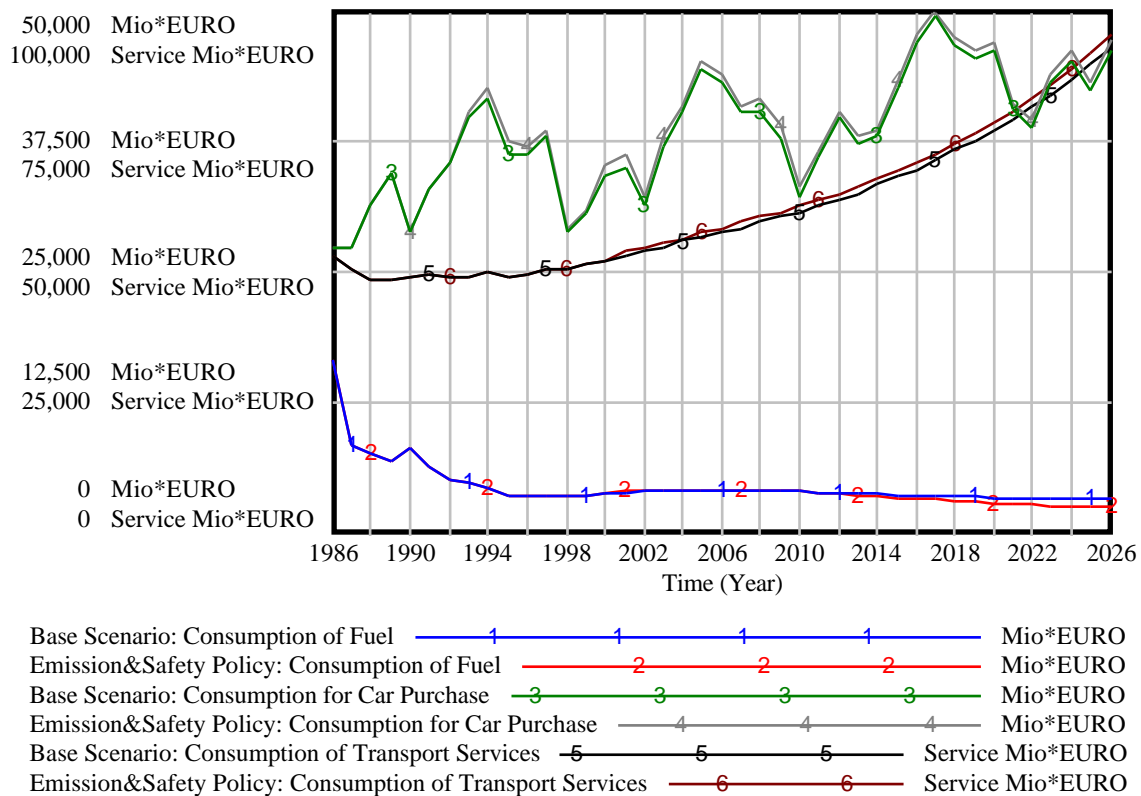


Figure 82: Transport related Consumption in Region 3 (E, GR, I, P)

In figure 82 the three different types of consumption expenditures are shown. It has to be mentioned that the values are net of all taxes, which is especially important for the consumption of fuel given in curves 1 and 2. For these curves it can be realised that, after 2010 with the strengthened reduction of CO₂ emissions and the directly corresponding fuel consumption the expenditures for fuel are decreasing compared to the base scenario. Curves 3 and 4 showing the expenditures for private car purchase indicate that these expenditures are growing in the emission & safety policy as the car prices are increasing since 1993 because of the enforced emission legislation that requires additional technology in the cars. The increase in prices is not equalised by the declining demand. Curves 5 and 6 describe the development of expenditures for transport services (bus, rail, air). It can be observed that with the strengthening of the speed limit in the year 2000 and the corresponding shift in modal-split in the longer distance bands away from car transport the expenditures for transport services increase compared to the base scenario.

Corresponding with the increased expenditures for transport services also employment in these sectors is growing. This is shown in the following figure:

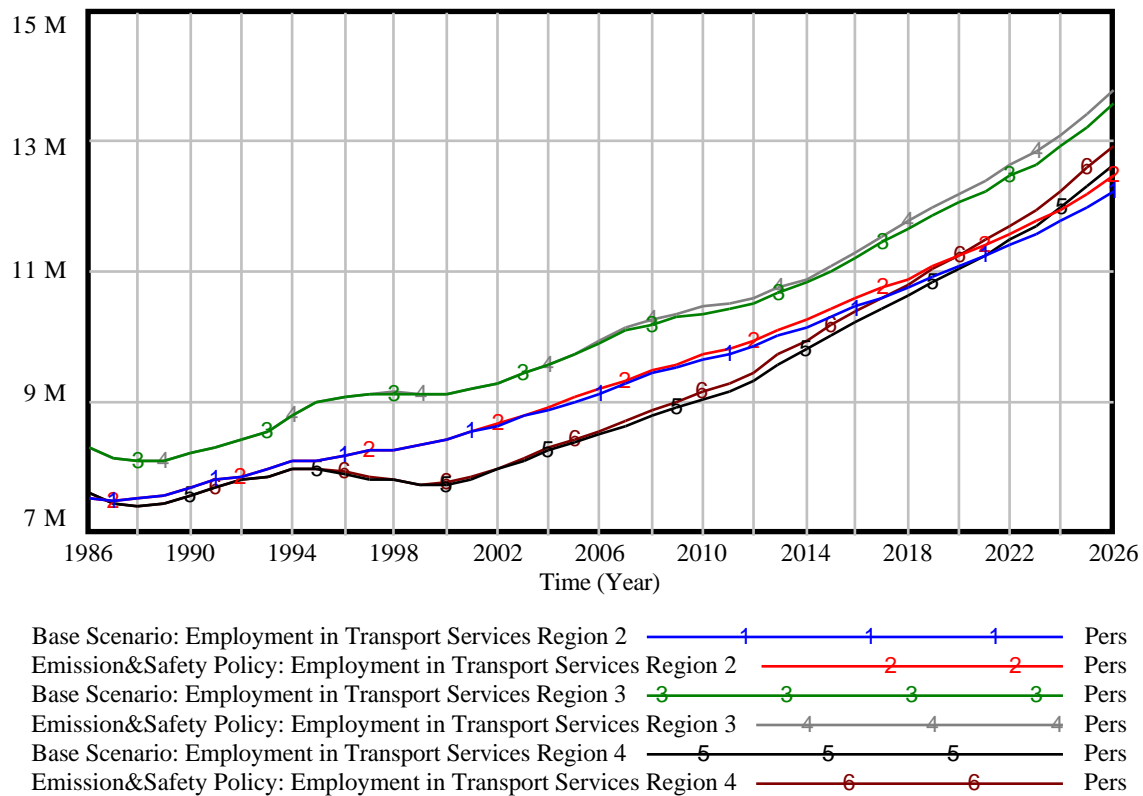


Figure 83: Total Employment in Transport Service Sectors in Region 2 (B, F, NL, L), Region 3 (E, GR, I, P) and Region 4 (DK, FIN, IRL, S, UK)

It can be observed that total employment in the transport service sector is growing. However, the picture is different if one looks at the different modes. While bus mode is slightly decreasing, rail mode does slightly increase and employment in air mode is growing strongly.

In general it can be stated from the economic point of view that the emission & safety policy package is advantageous in terms of increasing the GDP for all four regions.

7.3.3 Policy Package 2: Increased Fuel Tax plus Reduction of Labour Costs (IFT)

This package is designed to generate revenues from the transport sector while the amount of additional revenues is compensated by a reduction in the direct taxation and the social protection payments of labour such that the overall balance is neutral. The fuel taxation is imposed to diesel and gasoline fuel and as such to all road modes (gasoline and diesel cars, vans, trucks). Its likely impacts are an increase in the average cost of road transport for both freight and passengers and a shift in modal split toward non-road modes of transport.

The baseline for fuel taxation is given by the reference scenario with the values of the real tax rates from 1985 to 1995 and from 1996 to 2026 with 30% increase for region 1, 2, 3 and 40%

increase for region 4 for both diesel and gasoline tax. Upon this base development the balanced fuel tax policy adds additional tax increases from 2000 to 2010. During this period every two years the tax rate is increased by 5% for diesel and gasoline.

On the other hand the increased taxes cause additional fuel tax revenues for the government. Now it is not the idea that the government incorporates this money in their global budget. Instead the money should be used to reduce the labour costs, such that employment is fostered. This can be done by a reduction of employers contribution to overall social protection payments. Minor parts of it might also be spent to reduce employees contribution to overall social protection payments or their direct taxes. In this sense the policy is similar to the green tax approaches requesting for increased energy prices and reduced labour costs to improve both employment and environment situation.

7.3.3.1 Implementation in the Model

The direct levers for the increased fuel tax policy (IFT) are implemented in ENV (tax rates) and MAC (all kinds of labour taxation). Direct consequences of the changed tax rates are transferred to the TRA affecting the share of road transport costs that is depending on the fuel prices. This share varies for trip purposes and the trip distances, which is shown in the following table.

Table 48: Share of fuel costs on total transport costs per km

Purpose	Distance	Share Fuel Costs
Passenger road business transport	All	23%
Passenger road private transport	< 40 km	90%
	> 40 km	78%
Freight road transport	All	22%

As the total fuel price is calculated from three elements, which are pure fuel price, fuel tax rate and VAT each described by separate variables in the fuel tax model, the policy changes can be implemented directly in the tax variables for the different fuel types. Figure 84 describes the fuel tax rate for diesel and gasoline in region 2 for the base scenario and the green tax policy as the policy is short-named in the graphs.

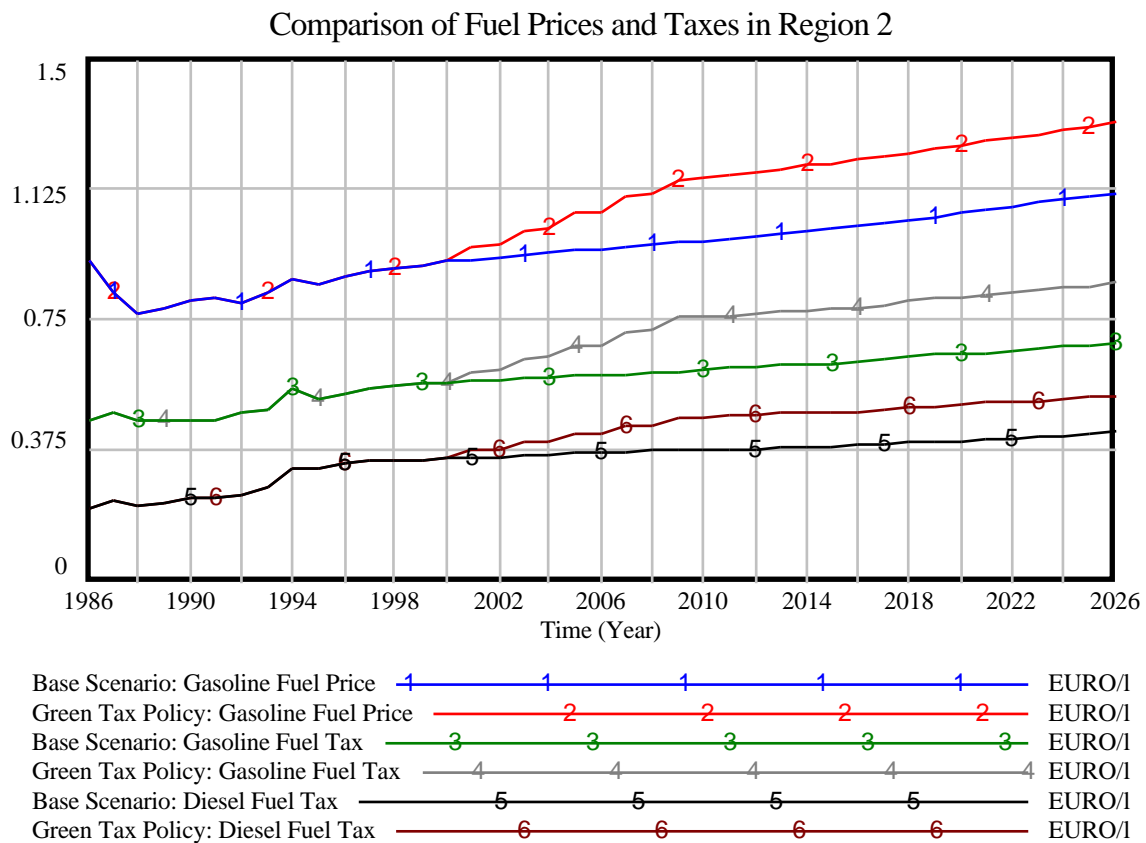


Figure 84: Development of Fuel Price and Fuel Taxes in Region 2 (B, F, L, NL)

The additional revenues are calculated by a comparison between base scenario fuel tax revenues and fuel tax policy revenues. The difference in revenues gives the amount of money by which the labour costs can be reduced. The reduction of labour costs is split on three links. The major link with 80% of additional revenues is connected with a reduction of social protection payments of the employers, which increases sectoral gross value added and causes new employment. With the remaining 20% employees tax payments are reduced spending 10% for a reduction of direct taxes and 90% for reduction of employees social protection payments. This effect increases total personal income in the four regions as well as individual disposable income.

7.3.3.2 Results of the Increased Fuel Tax Policy (IFT)

The changes in transport costs will effect the modal split and the trip distribution. Effects on the macro side can be assumed for employment and via the links with total transport expenditures to other macro variables like consumption. Furthermore the structure of the passenger car fleet can be changed as the higher fuel efficiency of diesel cars becomes more important, when fuel prices for diesel and gasoline are increasing.

Analysing the sequence of effects caused by the tax increase the first effect is performed on the road transport costs. As the share of fuel on transport costs is varying for different purposes and distances the effects vary.

In figure 85 it can be observed that the increase of fuel taxes provides a similar effect on the average variable costs of car mode (curve 5 and 6). The variable costs depend on one hand on the fuel price and on the other hand on the fuel efficiency of the current car vehicle fleet. Increasing fuel prices compared to the base run, will slightly increase fuel efficiency (e.g. by purchase of smaller cars) such that there is no fixed relationship between fuel price and road variable costs. In curve 1 and 2 the development of non-fuel cost for large-stand alone zones is shown. These include e.g. parking costs, insurance or road charges. They are strongly increasing from 1986 to 2026, which is the same for base scenario and policy. As for business transport it is mainly the non-fuel costs that drive cost developments the increased fuel tax provides only a very small effect on the total car cost per km (see curve 3 and 4). For private trips the cost increase is more significant as these mainly consider the out-of-pocket cost.

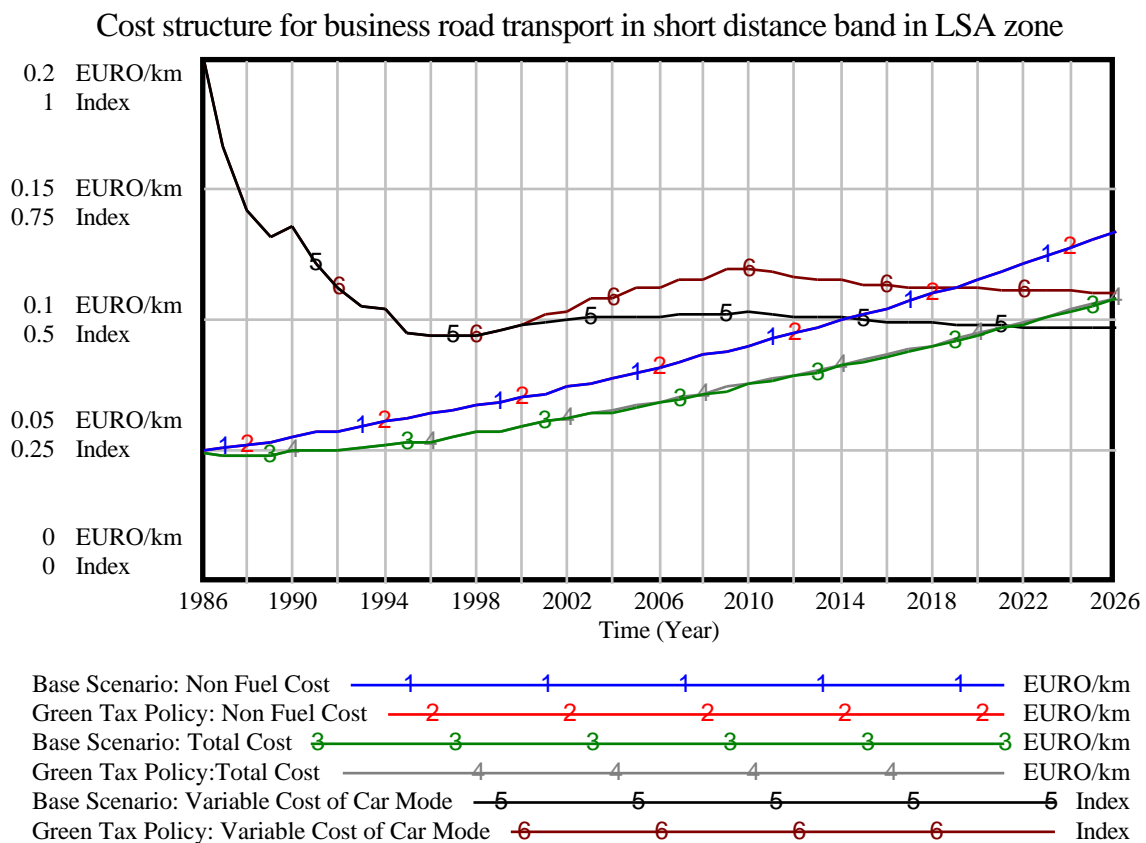


Figure 85: Cost structure for business road transport in short distance band in large stand-alone metropolitan zones (LSA)

The cost changes lead to changes of the relative attractiveness of the different modes such that especially air and rail mode become more attractive. This causes changes in transport performance that are shown in figure 86. It should be mentioned that the scale for car and for rail and air mode differ by an order of magnitude. Expressed as percentage around 2010 car loses nearly 1% of pkm while air is increasing by 3% and rail by about 1.5% because of the policy. How these effects change the modal-split is shown in figure 87.

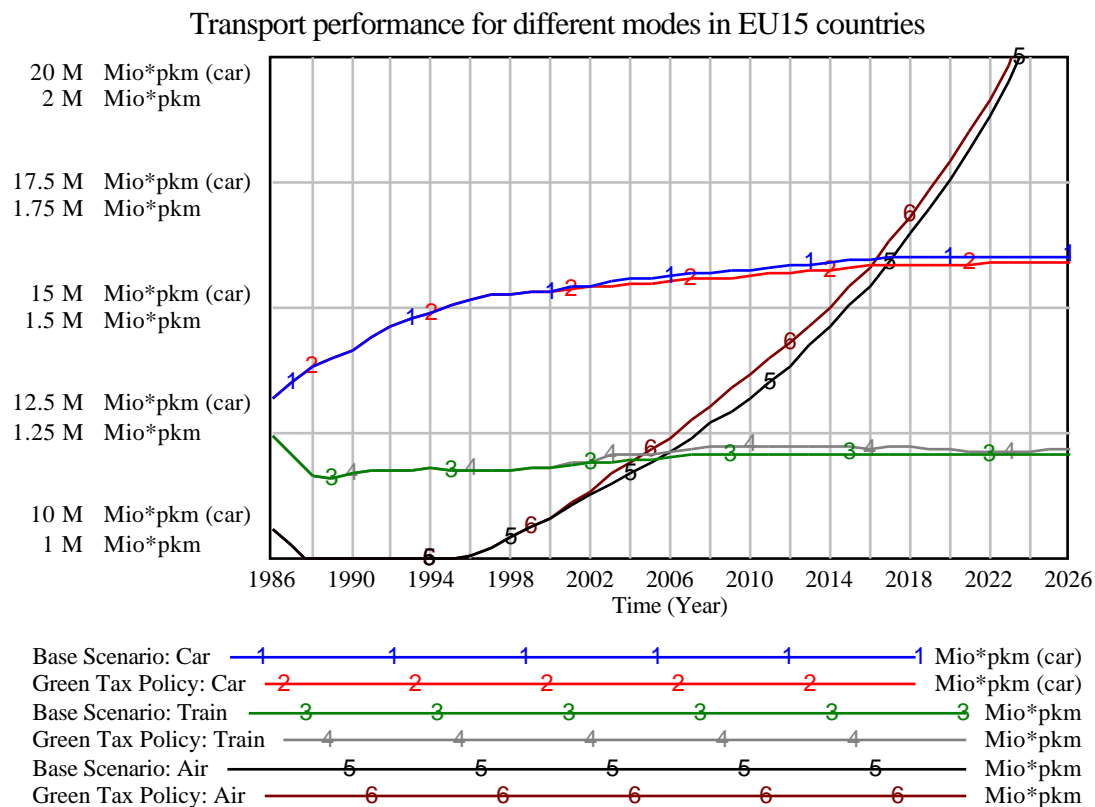


Figure 86: Passenger transport performance for base scenario and green tax policy

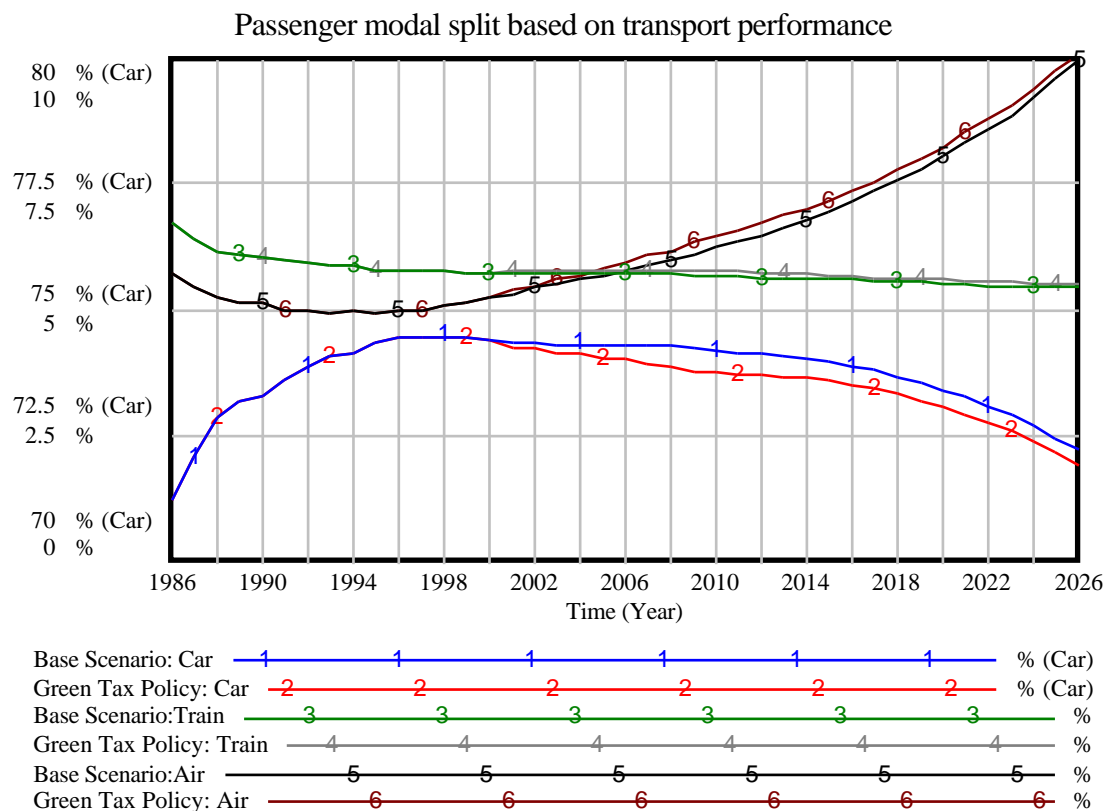


Figure 87: Passenger modal-split for EU15 in terms of transport performance

A second effect concerns the split of trip demand between the different distance bands. As figure 88 shows that changes occur in a way that in the short and the medium distance band (8-160km) trips decrease, while in the local and very short distance trips increase. An interesting indication is shown for the long distance band (> 160km) that is very slightly increasing, which can be explained by the availability of air mode and the higher importance of rail mode in this distance band compared with the short and medium distance band. Furthermore it can be observed that the changes by the policy are strongest at the end of the period of tax increases (2000-2010), while they diminish in the years after 2010.

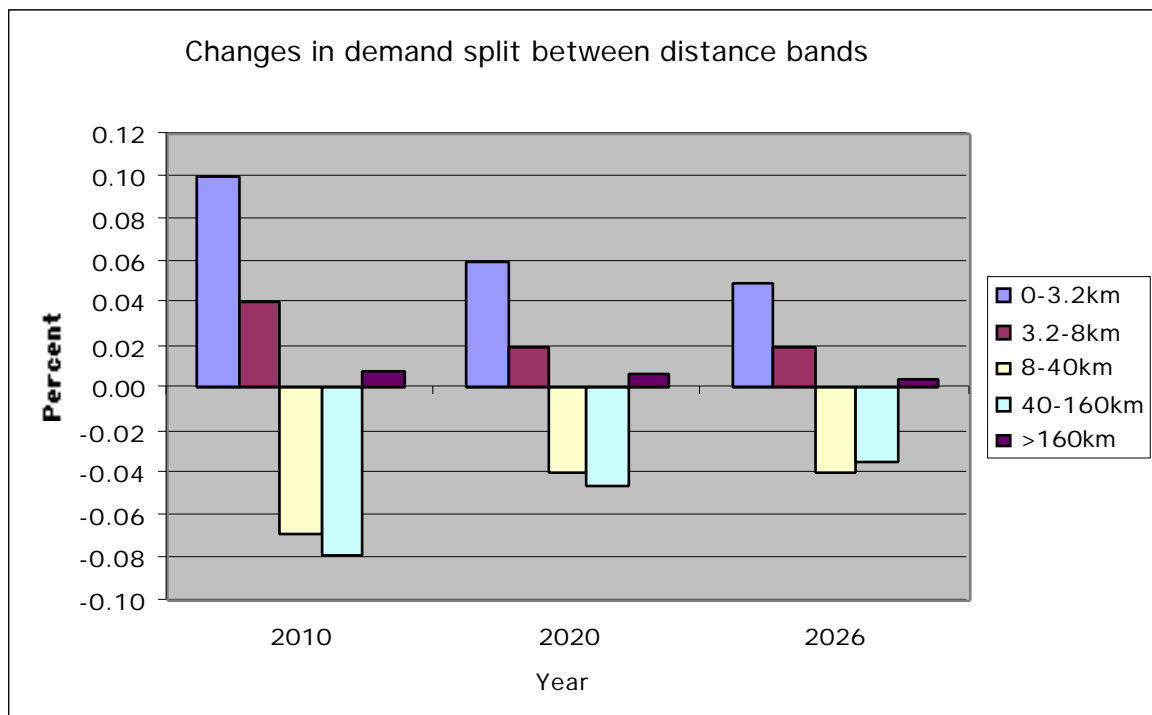


Figure 88: Changes in demand split by the IFT policy for the five passenger distance bands

For freight transport also changes in transport performances and in modal-split can be observed. However these changes are only partially driven by the changes in transport costs. In figure 89 one can realise that the development of freight transport performance for all freight modes is very similar in the base scenario and the policy. If we look at the numbers they indicate a decrease of 1,2% for truck tkm and a very slight decrease for ship tkm (-0.05%) and train tkm (-0.004%). The reason that all modes decrease can be found in the economic performance of the policy, which is slightly weaker compared to the base scenario. This leads to a reduction of freight demand of about 0.6% in 2010, such that it can be stated that ship and train perform better than the market development.

Basically this policy is not expected to generate economic disadvantages. The reason is that not all mechanisms fostering economy by reduced employers labour costs are yet considered. E.g. besides using the money for additional employment also additional investments can be produced, which is not implemented for the policy.

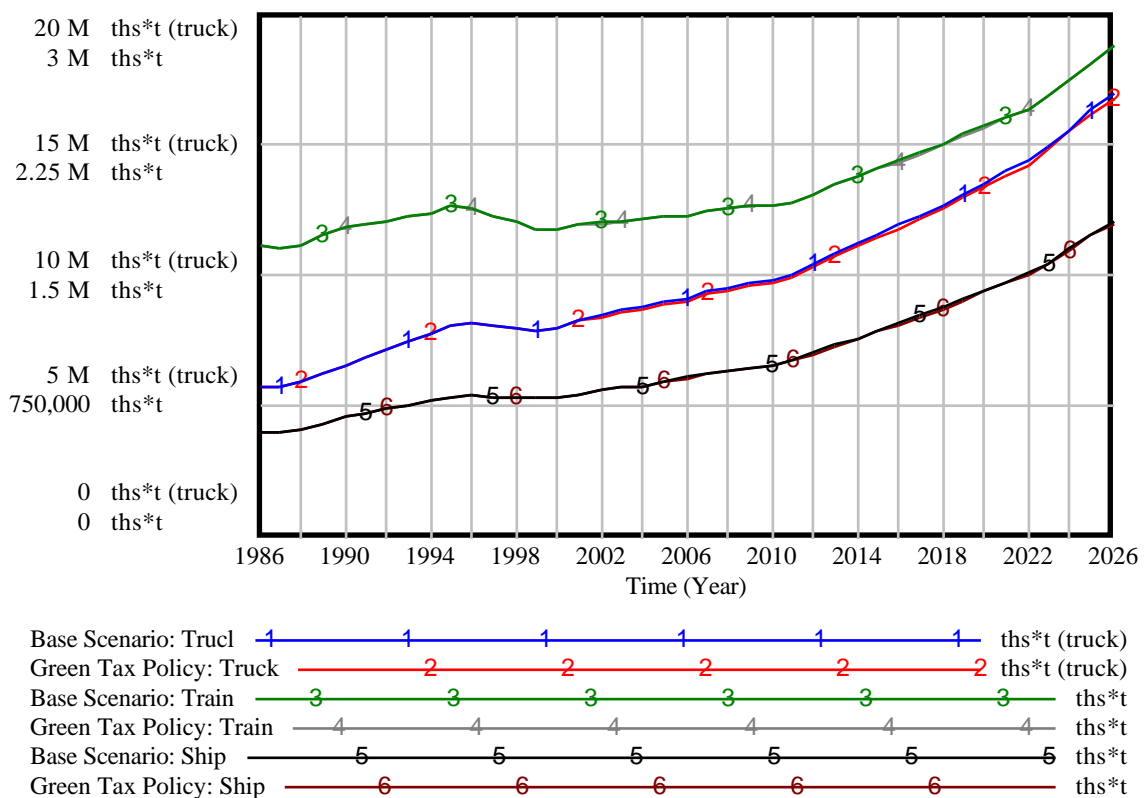


Figure 89: Freight transport volume for EU15 countries

In figure 90 the European trip demand for the three considered trip purposes (business, private, tourism) is shown. It has to be mentioned first that the scale for each of the purposes is different as the number of private trips (PE) is about 5 times higher than the number of business trips (BU) and about 35 times higher than the number of tourism trips (TO). Concerning the development of demand the tourism trips are steadily increasing while business and private trips are more or less stable with the beginning of the new millennium. The policy mainly effects the demand for private trips (curve 3 and 4) that are reduced by about 0.3 % considering the year 2020.

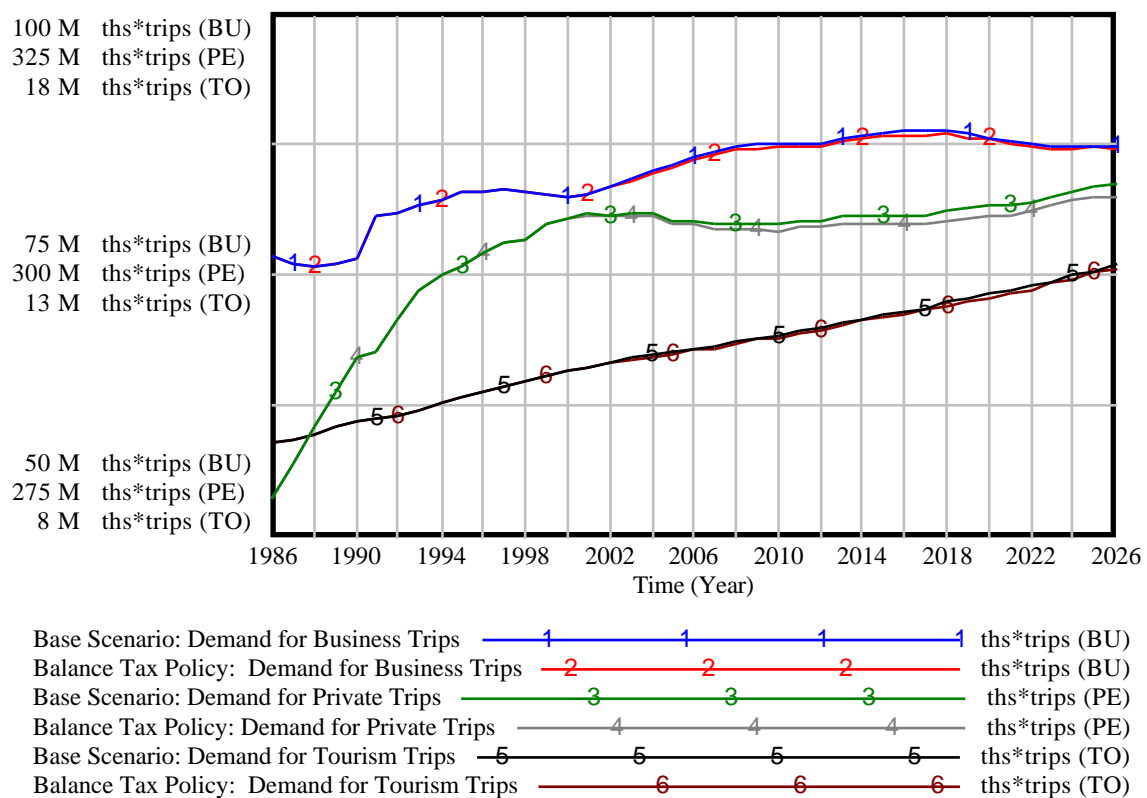


Figure 90: Passenger demand changes by increased fuel tax policy (yearly)

The increased fuel tax policy changes the difference of variable costs between gasoline and diesel passenger cars, such that diesel cars become more advantageous. The tax increase in total is calculated as additional 25% of the base tax level, which is lower for diesel than for gasoline, such that diesel fuel price is growing less fast than gasoline fuel price. Combined with a lower specific fuel consumption of diesel cars this leads to an increase of the relative cost advantage of diesel cars against gasoline cars. This positively influences the share of diesel cars of the new purchased cars, such that over time the share of diesel cars in the fleet is higher in the IFT policy than in the base scenario. As figure 91 shows the effect is different for the four regions and the the European Union. In EU15 (curve 1 and 2) the share of diesel cars is stable around 10% after 2000, while it increases to more than 12% by the policy. For region 2 (B, F, L, NL) and region 3 (E, GR, I, P) decreasing shares of diesel cars are observed. However the decreasing tendency is weakened by the policy.

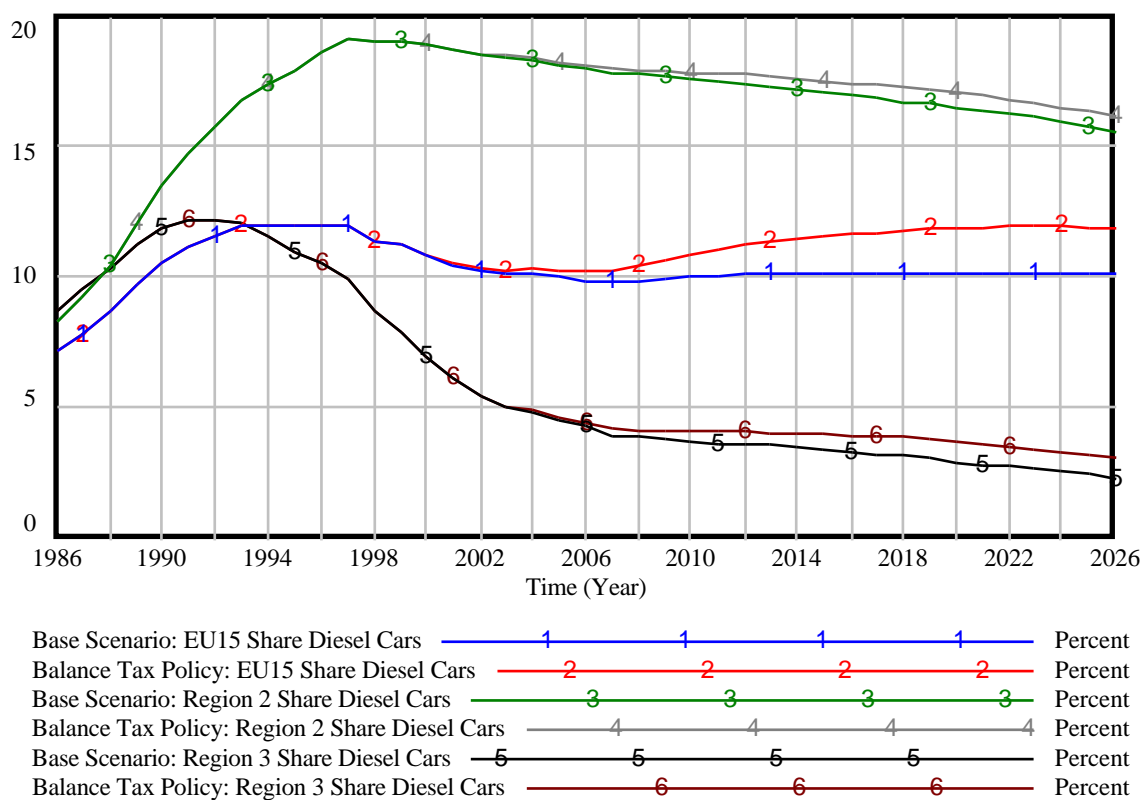


Figure 91: Share of diesel cars in European fleet and in the car fleet of region 2 and region 3

Figure 92 gives an overview on the order of magnitude of the additional revenues generated by the increased fuel tax policy in the four regions. Actually the curves indicate the net change in revenues between the base scenario and the IFT policy, because the revenues are influenced on the one hand by the increase of specific tax per unit of fuel and on the other hand by decreased fuel demand because of the price increase.

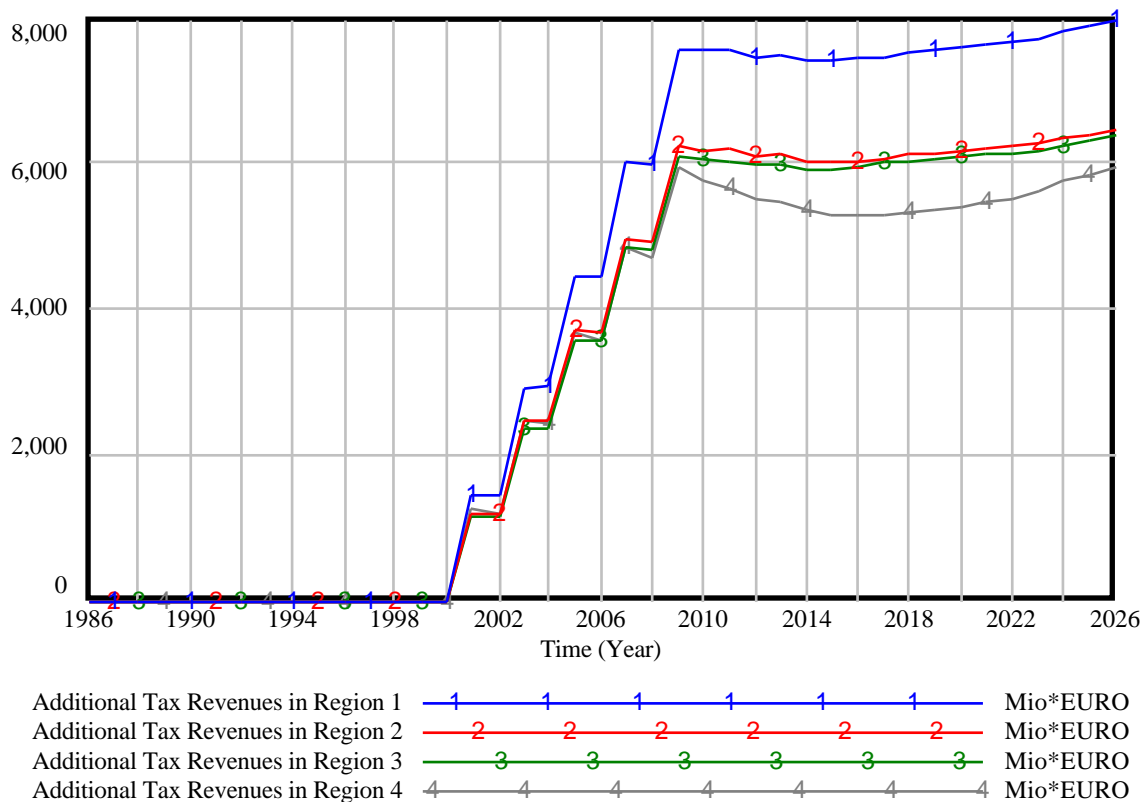


Figure 92: Additional fuel tax revenues generated by the increased fuel tax policy

Figure 93 presents the development of employment for region 1 (A, D) in terms of total employment, sectoral employment in transport services and in transport production. The changes in total employment by the policy are minor (curve 1 and 2). However, employment in transport services (bus, rail, air, truck, ship) is increased by the IFT policy especially during the period 2002 to 2016. This is caused by the shift in modal split towards the service modes in passenger transport, such that their GVA and consequently their employment is increased. The increase is diminishing after about 2016 as the economic development is slightly weakened in the policy (see discussion above), which reduces mainly demand for freight transport.

The employment in transport production is nearly not changing by the policy, though the passenger car fleet is reduced by about 2% looking at the year 2020. The reasons are either that employment in the car industry is substituted by employment in industries producing vehicles for transport services (e.g. rail waggons and planes) and that car industry employment is also depending on export, which is nearly not changing between the base scenario and the IFT policy.



Figure 93: Employment effects of green tax policy in region 1

To make clear the slightness of the changes of employment by the policy, results for certain points of time are presented in the following table 49.

Table 49: Development of employment in all regions at certain points of time

	[Mio Employees]		1986	2000	2005	2010	2020
Region 1	Total Employment	Base Scenario	36.40	37.82	39.51	40.45	41.20
A, D		IFT Policy	36.40	37.82	39.47	40.32	41.16
	Employment Services	Base Scenario	2.52	2.89	3.00	3.09	3.47
		IFT Policy	2.52	2.89	3.03	3.13	3.50
	Employment Production	Base Scenario	1.73	1.77	1.83	1.68	1.60
		IFT Policy	1.73	1.77	1.83	1.69	1.60
Region 2	Total Employment	Base Scenario	30.08	33.09	34.86	36.00	35.63
B, F, L, NL		IFT Policy	30.08	33.09	34.82	35.92	35.62
	Employment Services	Base Scenario	2.55	2.58	2.69	2.80	3.20
		IFT Policy	2.55	2.58	2.72	2.83	3.22
	Employment Production	Base Scenario	1.41	1.37	1.42	1.32	1.28
		IFT Policy	1.41	1.37	1.42	1.32	1.27
Region 3	Total Employment	Base Scenario	38.79	41.25	42.78	44.38	46.24
		IFT Policy	38.79	41.25	42.72	44.23	46.21
	Employment Services	Base Scenario	2.62	2.75	2.86	2.87	3.16
		IFT Policy	2.62	2.75	2.88	2.90	3.18
	Employment Production	Base Scenario	1.26	1.12	1.27	1.07	1.06
		IFT Policy	1.26	1.12	1.27	1.06	1.05
Region 4	Total Employment	Base Scenario	34.65	35.12	37.47	39.23	38.75
		IFT Policy	34.65	35.12	37.34	39.12	38.75
	Employment Services	Base Scenario	3.18	3.11	3.26	3.35	3.84
		IFT Policy	3.18	3.11	3.28	3.38	3.86
	Employment Production	Base Scenario	1.69	1.56	1.67	1.51	1.47
		IFT Policy	1.69	1.56	1.66	1.51	1.47

To highlight also one environmental aspect of the increased fuel tax policy figure 94 presents the development of total transport emissions of CO₂ in the EU15 countries (curve 1 and 2) and for region 1 (A, D) and region 2 (B, F, L, NL). It can be seen that the policy provides significant changes to CO₂ emissions from transport, though they are still increasing instead of decreasing as it would be expected e.g. by the Kyoto protocol. Considering the year 2020 the policy reduces yearly CO₂ emissions by about 1.7% for EU15 and by about 1.4% for the two displayed regions. The higher decrease in the total Union is due to a stronger decrease mainly in region 4 (DK, FIN, IRL, S, UK).

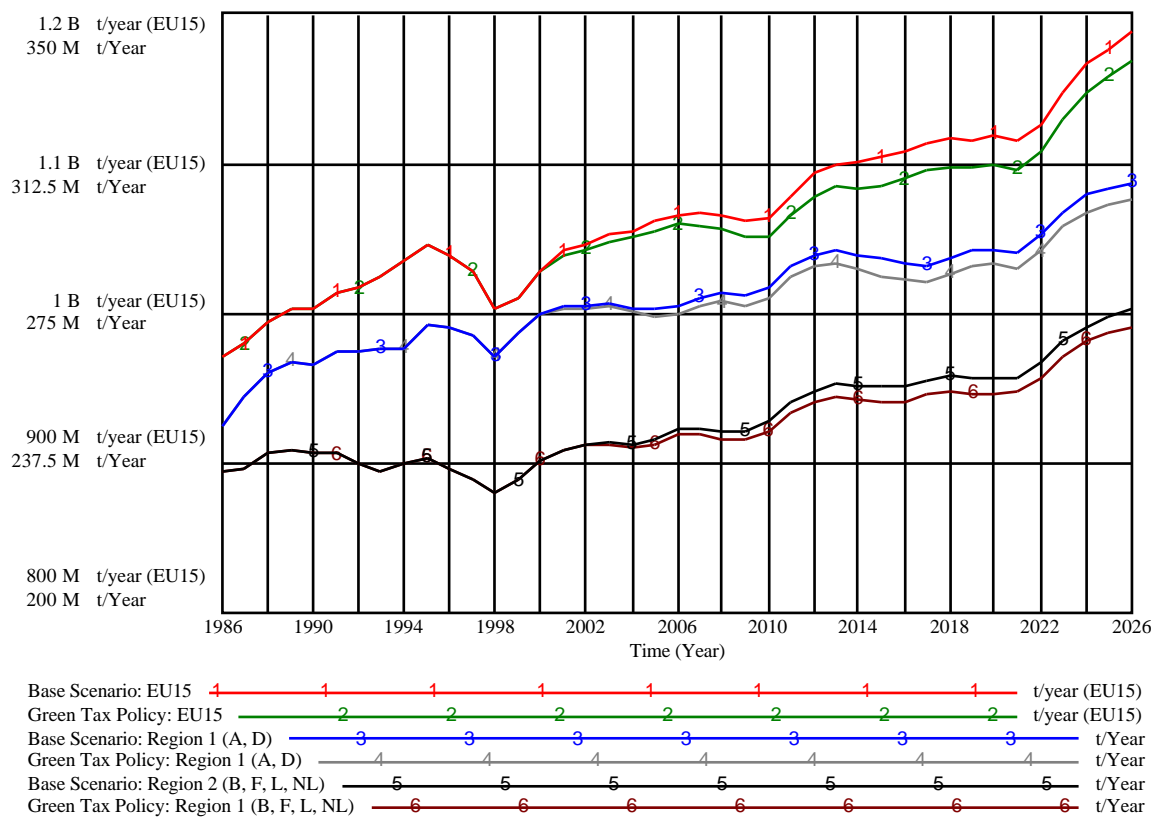


Figure 94: Development of transport CO₂ emissions in base scenario and with IFT policy

7.3.4 Policy Package 3: Balance Fuel Tax plus Reduction of Labour Costs (BFT)

This policy package is also designed to create a neutral taxation by increasing transport taxes and reducing labour costs. In contrast to the previous policy package (IFT) it is aimed to compensate the differences existing between gasoline and diesel taxation in many European countries. Also it introduces taxes for air mode of transport to compensate the taxation level between air and other competing modes of transport. Thus diesel and kerosene cost are increasing stronger than in the base scenario, while gasoline cost are kept to the development of the base scenario. The difference between fuel tax revenues in the base scenario and in the balanced tax policy is treated as additional revenues that are used to reduce the labour costs in the same way as explained for the increased fuel tax policy (see previous section).

The impacts of this policy on freight transport are directed to reduce road transport by trucks and diesel vans. Counteractive ship and rail transport increase such that a modal-shift towards non-road modes is expected. So, the policy is consistent with the aim to move freight transport from road to more environmental friendly modes.

For passenger transport the increase of diesel costs implies besides changes in modal-split towards non-road modes and reduced trip distances also a change of the car fleet shares between gasoline and diesel vehicles. As evidence is growing that emissions of particulate

matter are the most harmful emissions of transport for human health, these emissions should be reduced, which on the passenger side implies a reduction of the share of diesel cars. For this purpose a reduction of the fuel tax advantage of diesel is a reasonable instrument. Alternatively the development of better cleaning technology for particulate matter can be fostered, which is not implemented in the model. That means, the given improvement of cleaning technology in the base scenario is also applied for the BFT policy.

The introduction of a kerosene tax leads to higher air ticket prices and hence to a reduction of demand for air transport. The reduction effect is different for business and tourism transport. Competing modes especially high-speed rail should profit as their relative attractiveness increases. Also trip distances can be reduced.

7.3.4.1 Implementation in the Model

The implementation of the balanced fuel tax policy (BFT) is treated similar to the one of the increased fuel tax policy (IFT). It is based on the tax variables of diesel and kerosene fuel, which then amount to the total diesel respectively kerosene price together with VAT and the pure fuel prices.

The rate of both taxes is determined by the taxation level of gasoline fuel. It is assumed that the tax rates are adjusted to each other within a period of 5 years starting in the year 2000. The height of increase of the diesel tax rate is different for the four macro regions as in the year 2000 the regional difference between the four regions varies. The end values for the increase of the diesel tax are given in table 50

Table 50: Overall increase of diesel tax to reach the level of gasoline taxation after 2004

	Increase of diesel tax
Region 1: A, D	53 %
Region 2: B, F, L, NL	60 %
Region 3: E, GR, I, P	40 %
Region 4: DK, FIN, IRL, S, UK	14 %

The increase of kerosene tax is the same for all macro regions. It starts in the year 2000 and adds every year 20% of the current gasoline tax to the kerosene tax such that after 5 years gasoline and kerosene taxation are equal. For air transport the cost of fuel amounts to 25% of the total cost for air tickets.

The additional revenues are calculated in the same way as for IFT policy by a comparison between base scenario fuel tax revenues and fuel tax policy revenues. The difference in revenues gives the amount of money by which the labour costs can be reduced. The reduction

of labour costs is split on three links. The major link with 80% of additional revenues is connected with a reduction of social protection payments of the employers, which increases sectoral gross value added and causes new employment. With the remaining 20% employees tax payments are reduced spending 10% for a reduction of direct taxes and 90% for reduction of employees social protection payments. This effect increases total personal income in the four regions as well as individual disposable income.

7.3.4.2 Results of Balanced Fuel Tax Policy (BFT)

The effects of the BFT policy commence with an increase of fuel price for diesel and kerosene in dependency of the tax increase. The price increases lead to changes of modal-split and trip distribution for both freight and passenger, which are either performed by the altered relative attractiveness of the modes but also concerning the road modes by indirect effects via the network loads. However, the strongest reaction is the slowed down increase of air transport, which changes the modal-split in the passenger long distance band.

The first two figures present the development of prices and additional tax revenues. In figure 95 curve 1 and 2 depict the development of the diesel fuel price in region 1 reflecting the tax increase after 2000 and curve 3 and 4 present the European average price for kerosene as it is assumed that the pure kerosene price and the kerosene tax are the same all over Europe. From curve 5 and 6 showing the diesel fuel consumption in region 1 the reaction to the policy, which is to reduce diesel consumption e.g. by modal-shifts or by buying gasoline cars, can be observed. Figure 96 presents the additional tax revenue gained from the tax increase of diesel fuel and the new kerosene tax, which then can be used for the reduction of labour costs.

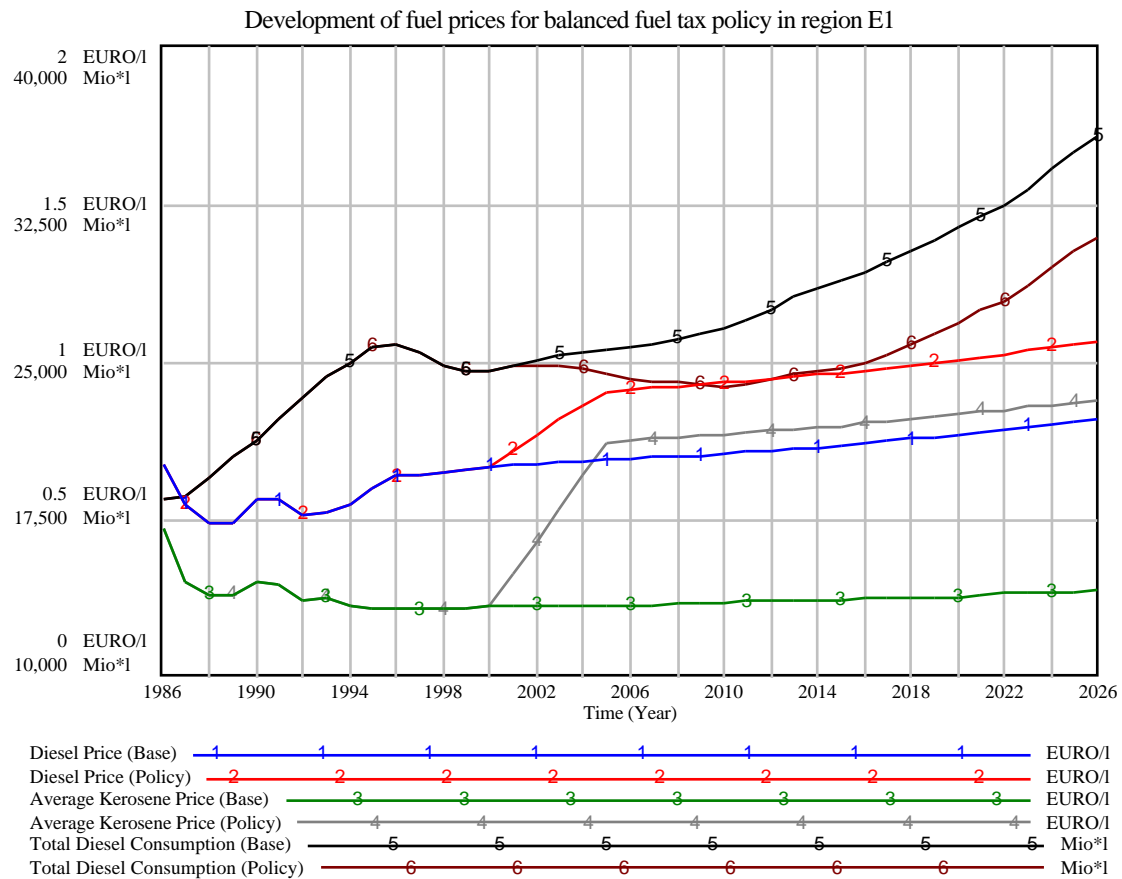


Figure 95: Development of fuel prices and diesel fuel consumption in region 1 with BFT policy

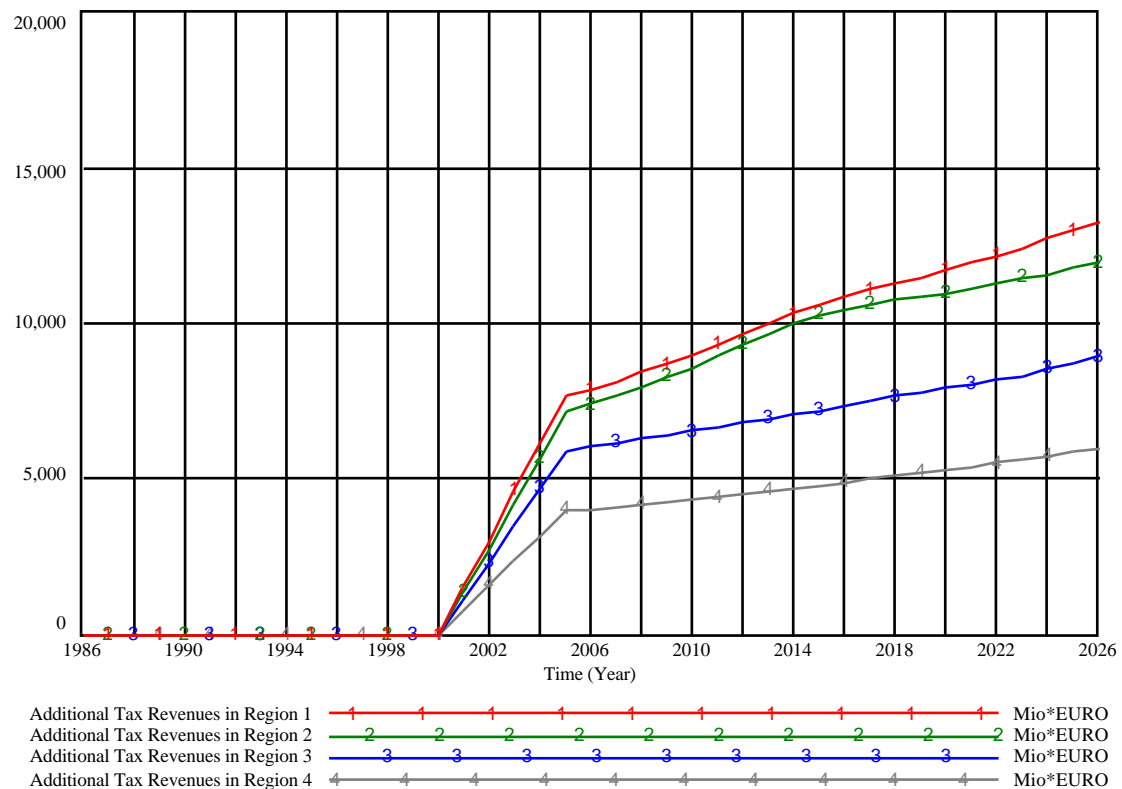


Figure 96: Additional fuel tax revenues of BFT policy

In the following these and other effects are discussed in more detail. Figure 97 presents the changes in specific transport costs as an example for selected relations. It can be realised that for business air transport shown for LSA-LSA relations like Paris-Madrid (curve 1 and 2) the base development would be a slightly decreasing cost curve that is changed significantly by the introduction of the kerosene tax after the year 2000. For tourism air transport shown for LSA-LDR relation (curve 3 and 4) the price level is lower and the effect of the policy more moderate. The smallest of the effects is observed on road freight transport shown with the example of unitised freight in the medium distance band (150-700km) of relations between region 2 and region 3 (curve 5 and 6). This can be explained by the minor influence of fuel cost of 22% on freight road transport cost.

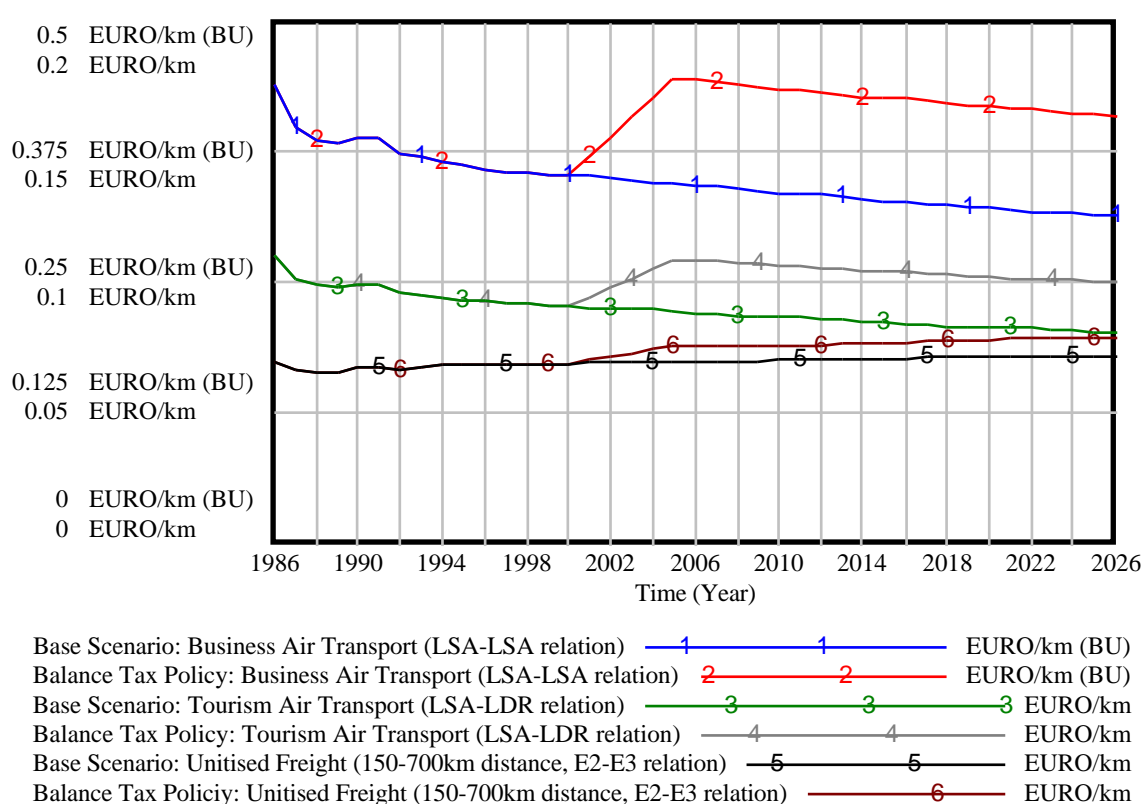


Figure 97: Examples of policy influences on specific transport costs for different relations and purposes

Figure 98 presents the effects of the BFT policy on passenger transport performance. Curve 1 and 2 indicate that the changes for car transport are minor, which is due to the fact that only owners of diesel cars are affected by the tax increase. This can be made clear by a comparison with the IFT policy (see figure 86), which revealed a noticeable decrease for car transport. The effects on rail transport (curve 3 and 4) are similar as in both policies rail transport increases, though it can be stated that in the BFT policy the increase of rail is a bit stronger. Air transport (curve 5 and 6) is reduced significantly by the BFT policy, which is in contrast to the effect of the IFT policy where it slightly increases. This reveals that there is a strong interdependency between air and rail transport performed by the competition in the long distance band ($> 160\text{km}$)⁷⁴.

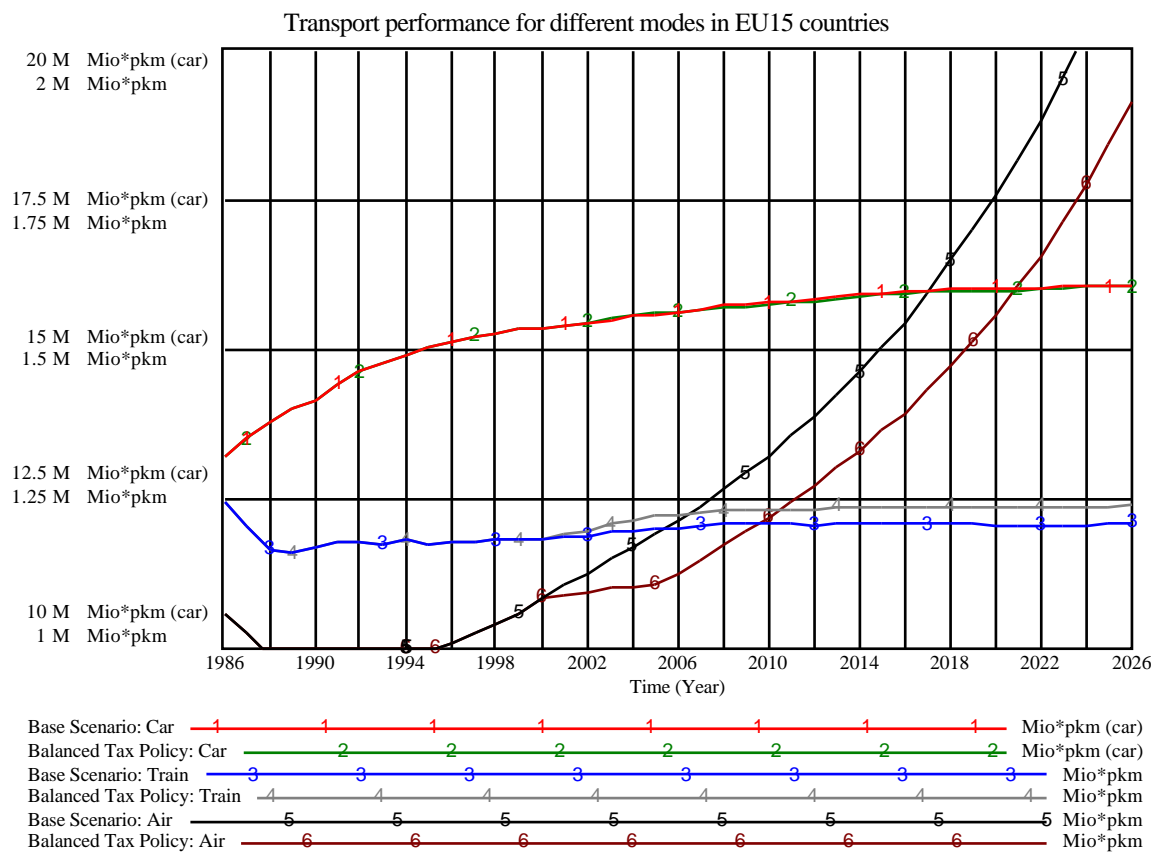


Figure 98: Comparison of passenger transport performance between base scenario and BFT policy

⁷⁴ Actually the competition occurs for distances quite longer than 160km, such that this specification is just to remind to the categorisation used in ASTRA for the passenger long distance band.

Also based on transport performance figure 99 shows the freight modal split in the medium long distance band (150-700km) for region 2 (B, F, L, NL). Again the values are based on the origin-region-concept, which means that a trip from region 1 to region 2 is added to the transport performance of region 1, which is the origin of the trip. In general it can be stated that road and ship modal-split increase over time, while rail modal-split decreases. The changes caused by the BFT policy especially the increase in road diesel tax, which are a decrease of road modal-split and an increase in rail and ship modal-split can be taken from the figure. Expressed as percentages for the year 2020 road transport by HDV loses about 1% of its share in the medium long distance band, while rail and ship each gain about 0,5% more of the modal split. Compared with the base value of the modes ship increases its share of the modal-split by nearly 3% and rail by more than 2% by the policy.

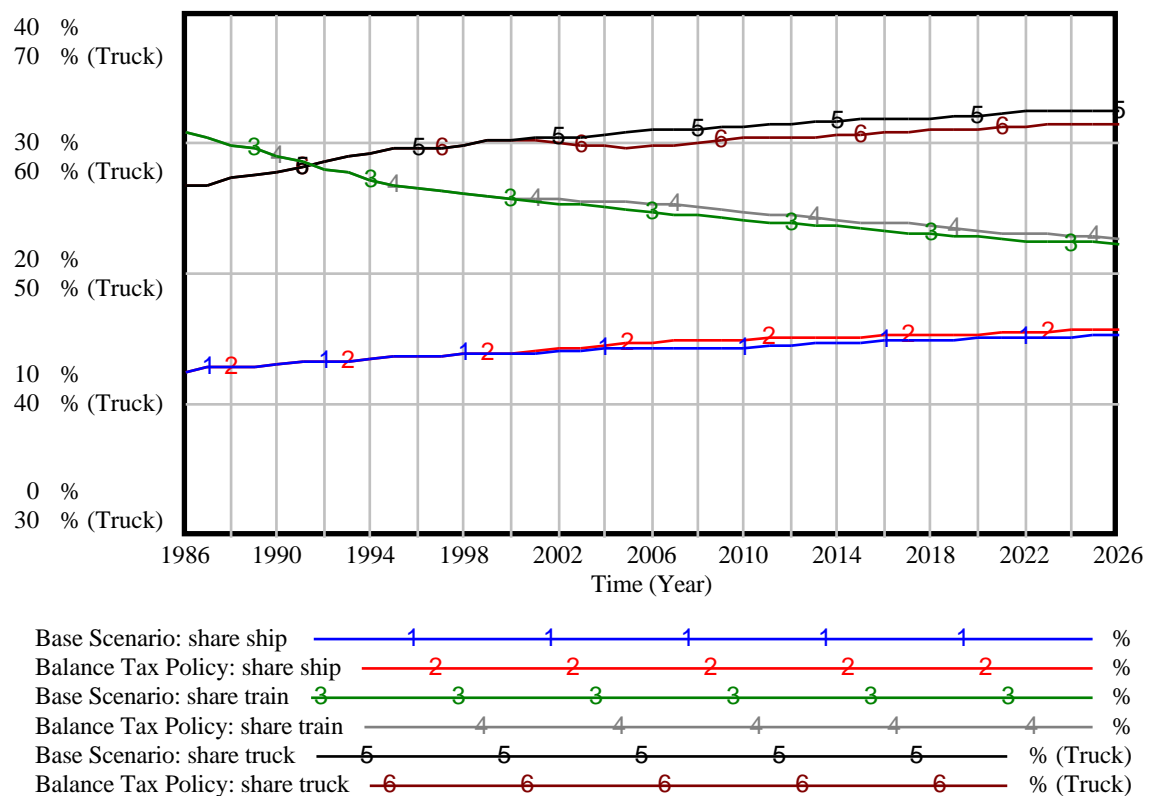


Figure 99: Freight modal split in region 2 (B, F, L, NL)

In figure 100 the effects on air transport by the BFT policy within the EU15 countries is shown. Curves 1 and 2 indicate the development of the number of air trips for all EU15 countries. In the base scenario the increase of air trips reaches a factor of 2,5. Compared with the base scenario the BFT policy reduces the number of air trips by about 15% in the final years of the simulation. A similar reduction can be identified for the number of air passenger-km within EU15 (curve 5 and 6). Furthermore as an example of more detailed information the transport performance for air transport starting at metropolitan-areas-plus-hinterland zones (MPH) is shown in curve 3 and 4. The pattern and the reaction to the policy is similar as for the other curves.

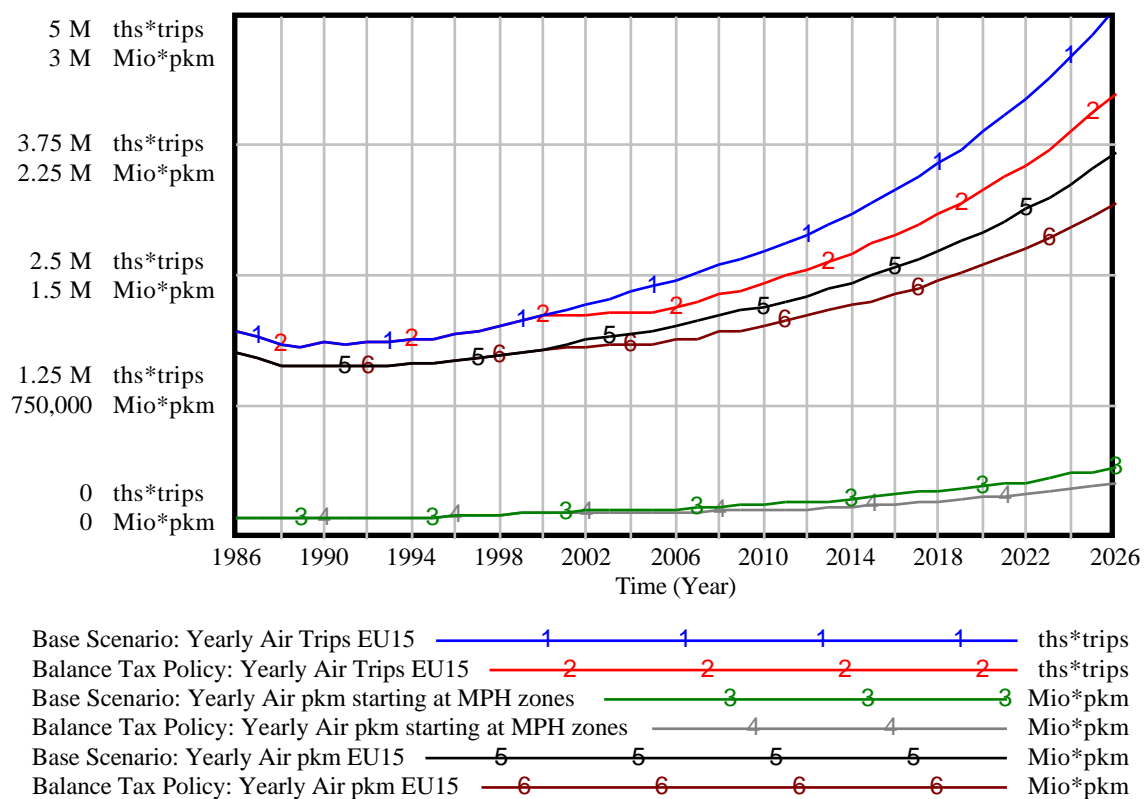


Figure 100: Effects of balanced tax policy on air transport

The BFT policy changes the difference of variable costs between gasoline and diesel passenger cars, such that diesel cars become less advantageous. However the variable cost of diesel cars are still a bit lower than for gasoline cars, as diesel engines are still more fuel efficient. But for certain countries e.g. Germany the vehicle tax on diesel cars is higher than on gasoline cars and in general comparable diesel cars are more expensive in purchase.

From figure 101 it can be seen that the outcome of the described influences in the first 15 years is in general a growing share of diesel cars in the vehicle fleet. This growth slows down over time and even vanishes around 1998 as the difference in fuel efficiency and between diesel and gasoline fuel prices diminishes such that the overall market share of diesel cars in EU15 countries (curve 1 and 2) reaches a plateau with a share of about 13%. For region 2 (curve 3 and 4) and for region 3 (curve 5 and 6) the level of the plateau is different, which is mainly due to the different price structure in these countries.

The result of the BFT policy that starts at 2000 can be clearly identified in all curves. The policy reduces the share of diesel cars significantly. The most significant effect occurs in region 2 where the price difference initially before 2000 was the highest. For region 3 it can be observed that the share of diesel cars shrinks to 0% at the end of the simulation period, which would be in line with the general forecast of the MEET project⁷⁵.

For a comparison of the effects of the increased fuel tax policy (IFT) and the balance fuel tax policy (BFT) figure 102 is presented, that shows the same curves for the IFT policy as in figure 101 for the BFT policy.

⁷⁵ HICKMANN ET AL. (1997)

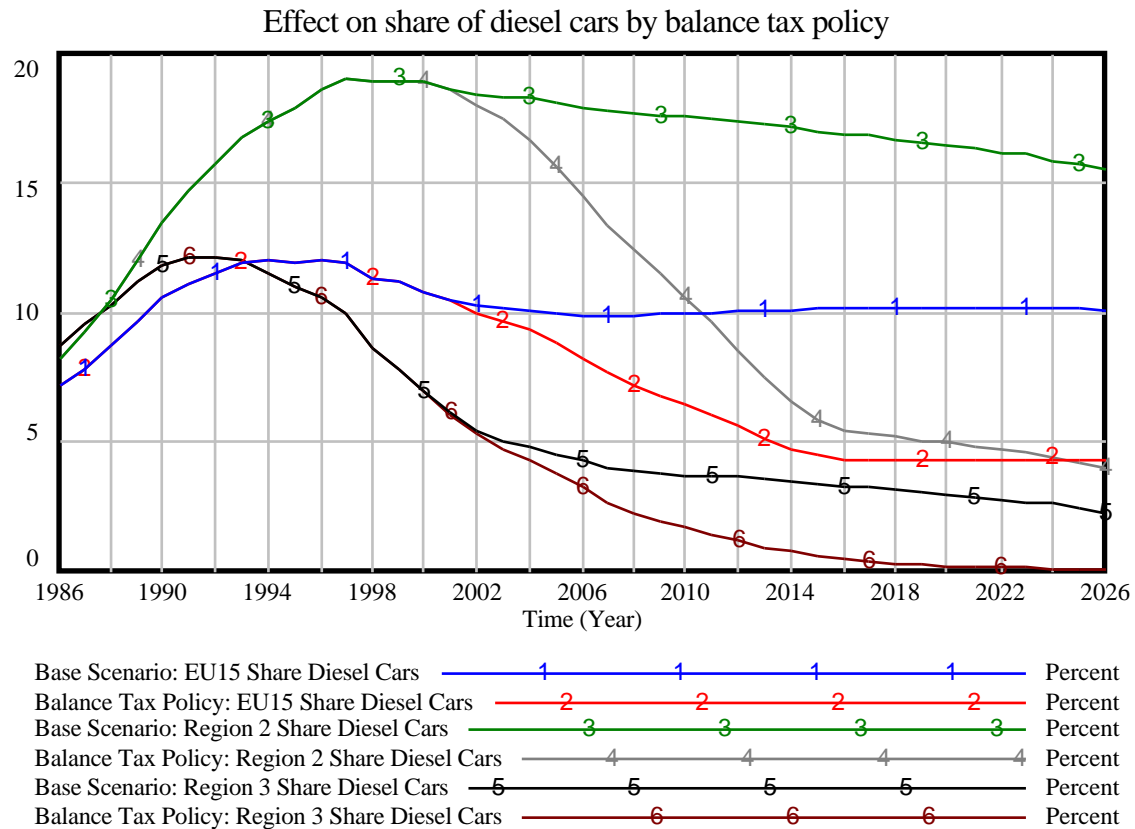


Figure 101: Influence of balance tax policy(BFT) on share of passenger diesel cars in EU15, region 2 (B, F, L, NL) and region 3 (E, GR, I, P)

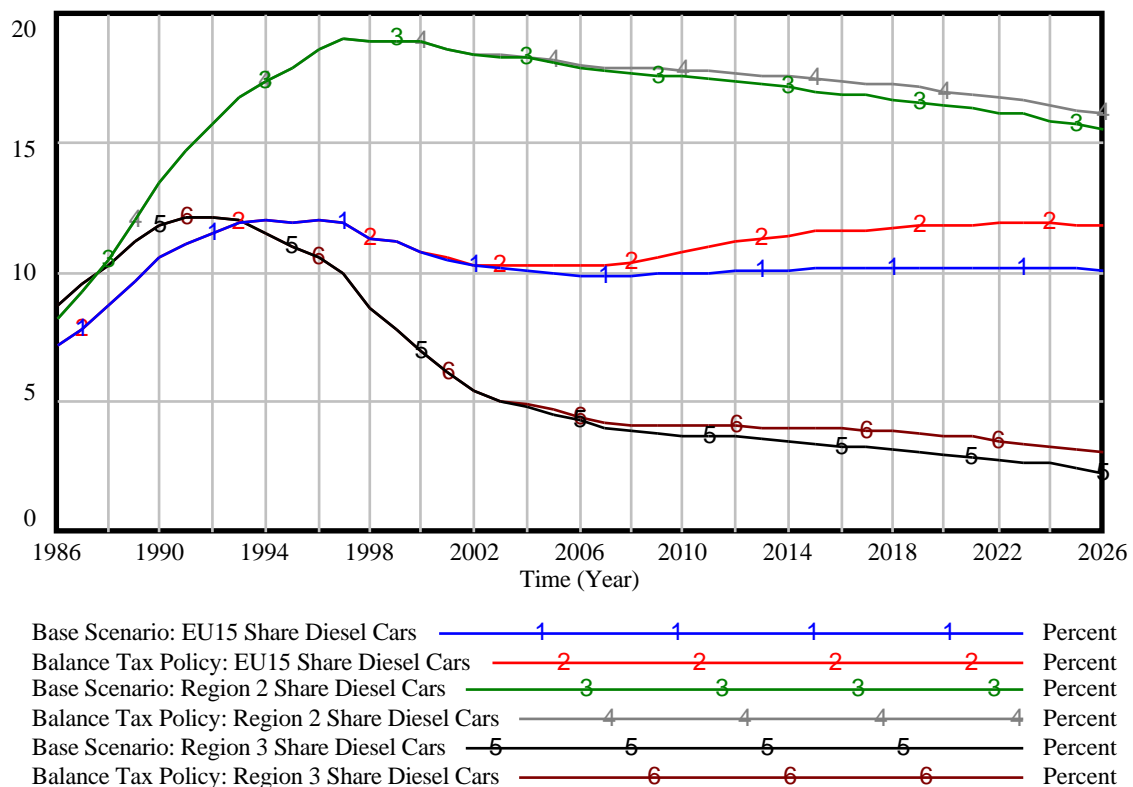


Figure 102: For comparison development of share of diesel cars with IFT policy

The changes in the car fleet structure between diesel and gasoline cars is one influence effecting the immission concentrations of soot particles, which are calculated as potential risk indicators. Figure 103 presents a small selection of the over 300 potential risk indicators for soot particles (SP) that are calculated by the ENV for each region. The results in the figure are focussed on large stand-alone metropolises of region 2 (B, F, L, NL) and especially on main roads that are disturbed by traffic lights or crossings. All curves follow a similar pattern, that shows an increase of concentration of soot particles until about 1992/93 followed by a stronger decrease in the next 15 years and by smoothed decrease in the final years. The reason is that until the turning point in 1993 the share of diesel passenger cars grows while their emission factors for SP are constant or even increase. Starting with EURO I legislation for all road transport means the emission factors start to decrease.

Curves 1 and 2 indicate the average concentration of soot particles in the LSA zone, which means the concentration that is given as an average for the whole zone. This is lower than the other curves as they indicate concentrations for locations that are affected directly by transport emissions. Curves 3 and 4 present average SP concentrations alongside urban main roads with traffic lights. It can be observed that in the initial years these concentration are about 25% higher than the average concentration in the zone. In the final years the four curves adapt to each other. In contrast to the previous two curves the curve 5 and 6 present the worst case for soot particles concentrations alongside an urban main road, which is represented by low wind velocity, high average daily traffic and most unfavourable wind direction to the road. It can be observed that under this conditions the concentrations of soot particles are nearly four times the average concentrations in the zone in the first decades of the simulation.

Looking at the policy effects it can be realised that the policy is most effective in reducing the worst case concentrations (curve 5 and 6), while the effect on the other locations is smaller. This can be explained by the influence of the background concentration of soot particles that contributes for a higher share of the concentration at the average locations, while the worst cases are mainly transport influenced. The background concentrations consider besides transport network related emissions also non-transport sources like private heating.

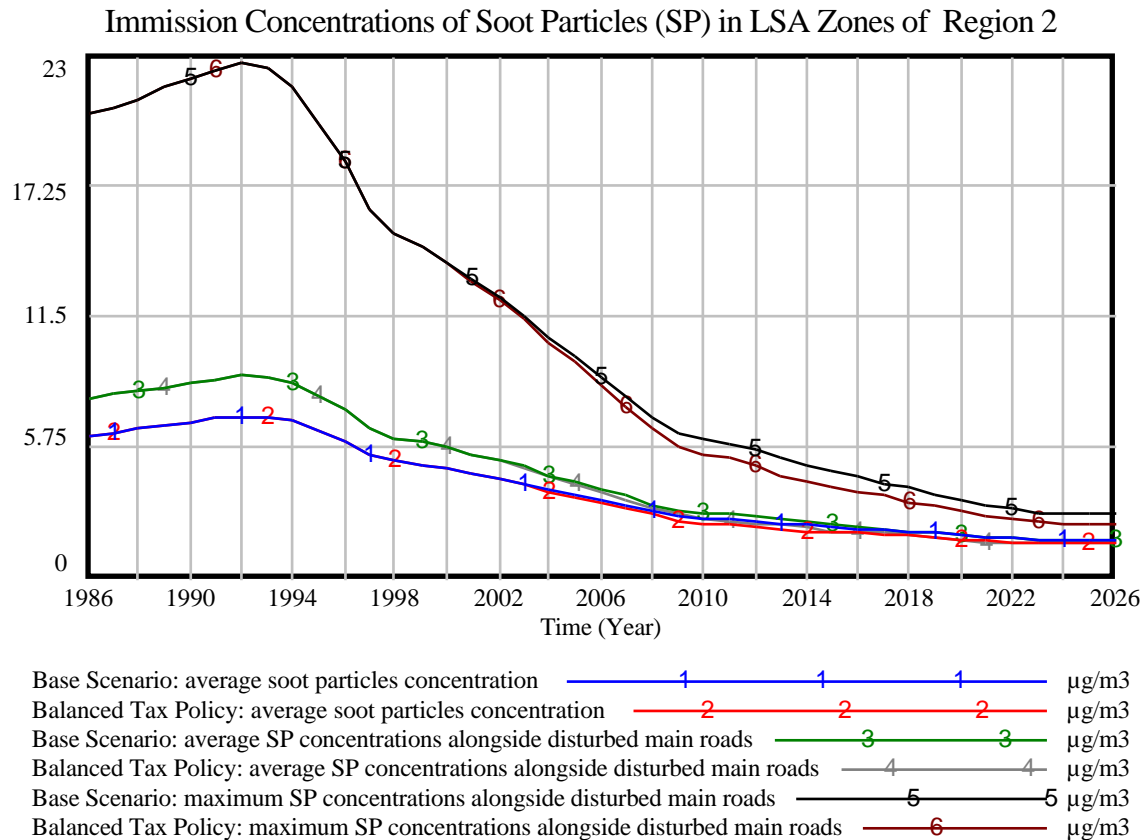


Figure 103: Concentrations of soot particles in LSA zones in region 2 (B, F, L, NL)

Two issues have to be clarified. Soot particles are not identically with particulate matter as soot particles emerge from the combustion of fossil fuels (or wood) and consist of a core of carbon combined with other chemicals. So, SP do not include particulates from brakes or tyres. Recent studies try to include also these and other particulates and therefore focus on all particulate matter below a certain diameter (10 or 2.5 µm), which should be the most harmful as they are able to go deeply into the lungs. Nevertheless, looking at German environmental targets for soot particles the current as well as the future simulated concentrations of soot particles violate these targets as the long-term immission standard for soot particles suggested by the German LAI is 1.5 µg/m³.⁷⁶ For concentrations alongside roads a guideline from 1998 prescribes an immission concentration below 8 µg/m³, which seems to be very high compared with the LAI suggestions.⁷⁷

⁷⁶ LAI (1992)

⁷⁷ 23. Bundesimmissionsschutzverordnung (23. BImSchV) (1998)

Finally, another comparison between effects of the IFT policy and the BFT policy is presented in figure 104. In both policies the diesel fuel price is increased, which effects road freight transport cost and reduces slightly its attractiveness. The increase for the BFT is in general for all regions higher than for IFT. The effect on road freight transport performance is indicated in curve 1, 2 and 3. In the base scenario road transport performance reaches the highest level, while a slight reduction is observed for the IFT policy and a significant reduction for the BFT policy. So, for rail transport performance one would expect an increase by the two policies gaining a certain share of reduced demand from road transport. However, curve 6 for rail transport in BFT policy shows also a slight decrease compared to base scenario as well as to IFT policy (curve 4 and 5), which would not be expected.

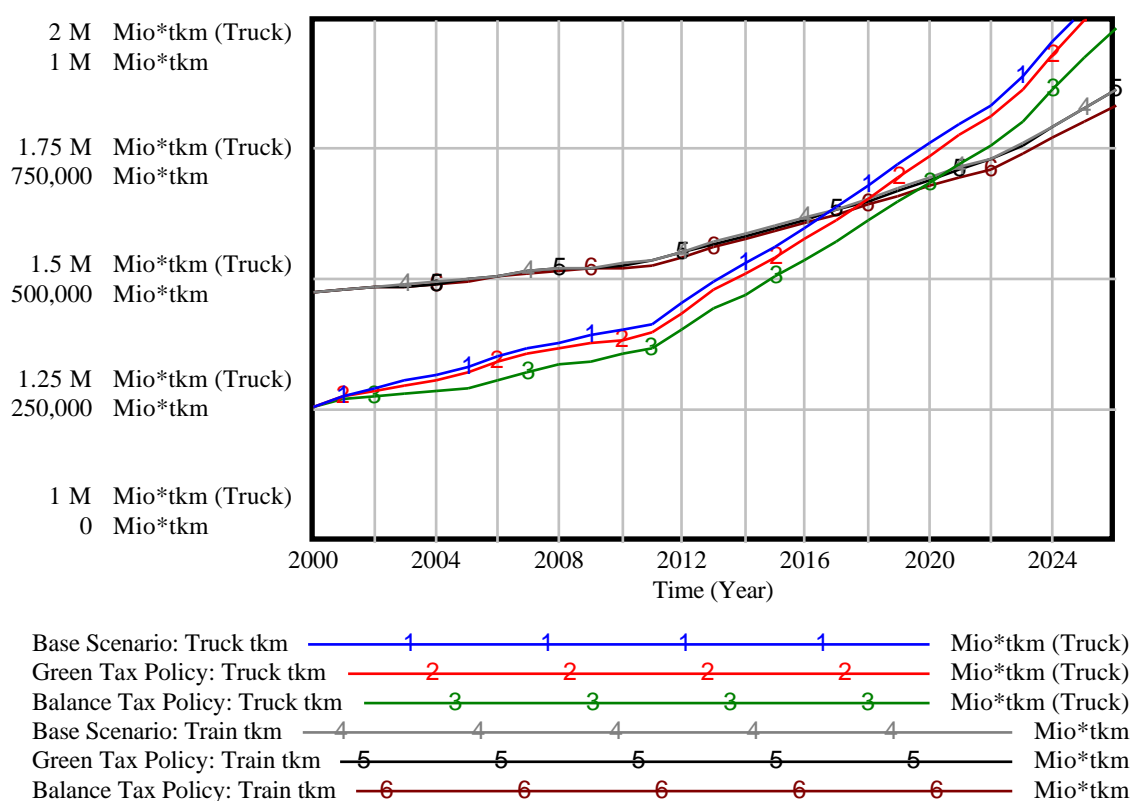


Figure 104: Comparison of freight transport performance between increased tax policy and balanced tax policy

Obviously other impacts in the model have to be discussed to explain these parallel decrease of freight transport performance. The direct cause results from a general decrease of freight demand because a reduced growth of GDP in the BFT policy. The main reason in the model is a reduction in investment as especially by the kerosene tax the demand for air transport is significantly reduced as well as the diesel price reduces road freight demand. But the demand drives the investments for these modes. Though in the first years after introduction of the policy in 2000 demand is transferred from air and road freight to other modes there is no complete compensation in terms of investments as especially for air transport the specific investments per passenger-km respectively per trip are much higher than for other modes. But

the investments contribute to the accumulation of the capital stock such that over the years the capital stock grows significantly slower in the BFT policy. As the capital stock is one major driving force for potential output and GDP also with a lag of a few years the growth of GDP is reduced in the BFT policy. Now the feedback loop is closed as GDP is the main driver of freight transport generation. However, there are some effects that could compensate for the reduced investment and the reduced GDP that could not yet been considered in the ASTRA model. Price increases especially if they are introduced by policies, which implies that the increase is announced some time ago before the policy is coming into force, induces research and technology improvement incentives. This would lead to investments into these fields, which could compensate the gap in the demand driven investments. It could even overcompensate the gap if for instance efficiency improvements are higher than fuel price increases such that costs could even decrease with positive effects on demand but also positive effects in other fields e.g. emissions.

A further influence that is not as grave as the one explained above is the change in consumption structure. The BFT policy increases total transport consumption of households, which is the balance of increased gasoline consumption, reduced diesel consumption, increased share of gasoline cars, reduced air transport demand and increased demand for bus and rail transport. However, weighted transport consumption is taxed higher than average non-transport consumption, which means that overall consumption excluding taxes is reduced as more taxes have to be paid when consumption expenses are transferred from non-transport to transport consumption. As overall consumption is also a driver of investments this enforces the loop explained above.

It seems that for the BFT policy the insufficient consideration especially of the increased incentives for technology improvements in air transport by price increases leads to an underestimation of the potential of the policy. The need for accelerated technological improvements in air transport could also be enforced by capacity constraints of air transport facilities e.g. leading to the introduction of the “Super-Jumbos”. These constraints are not implemented in the model. For these reasons the development of GDP in this case probably does not tell the true story.

7.3.5 Policy Package 4: Fuel Taxation and Investment in TEN (Rail-TEN, All-TEN)

In this policy package the taxation level is imposed to cover the expenses for the construction of the priority projects of the Trans-European Network (TEN). The taxation approach is similar to the IFT policy package, which means that the tax is imposed on all road modes of transport. The difference lies in the use of the revenues of such funds, which will be earmarked for TEN transport investments. This package is implemented with two options: the first option is to implement only the TEN projects for rail mode (Rail-TEN policy) and the second option is to implement the TEN projects for all modes (All-TEN policy). For both options it is assumed that the implementation takes place according to the current plans between the years 2000 and 2015. As it takes some time to construct infrastructure lags are implemented between the investment in new infrastructure and the improvement of transport

by the new infrastructure e.g. reduced travel times. Fuel taxes are raised by the same percentage for all macro regions.

7.3.5.1 Implementation in the Model

The Rail-TEN policy supposes that all rail infrastructure projects belonging to the priority Trans-European Network (TEN) will be implemented according to the current plans between the years 2000 and 2015. This leads to needed investments of 116 Bill EURO during this period. The All-TEN policy assumes that additionally to the rail priority projects also the road priority projects are realised for which then the total investments of 138 Bill EURO are needed. The investments are spread over time according to current planning, which leads to the investment plan presented in table 51.

Table 51: Investment plan for Rail-TEN and All-TEN policy package

Yearly Investments [Bill EURO]	Rail-TEN policy			All-TEN policy		
	2000-2004	2005-2009	2010-2014	2000-2004	2005-2009	2010-2014
Region 1: A, D	3.832	3.065	0.766	3.902	3.121	0.780
Region 2: B, F, L, NL	2.132	1.705	0.426	2.325	1.860	0.465
Region 3: E, GR, I, P	4.120	3.296	0.824	5.602	4.482	1.120
Region 4: DK, FIN, IRL, S, UK	1.529	1.223	0.306	1.953	1.563	0.391

The investments are funded by increased fuel taxes for gasoline and diesel in all regions. The increase is adjusted such that during each of the five years period exactly the additional revenues are generated that are needed for this period. That means e.g. for the Rail-TEN policy (All-TEN policy) in the first five years an increase by 13% (16%), second period 10% (13%) and third period 4% (5%). The investments are considered in the investment model and by such contribute to the capital stock of the effected region.

As it takes some time to build the infrastructure, improvements in terms of reductions of travel times commence from the year 2005 for rail and 2002 for road. For rail the improvements are implemented as yearly reductions in travel times for passenger trips over more than 40km distance and for freight transport over more than 50km distance between the years 2005 and 2015. The percentage reductions are shown in table 52.

Table 52: Yearly improvements of rail travel times by new rail-TEN infrastructure between 2005 and 2015

[%/year]	Trip purpose / Goods category	Percentage time reduction
Passenger	Medium distance all purposes	- 2,2
	Long distance business trips	- 2,2
	Long distance tourism trips	- 3.2
Freight	Bulk and semi-bulk goods (> 50km distance)	- 0.5
	Unitised goods (> 50km distance)	- 1.0

The basic investments into the road infrastructure are driven by the development of GDP as it is assumed that basically a certain share of GDP is invested in the transport infrastructure. To reflect the construction of the priority road TEN the share of GDP invested in infrastructure is increased such that the difference amounts to the invested money. It is assumed that the investments only improves the motorway network.

7.3.5.2 Results of Rail-TEN policy and All-TEN policy

The results of the two policies are very interesting as they demonstrate either the dependency of the modes from each other e.g. taking a policy action for one certain mode can have strong effects on other modes and the time dependency of different policy actions e.g. leading to relative advantages of a mode in an initial stage but turning around the relative advantages between two modes in the long-run.

The reactions on the Rail-TEN policy can be clearly observed in figure 105. They reflect the different pattern of price changes and infrastructure improvements in four periods after the year 2000. In the first period from 2000 to 2004 taxes are increased for road transport by the highest percentage of all periods. Consequently road vehicle-km are reduced while air and rail vehicle-km increase compared to the base scenario. In terms of passenger transport performance (pkm) rail is increased by more than 1% and air by 3%. In the period 2005 to 2010 the road tax level is slightly reduced and the rail infrastructure is improved such that rail travel times are reduced. The two main effects are that either air vehicle-km are gradually reduced close to the level in the base scenario and rail vehicle-km strongly increase. So, in terms of pkm rail gained 5% in 2010 compared to the base scenario. With the beginning of the third period from 2010 to 2015 the additional road taxes are strongly reduced while rail travel times further improve by the new infrastructure. Now, air transport at 2011 falls below the level of the base scenario, while road transport over the period approximates towards the level of the base scenario. Passenger rail transport is growing further and reaches in 2015 in terms of pkm an increase of about 9%. After 2015 car transport in Rail-TEN and base scenario are nearly identically, while air mode is further reduced and the gap between base scenario and Rail-TEN policy is widening. For rail transport the transport performance is further growing such that at the end of the simulation rail mode gained about 13% compared to the base scenario.

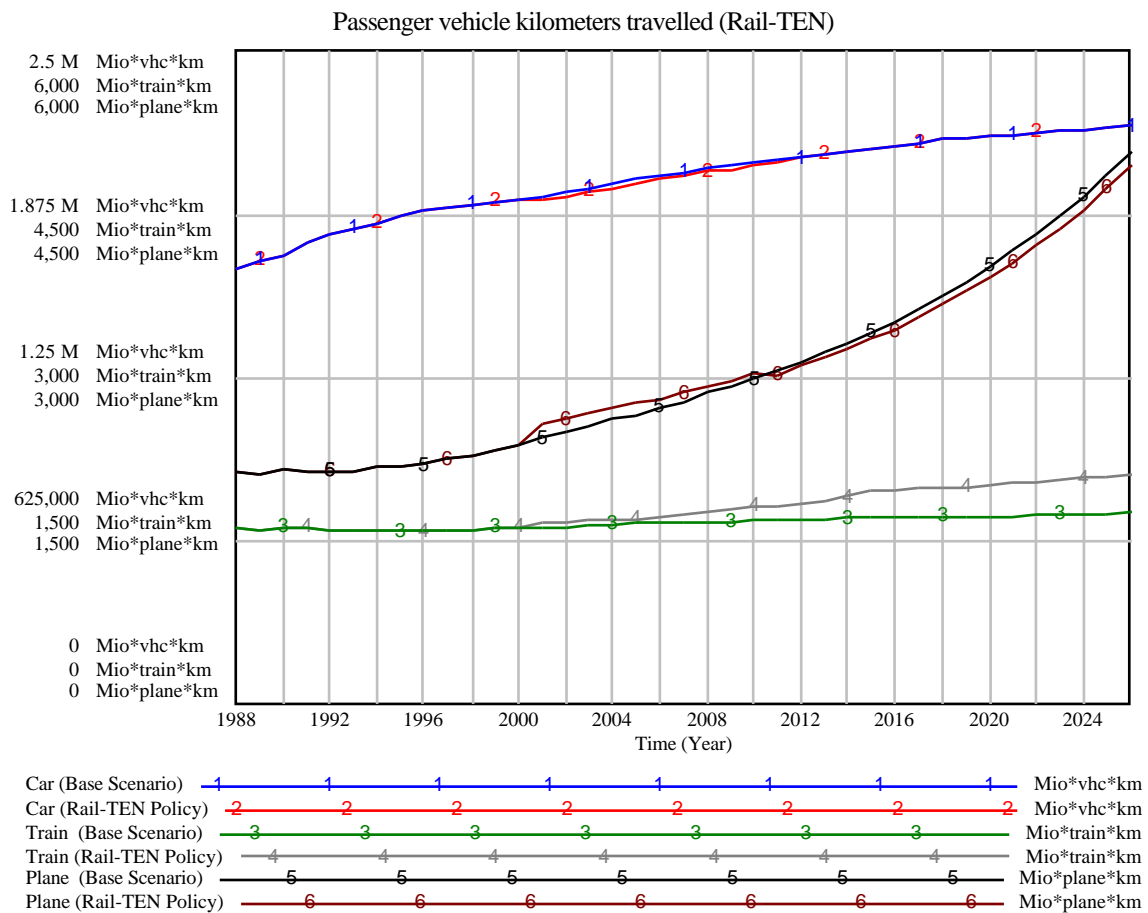


Figure 105: Results for vehicle kilometres travelled in Base scenario and Rail-TEN policy⁷⁸

For the All-TEN policy results are very similar. The main but still slight difference is that by the higher increase of the road taxes in the All-TEN policy car mode is a bit more reduced during the period 2000 to 2015 as well as the gains of air and rail are a bit higher in this time.

⁷⁸ Hint: it should be mentioned that in figure 105 as well as in some of the other figures the y-axis is not always identically for all variables as some times values differ by one or more order of magnitudes or are given with different unit of measurements.

Figure 106 underlines the message of the previous figure 105 as it shows that the “winner” of the Rail-TEN policy in comparison to the base scenario is rail mode. However, also with the Rail-TEN policy it is possible only to stabilise the modal-split share of rail mode. In the long-run the modal-split share of air mode will more than double while the share of car mode is decreasing after having reached a peak level plateau from 2000 to 2010.

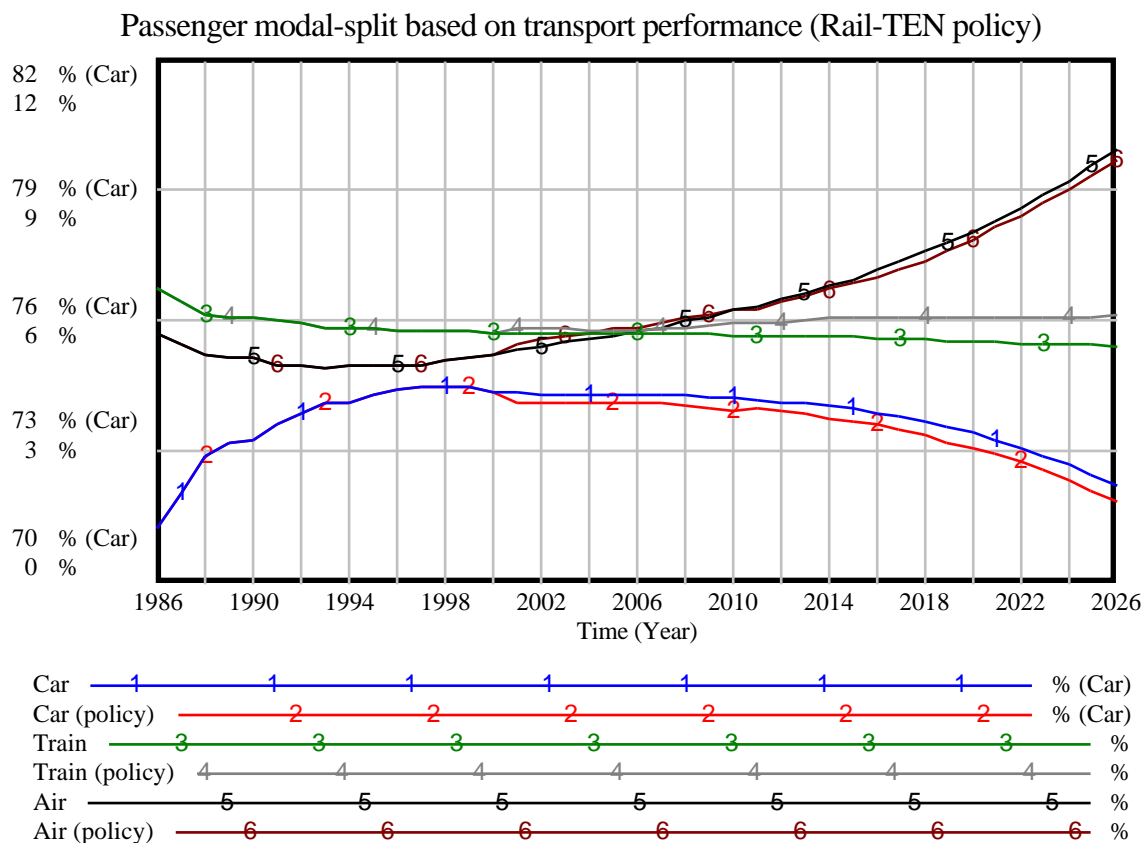


Figure 106: Modal-split in EU15 based on transport performance for Rail-TEN policy compared with base scenario⁷⁹

⁷⁹ Not shown are the shares of bus and slow mode.

In figure 107 the modal-split for freight transport based on transport performance (tkm) in the medium-long distance band (150-700km) in region 3 (E, GR, I, P) is shown. The result is as expected: rail mode increases its share of the modal-split from the year 2005 onwards, when the first rail infrastructure construction is completed. In 2015 the rail modal-split is increased by nearly 4% compared to the base scenario, which means a growth of 19% over 10 years

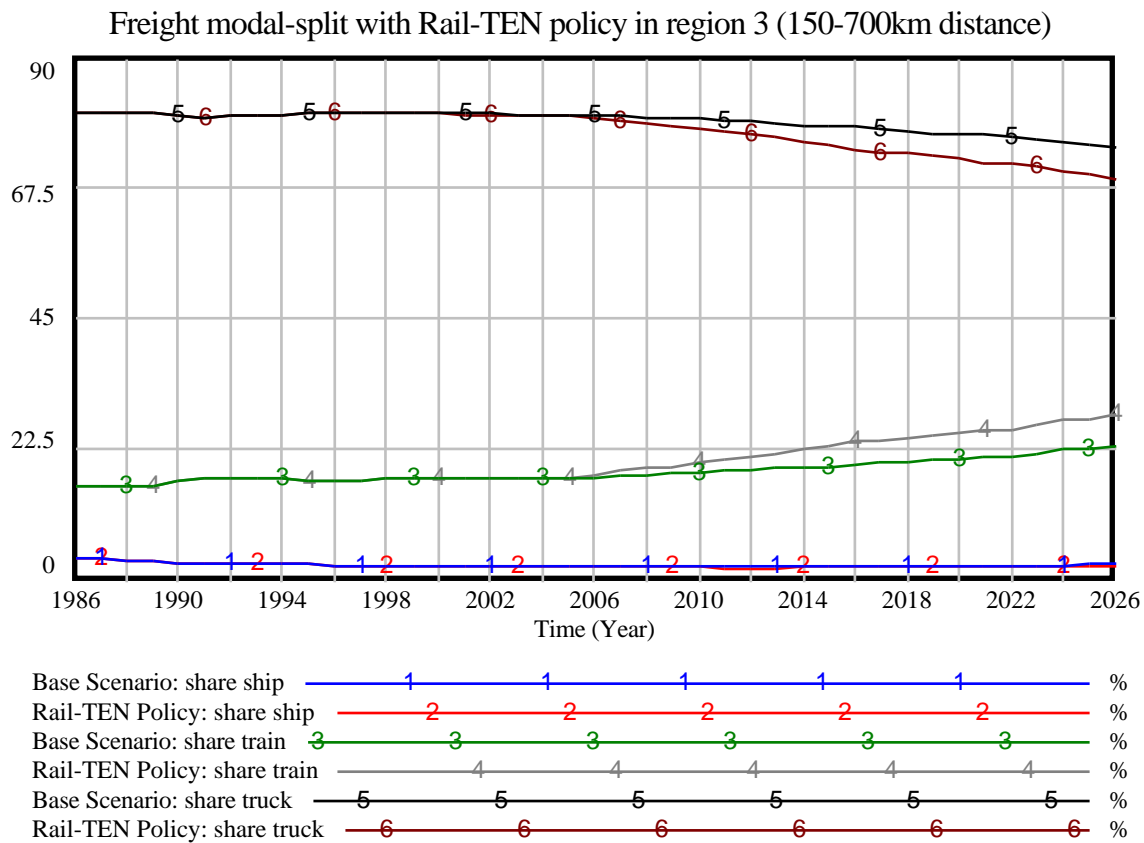


Figure 107: Freight modal-split with rail-TEN policy in region 3 (E, GR, I, P) based on transport performance (tkm)

The highest share of the investments in the Rail-TEN policy belongs to region 3 (E, GR, I, P). In figure 108 it can be observed that the amount of infrastructure investments significantly increases the total investments in this region (curve 3 and 4) in the period 2000 to 2010. During this period the GDP is only very slightly changed, but after 2010 the GDP in the Rail-TEN policy is increased compared to the base scenario. This again effects investments such that these are also after about 2015 significantly higher than in the base scenario.

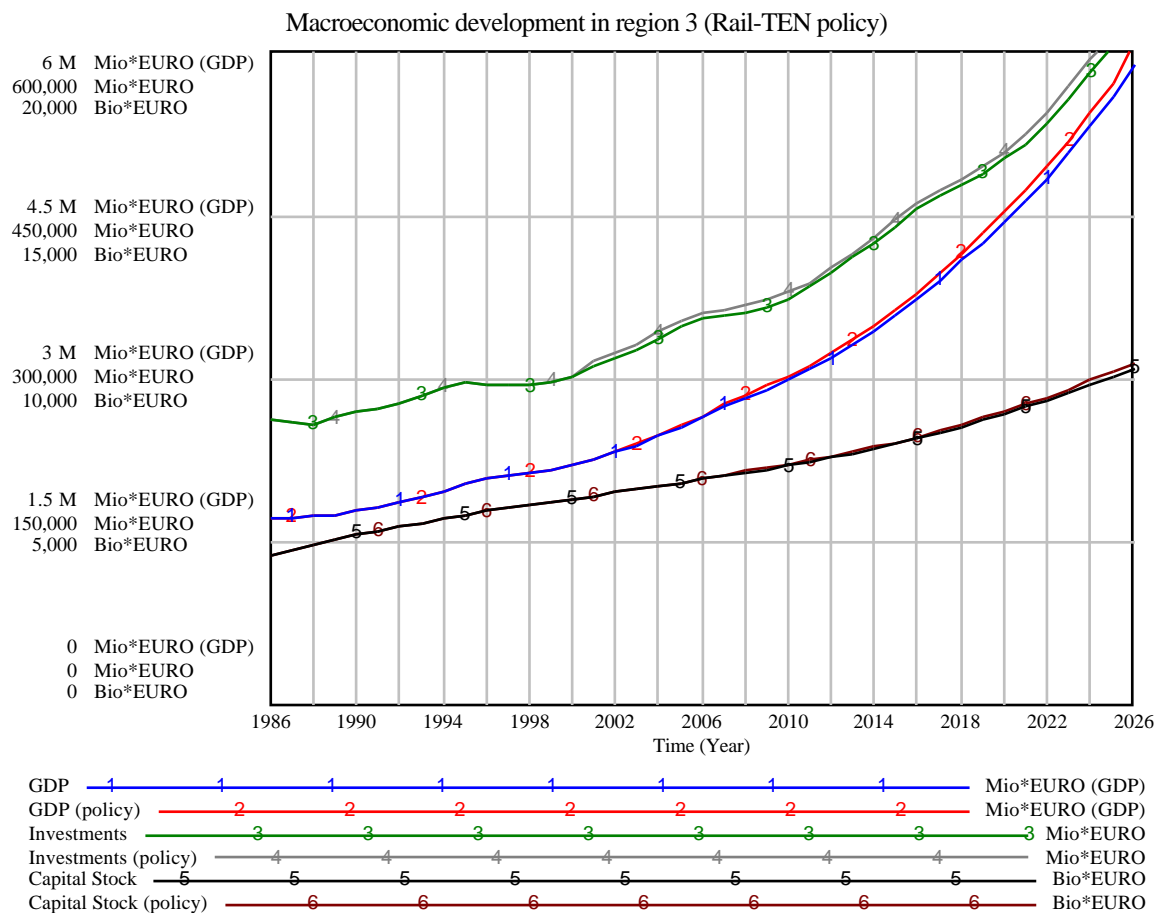


Figure 108: Development of macroeconomic indicators in region 3 (E, GR, I, P) with Rail-TEN policy

Figure 109 presents one of the most important environmental indicators, which is the emission of CO₂. For region 1 (curve 1 and 2) and region 2 (curve 3 and 4) the yearly hot⁸⁰ CO₂ emissions from driving summed over all modes is shown. It can be observed that these are growing over time but that also the Rail-TEN policy reduces these emissions in a period from 2005 to about 2020 significantly. It seems that in the period before 2005 the reduction in road transport and the increase in air transport (see explanation to figure 105) mostly compensate. In the next fifteen years the increase in rail transport with reduced air transport after 2010 lead to a significant decrease of CO₂ emissions compared to the base scenario. However, growing GDP compared to the base scenario closes the gap between CO₂ emissions in the base scenario and the Rail-TEN policy in the final years of the simulation.

Despite the growing CO₂ emissions the specific emissions of transport related CO₂ shown for region 1 (A, D) per unit of GDP decrease over time such that the “CO₂-efficiency” seems to improve over time (curve 5 and 6). The Rail-TEN policy slightly enforces this effect.

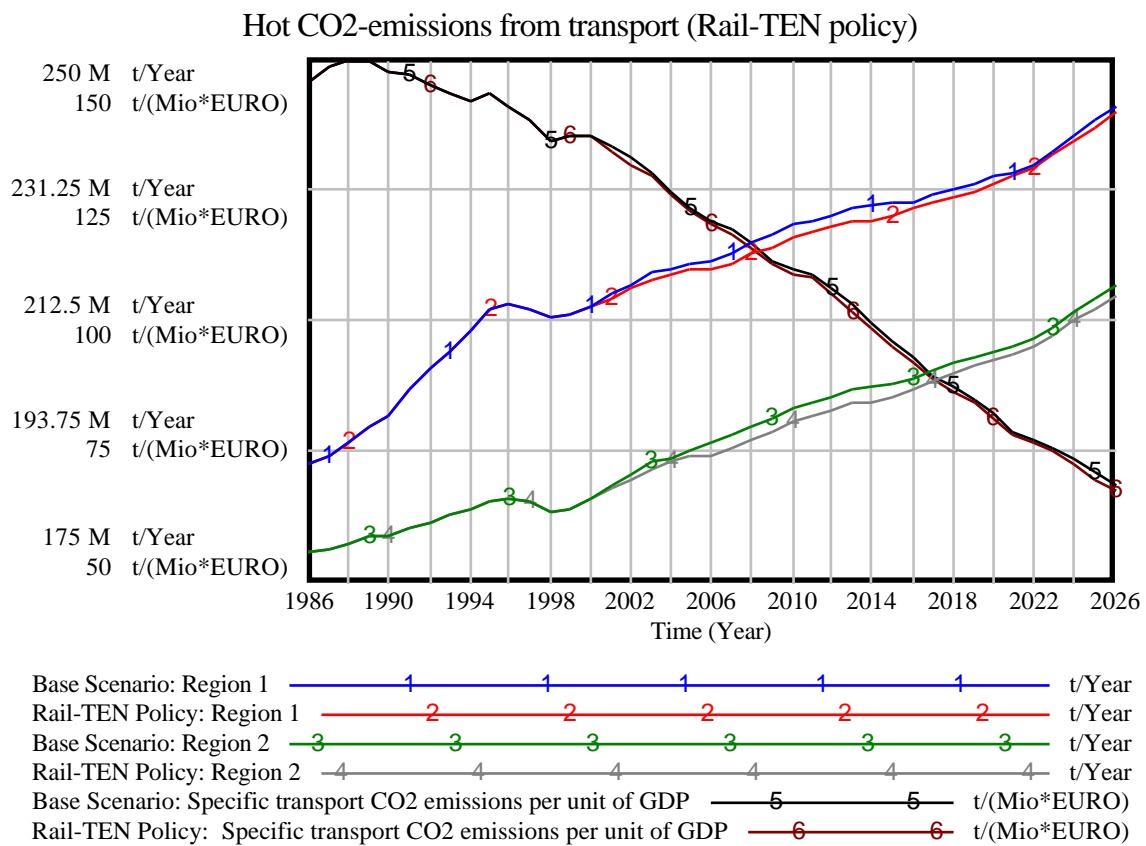


Figure 109: Yearly hot CO₂-emissions from transport in region 1(A, D) and region 2 (B, F, L, NL) and specific CO₂ emissions in region 1

⁸⁰ “Hot” means the emissions occurring from the driving activity, which excludes e.g. fuel production emissions

As figure 110 shows the effect of the Rail-TEN policy on the NO_x emissions of transport is very low. The shape of the curve is following the base scenario development, which is determined by the diffusion of EURO emission legislation into the vehicle fleet and the growing air and road freight transport in the final years of the simulation.

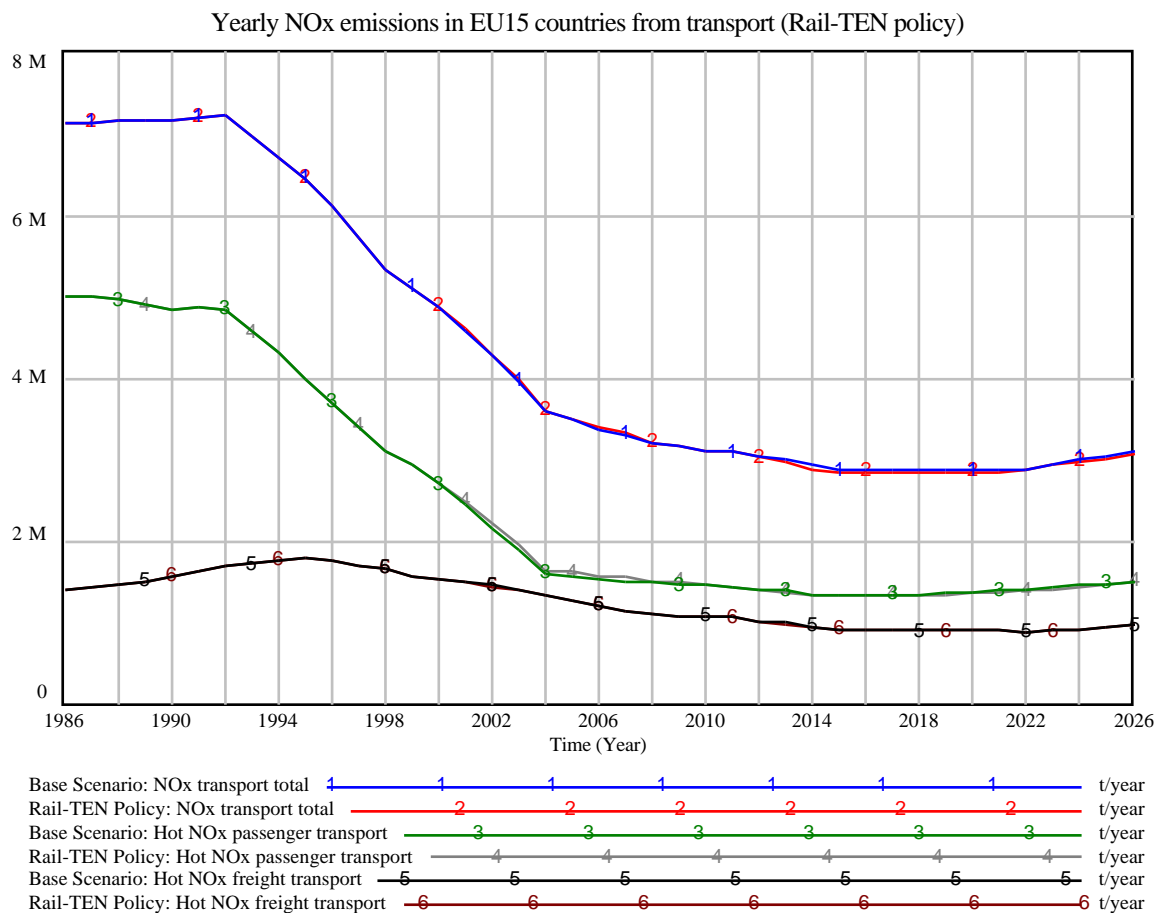


Figure 110: Development of yearly NO_x emissions in EU15 countries with Rail-TEN policies

One might look at two different investment multipliers for the Rail-TEN and the All-TEN policies. The first multiplier measured after 15 years investment indicates the change in GDP compared to the base scenario values at the year 2016 with the overall investment. The year 2016 is chosen as then all investments are made, the infrastructure is implemented and the taxes are reduced to the original level. The second multiplier compares the change in GDP in the final year (2026) with the overall infrastructure investment to find out if in the long-run different results can be obtained. The calculation of the multipliers considers that future payments (e.g. investments) or future returns (in this case increased GDP) are valued less than today's payments and returns. Therefore investments and future returns are discounted with a discount rate of social return of 3%, which is e.g. also used for German infrastructure planning. Table 53 presents the results for the two policies:

Table 53: Investment multipliers for Rail-TEN and All-TEN policy at 2016 and 2026 for EU15

Policy	Investment	2016		2026	
		Increase in GDP	Multiplier	Increase in GDP	Multiplier
	[Bill EURO]	[Bill EURO]		[Bill EURO]	
Rail-TEN	100	68	0.68	157	1.57
All-TEN	119	81	0.68	185	1.55

Remark: all monetary values are discounted with a rate of social discount of 3%

Obviously the success of the policies takes some time as in the short-run the multiplier is below 1 while in the long-run the multipliers are positive with similar values of 1.55 for Rail-TEN and 1.57 for All-TEN policy. These multipliers indicate that in the long-run both policies are economically positive. However, the value of the multipliers do not foresee an “economic bonanza”. For regional multipliers some variation can be expected as there is an imbalance of regional source of tax revenues and location of investment. E.g. for region 3 the additionally collected taxes cover only about 70% of the investments made in this region, while in other regions more taxes are collected than investments are made.

As the long-run multipliers without discounting are quite high, important risks and uncertainties should be mentioned here (though they have already been mentioned before in this report). Considering the decreasing population development the high growth rates of GDP can only be reached with strong labour productivity increases or a filling of the demographic gap by increased immigration. The high sensitivity of investments and subsequent the capital stock and potential output may overdraw the outcome of policies changing air transport as its related investments react highly sensible as well in positive as in negative direction. This could hold also for the Rail-TEN and the All-TEN policy, which increases air transport in the first 10 years strongly.

7.3.6 Integrated Policy Programme (IPP)

The integrated policy programme comprises most of the measures of the previously described policy packages. Only the increase of the kerosene tax to balance it with the gasoline tax and the All-TEN policy package is not integrated into the policy programme. So, for the description and implementation of the measures it is referred to the previous sections. The results of the integrated policy programme (IPP) are presented in the following.

Three policy packages raise additional revenues, which are used to reduce the labour costs: increased fuel tax (IFT), balanced fuel tax (BFT) and integrated policy programme (IPP). In figure 111 the difference in additional revenues for the three policies can be observed for region 2 and region 4. The IFT policy (curve 1 and 4) creates revenues with a similar pattern and level for both phases starting with the stepwise increase at 2000 and reaching relatively stable level after 2010. In the BFT policy (curve 2 and 5) an initial 5-years phase with strong increase is relieved by a phase with steady but modest growth. The reason for this growth is that the additional revenues are gained from the fuel types whose use is stable (diesel) or growing (kerosene) over time. In the IPP (curve 3 and 6) for the initial 10 years phase IFT, BFT (excluding kerosene tax) and Rail-TEN taxation development are overlapping leading to

the highest additional revenues of all policies. However, after 2010, when Rail-TEN policy taxes are reduced and enforced after 2015 when all rail infrastructure is implemented the additional revenues decrease continuously. The reasons can be seen in a continuous modal-shift away from road modes and an increased fuel efficiency of cars as technological development towards more efficiency is fostered by the higher fuel prices in IPP.

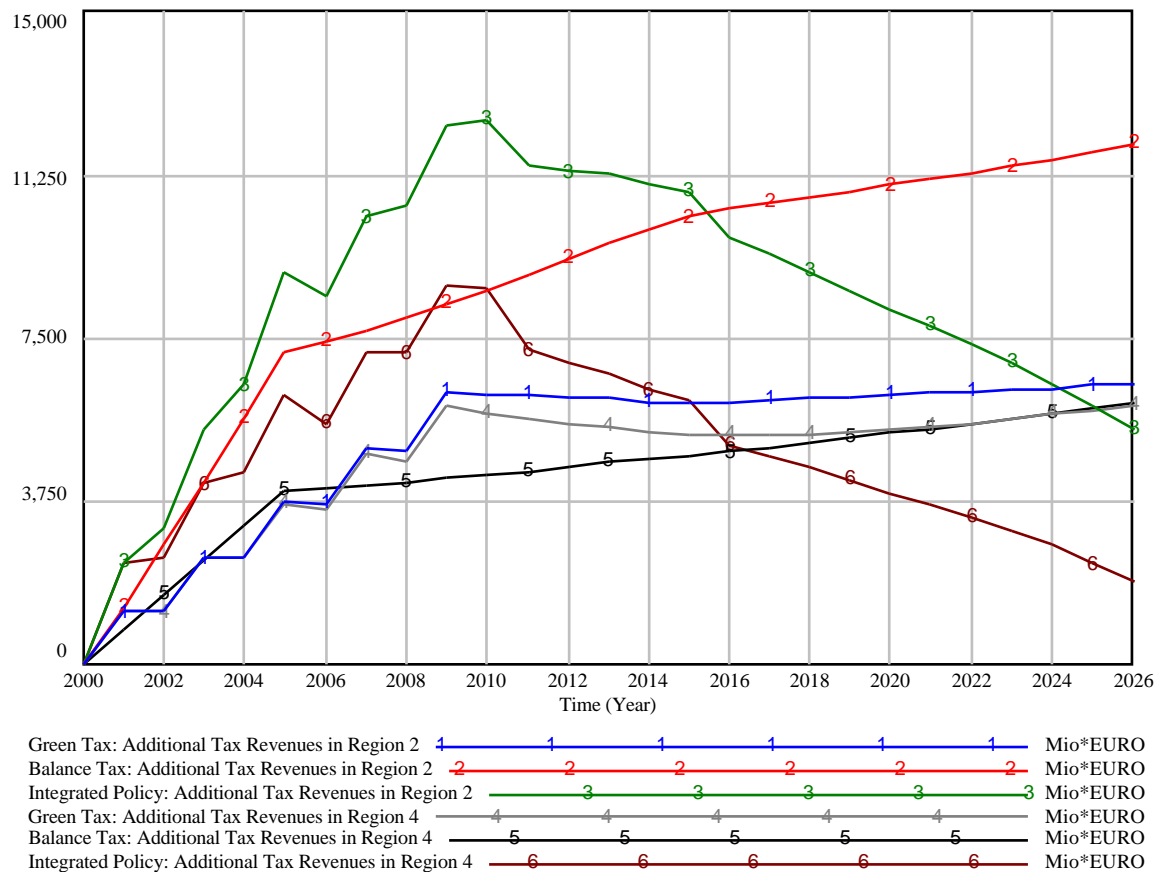


Figure 111: Additional tax revenues in region 2 and 4 that are used to reduce labour costs (IFT, BFT, IPP)

The subsequent figure 112 presents the change in fuel consumption by the IPP policy. It can be observed that in the long-run gasoline consumption is reduced significantly while diesel consumption is more or less stable as well as kerosene consumption, such that in total the use of fossil fuels is reduced. It should be reminded that the policies do not yet include the introduction of alternative fuels, which could be an important option for further investigations with ASTRA.

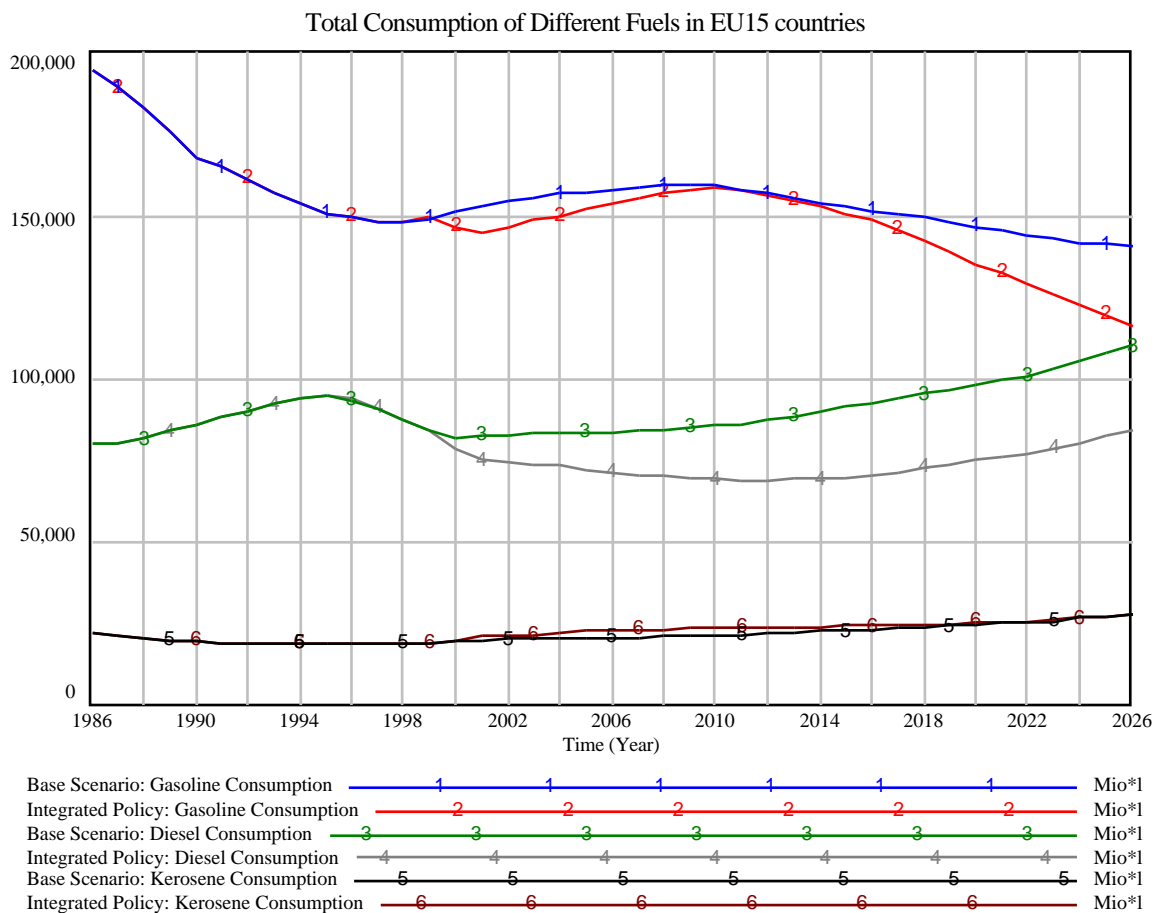


Figure 112: Consumption of different type of fuels in the EU15 countries with IPP

In figure 113 presenting the passenger modal-split in EU15 countries based on transport performance it can be observed that car modal-split is significantly reduced by the IPP. The reason is that this policy imposes the highest tax increase (+25% for road fuel + balanced diesel tax + tax for funding Rail-TEN) and in parallel improvements for the competing rail mode. Nevertheless it seems that at the final years of the simulation the gap of car share on modal-split between base scenario and IPP shrinks, which is due to the economic improvements of the IPP increasing also income and subsequently car-ownership. The share of rail mode is stabilised on a higher level by the IPP, while air mode share is increased especially in the intermediate years with high taxes (funding of Rail-TEN) and not yet completed Rail-TEN infrastructure. The subsequent figure 114 highlights the difference between Rail-TEN policy and integrated policy for the car and air passenger transport performance. Here also the big difference in terms of car pkm (curve 2 and 3) between rail-TEN and integrated policy, which includes rail-TEN, should be mentioned.

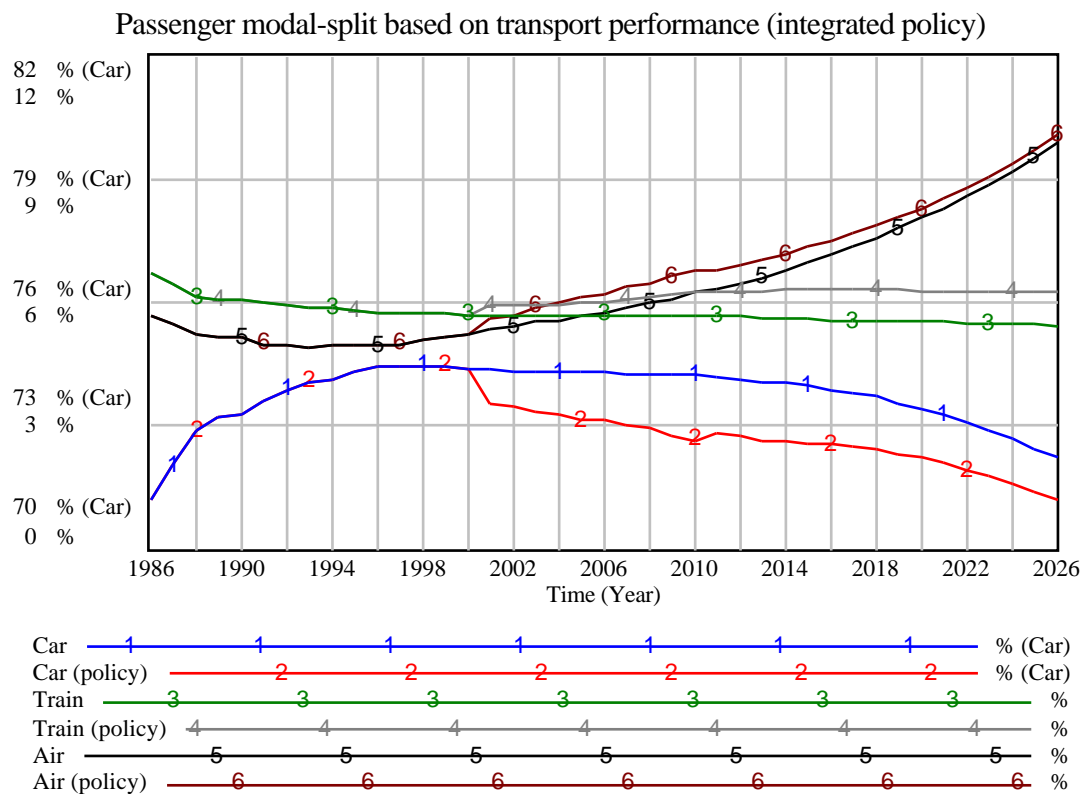


Figure 113: Passenger modal-split in EU15 countries based on transport performance (pkm)

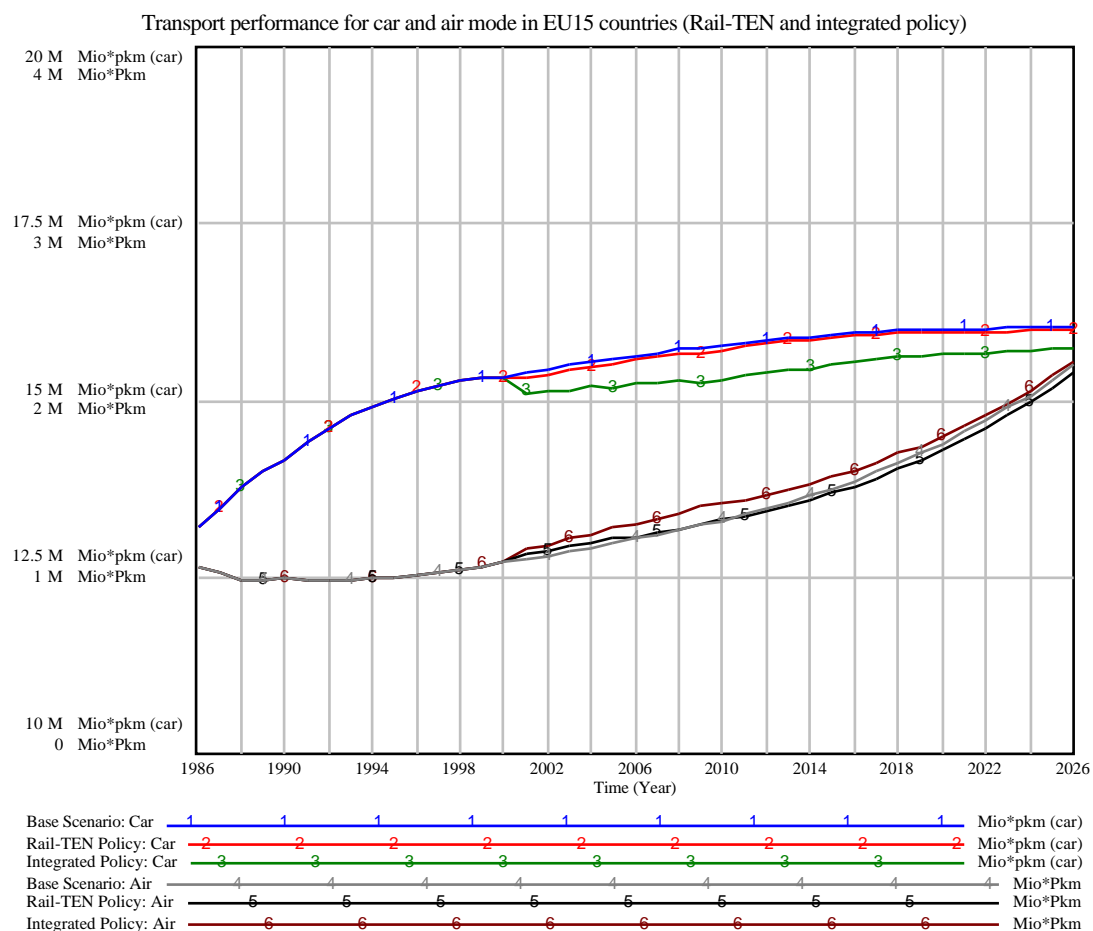


Figure 114: Comparison of car and air mode transport performance in base scenario, Rail-TEN policy and integrated policy

Figure 115 presents the effects of the IPP on freight transport performance in EU15 countries. Similar to the Rail-TEN policy rail mode increases slightly between 2000 and 2010 and increases significantly after 2010. In the long-run ship mode is growing strongest but it is only slightly effected by the IPP. Only during the intermediate period 2000 to 2010 with high taxes and not completed Rail-TEN an effect of the IPP on ship mode can be observed. Freight road mode is continually decreased by the policy compared to the base scenario. Nevertheless growth in freight road mode is not stopped.

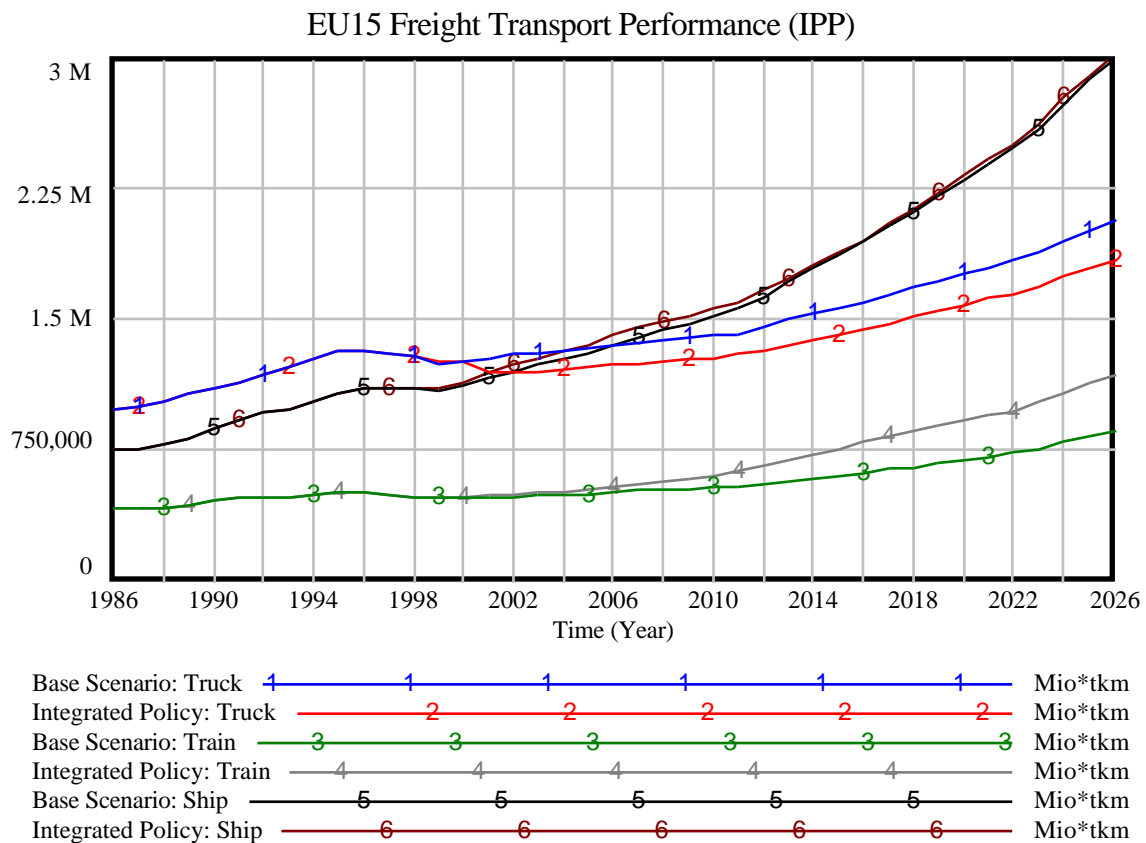


Figure 115: Freight transport performance in the EU15 countries with IPP

In the macroeconomic sphere transport contributes with three elements to the private consumption: fuel consumption, car purchase and demand for transport services (e.g. bus, rail, air). These elements are shown for region 3 (E, GR, I, P) in figure 116. Consumption expenditures for fuel consumption (curve 1 and 2), which exclude taxes, are hardly effected by the IPP. Only a slight decrease at the end of the simulation can be observed. Car purchase (curve 3 and 4) is also effected by the policy (e.g. car prices increase when new emission legislation comes into force earlier), though the structure of this curve is mainly determined by the age structure of the vehicle fleet and the income development. The expenditures for transport services (curve 5 and 6) grow continuously over time, which is even enforced by the policy mainly due to increased use of rail.

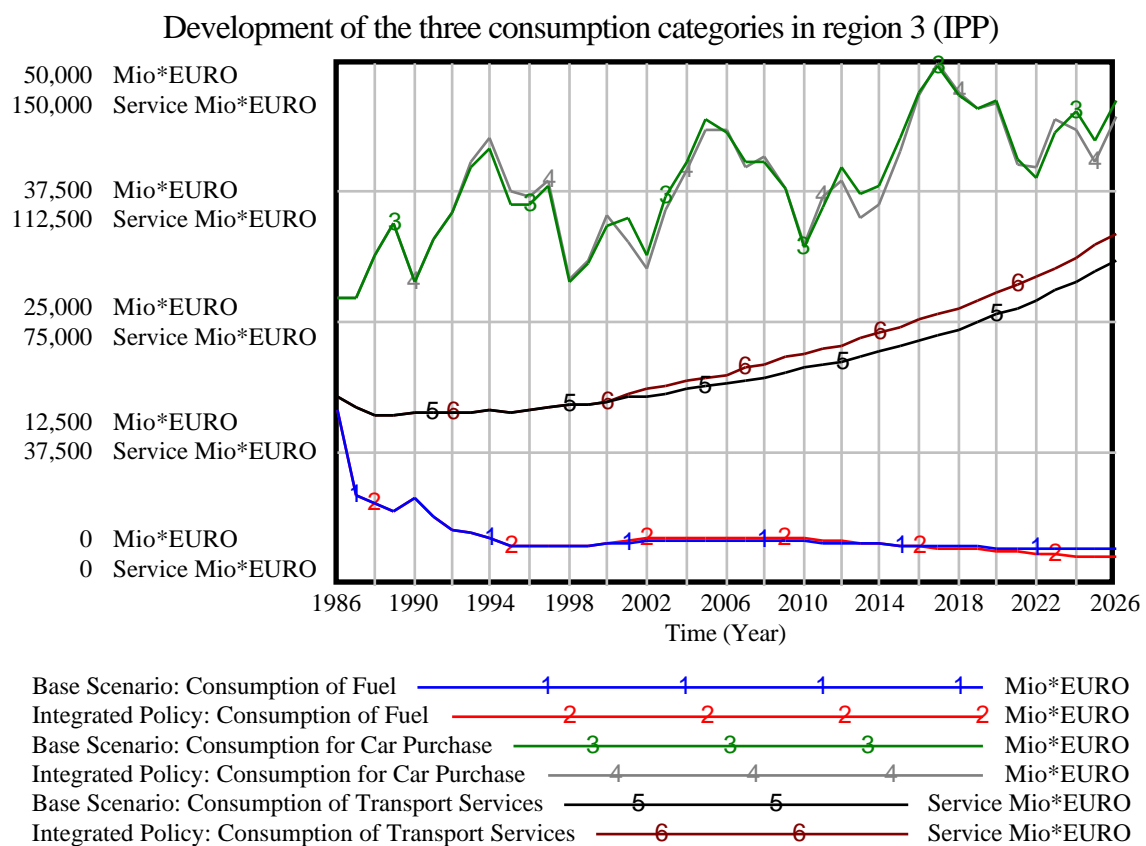


Figure 116: Change of consumption structure with IPP policy in region 3 (E, GR, I, P)

Corresponding to curve 5 and 6 in previous figure 116 showing transport service consumption the employment linked with this consumption activity is shown in curve 5 and 6 of the following figure 117. The employment in the service sector is also positively effected by the policy and the overall trend is increasing. However the slope of the curve is not as steep as the consumption expenditure curve since the labour productivity increases over time. The overall employment (curve 1 and 2) is also increasing over time until around 2015 reducing the unemployment significantly (curve 3 and 4). After 2015 employment decreases due to demographic reasons mainly the diminishing national population.

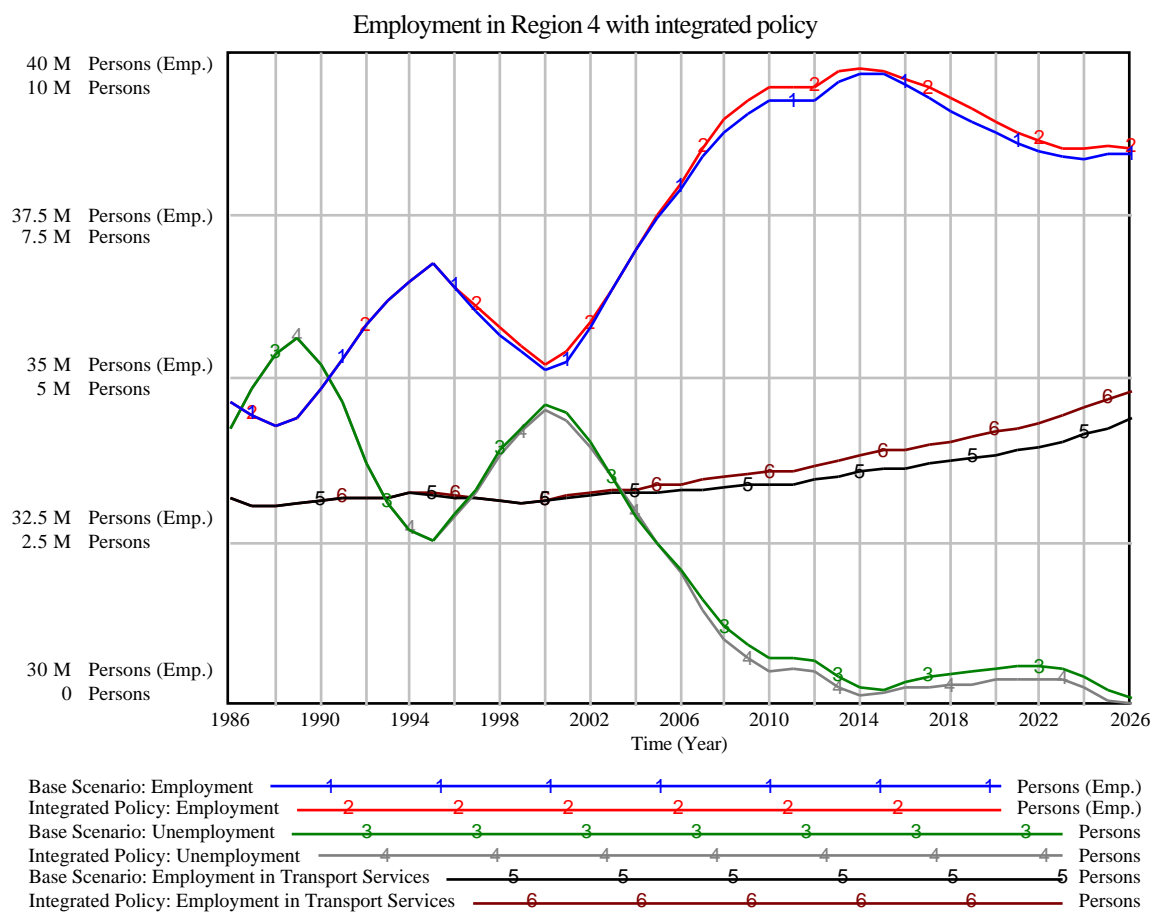


Figure 117: Employment in region 4 (DK, FIN, IRL, S, UK) with IPP

The number of fatalities by transport accidents caused by passenger transport means is shown in figure 118. For bus and air transport the increase in transport performance caused by the policy leads to an increase in the number of fatalities. For car transport the reduced transport performance plus the enforced speed limit and improved safety-belt usage significantly reduce the number of fatalities.

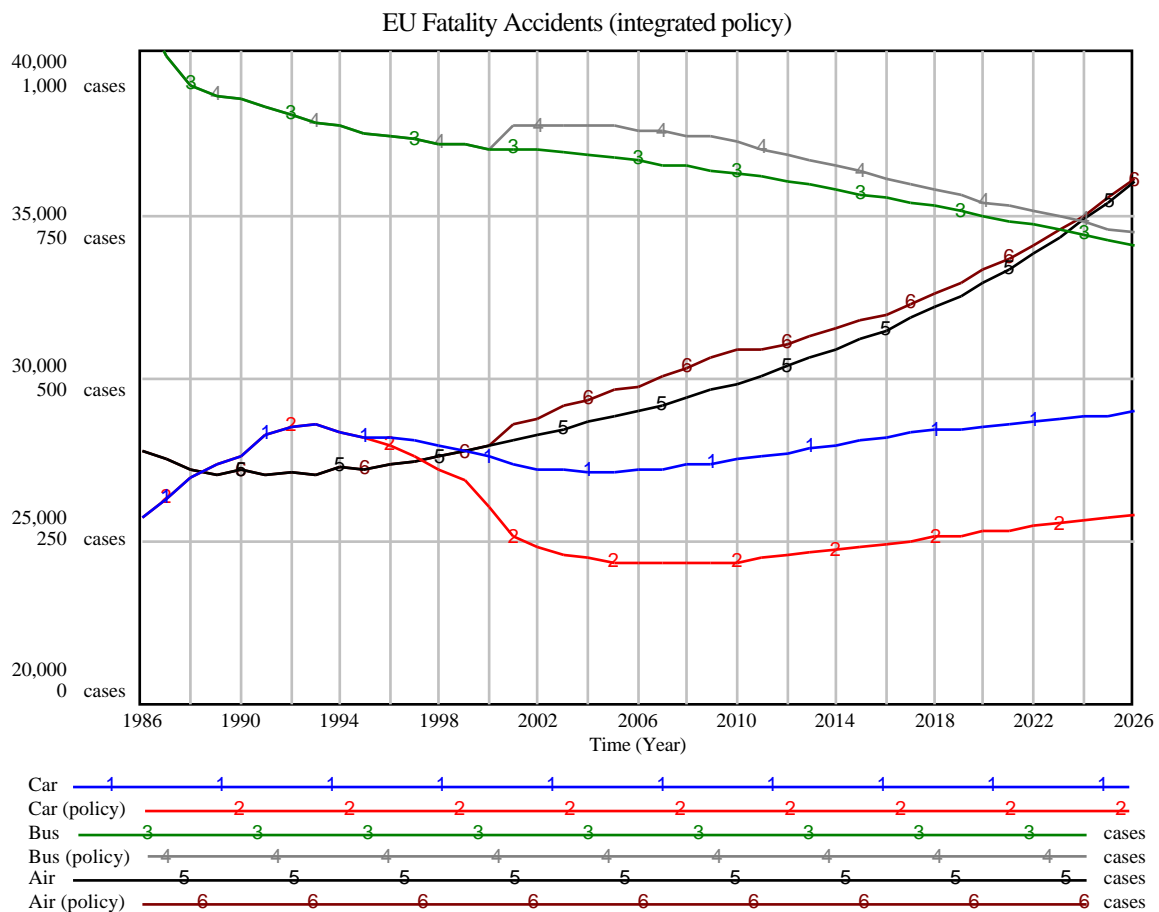


Figure 118: Development of EU15 fatality accidents with integrated policy programme

In figure 119 it can be observed that the trend for total transport CO₂ emissions is growing over time, while with the integrated policy package a trend seems to be reached that stabilises the emissions around the level of the 1990 values until 2026. However, considering international agreements e.g. Kyoto protocol with time horizon 2008 to 2012 a reduction would be expected. In addition, other studies demand for stronger reductions e.g. OECD-EST project⁸¹. From curve 3 and 4 it can be realised that a major contribution to reductions is provided by the decreased hot emissions, which are mainly due to modal-shifts and technical improvements. The changes for CO₂ emissions of other transport related sources (e.g. fuel production, vehicle production) oscillate over time with a horizontal trend. The effect of the policy on these emissions is minor compared to the changes in hot emissions.

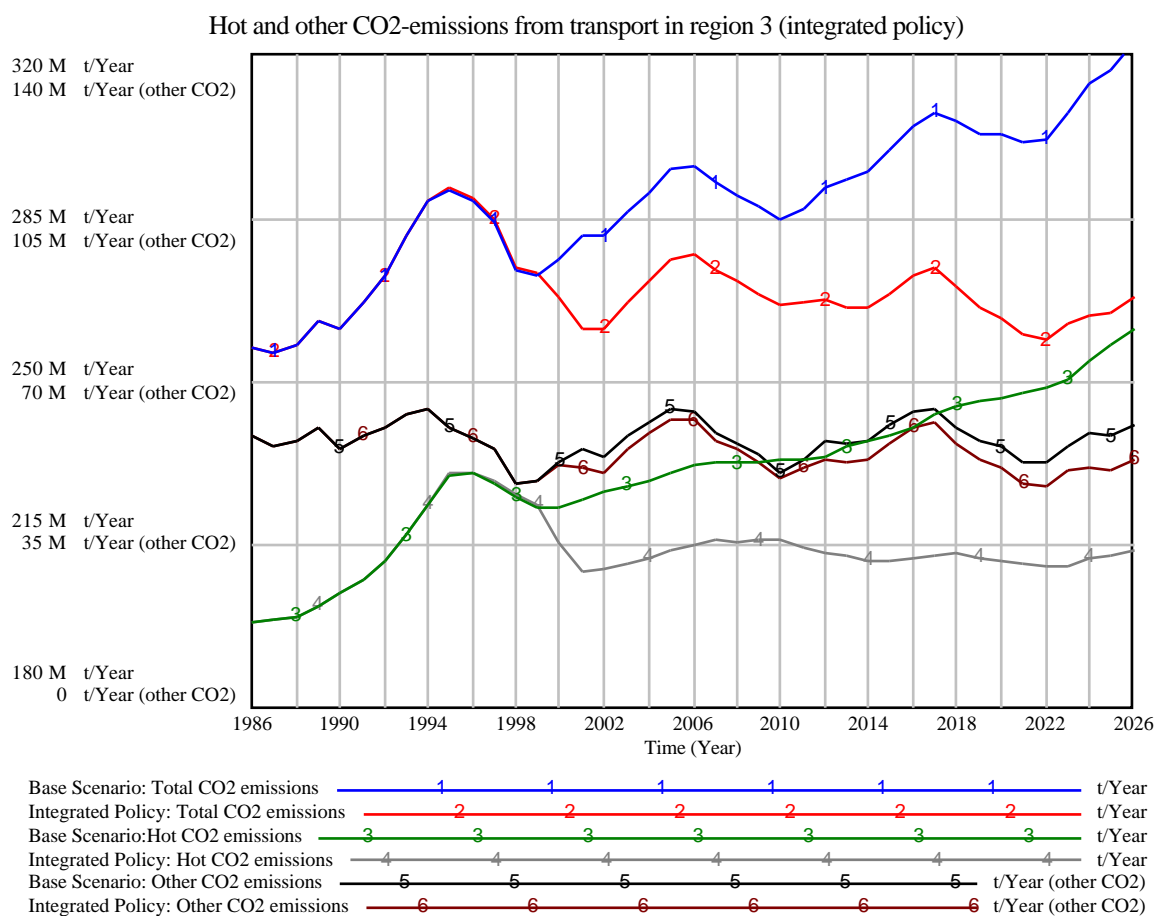


Figure 119: CO₂ emissions from transport in region 3 (E, GR, I, P) with IPP

Resuming the results of the integrated policy programme (IPP) it can be concluded that it provides synergies between the integrated single policy packages or measures. Though it generates the highest tax revenues in a 15 years period the growth in GDP is higher than for other packages and the adverse effects of several environmental impacts (e.g. CO₂, accident fatalities) are reduced to a greater extent than for other packages.

⁸¹ OECD (1996), OECD (2000)

7.3.7 Comparison of the Policy Packages

In the previous sections the results of each policy package are presented in comparison with the base scenario or at most with a selected item of a similar policy. In this section for a set of major variables an overview of results of all policy packages for EU15 is presented.

In figure 120 the development of GDP aggregated over all EU15 countries for all policy packages⁸² is presented. The graph covers only the time period 2020 to 2026 as the curves are very close to each other if the complete time axis is presented. Also the differences between the policies in terms of GDP grow over time such that at the end of the simulation period for most comparisons the biggest gap is observed. Drawing a ranking of the policy packages one can identify three groups: the top group with integrated policy programme (IPP), Rail-TEN policy closely followed by improved emission and safety policy (ISE); the middle group with base scenario and increased fuel tax policy (IFT) and the package with the poorest performance the balanced tax policy (BFT). So, it seems that the policies integrated into the policy programme develop synergies. It should also be reminded that the balance tax policy is hampered by the problem that following kerosene taxation technological improvements that might compensate negative effects can be expected, which is not yet reflected in the model.

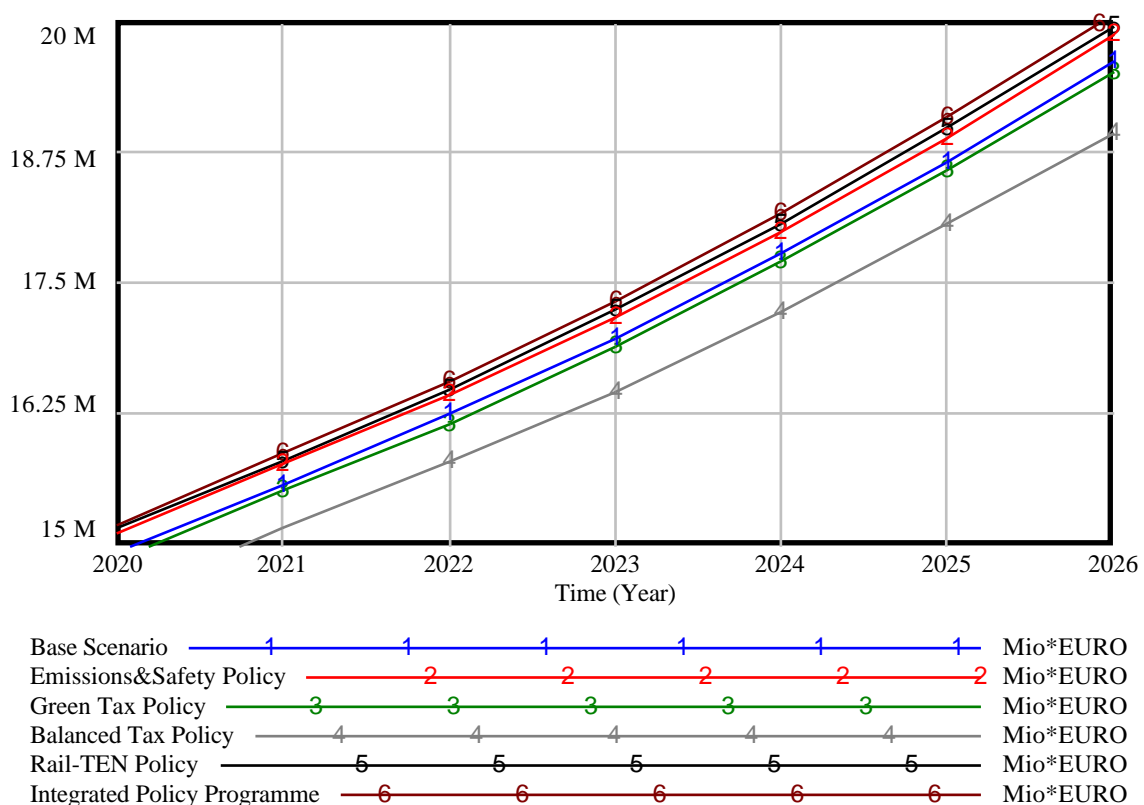


Figure 120: Development of GDP in EU15 countries between 2020 and 2026

⁸² The All-TEN policy was excluded as it is very similar to the Rail-TEN policy.

In figure 121 the passenger transport performance for EU15 is presented. The time axis starts at 2000 as the developments until this year are nearly the same for all policies. Until 2012 the base scenario shows the highest transport performance, which is after 2014 only overtaken by the Rail-TEN policy (curve 5). The IFT and the BFT (curve 3 and 4) belong in the beginning also to the top group but over time the gap to the base scenario increases such that at the end of the simulation the BFT has the lowest transport performance. A reason for this is surely the poorest economic performance of the BFT policy but also the fact that it is dampening the air transport growth most successfully. On the other hand the ISE and IPP (curve 2 and 6) show the biggest gap to the base scenario in the period 2000 to 2010. But afterwards they start to close the gap, for which also their good economic performance is one reason.

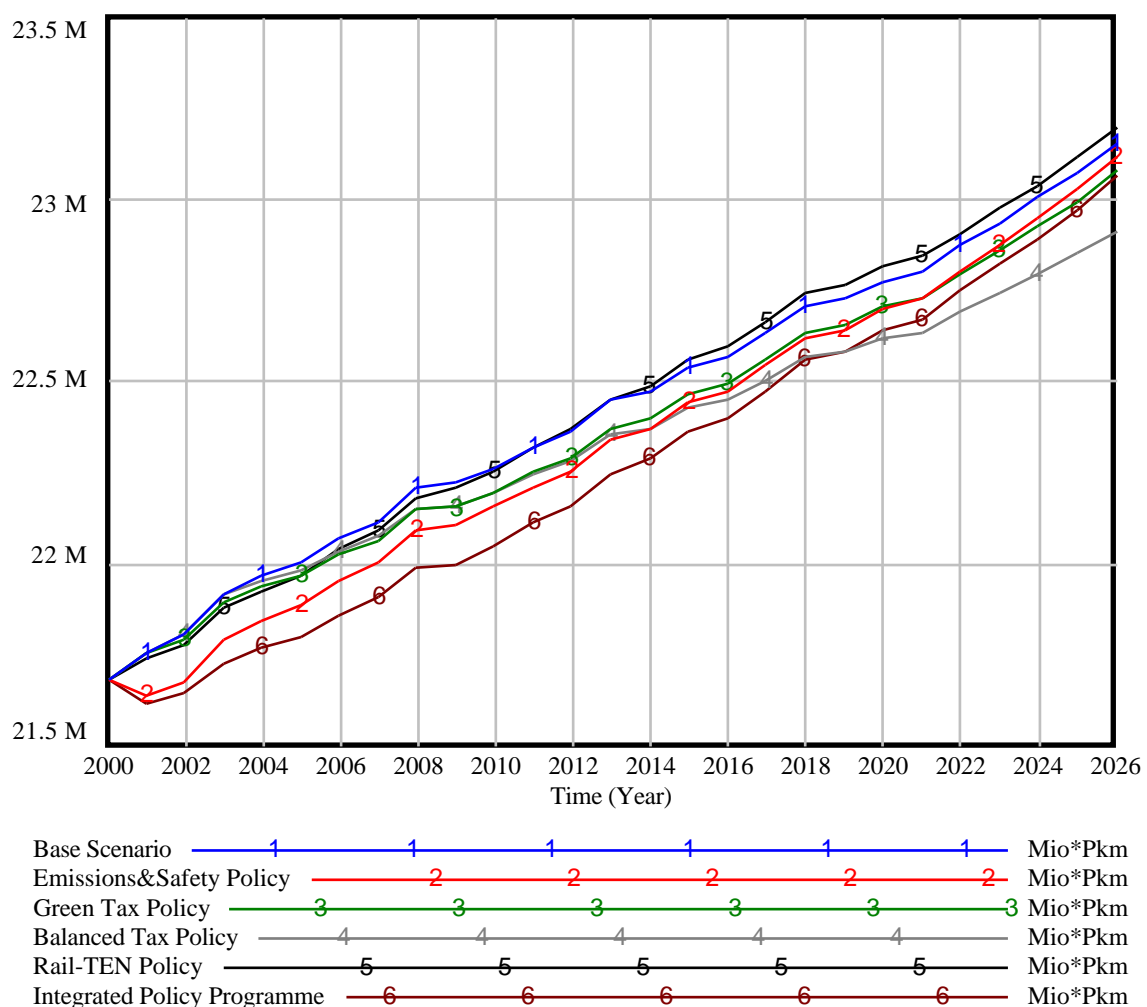


Figure 121: Passenger transport performance in EU15 countries

Similar results as for passenger transport are presented for freight transport performance in figure 122 for the years 2000 to 2016. However, for freight the three economically most successful policies (ISE, Rail-TEN, and IPP) show a higher transport performance than the base scenario already around the year 2010.

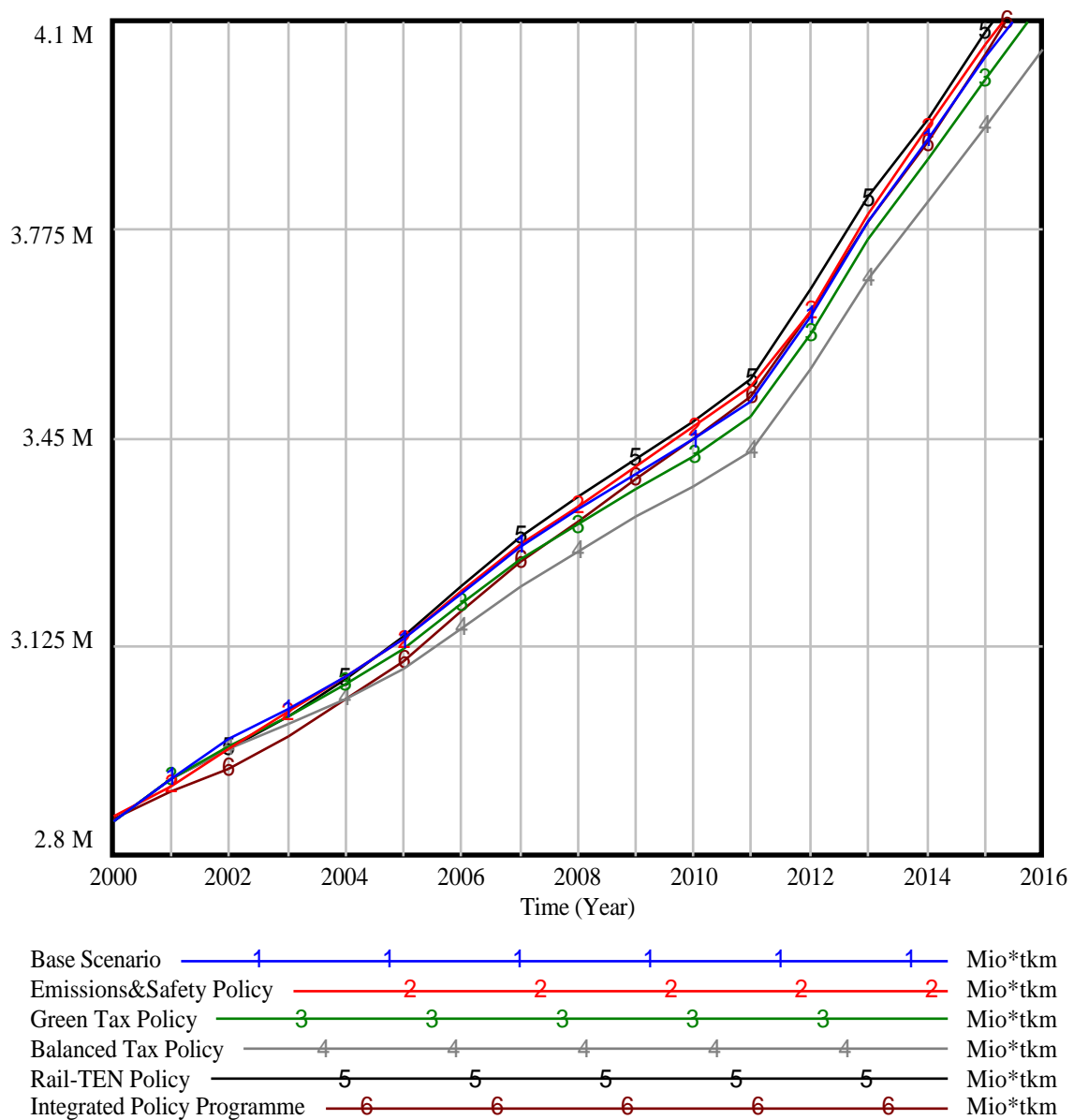


Figure 122: Freight transport performnace in EU15 countries

Figure 123 shows the average fuel consumption of gasoline cars in region 1 (A, D) from 2000 to 2026. Before 2000 the development is nearly the same for all policies. Three effects can be observed. First in ISE and IPP (curve 2 and 6) the additional reduction in fuel consumption after 2010, which is a policy measure of the ISE leads to a significant decrease of average consumption after 2010. Second, higher fuel prices in the policies induced by the taxes provide incentives for faster technological progress in terms of increased fuel efficiency. This can especially be observed for IFT (curve 3) compared to the base scenario (curve 1). Third the balancing of diesel tax with gasoline tax leads to a higher average gasoline consumption as the relative share of gasoline cars with cubic capacity over 2000 ccm increases in the gasoline car fleet (curve 4 and 6). Though for IPP (curve 6) the initial increase by the shift from diesel to gasoline cars is overcompensated after 2015 by the technological improvements induced by the prices (IFT) and the regulation policy (ISE).

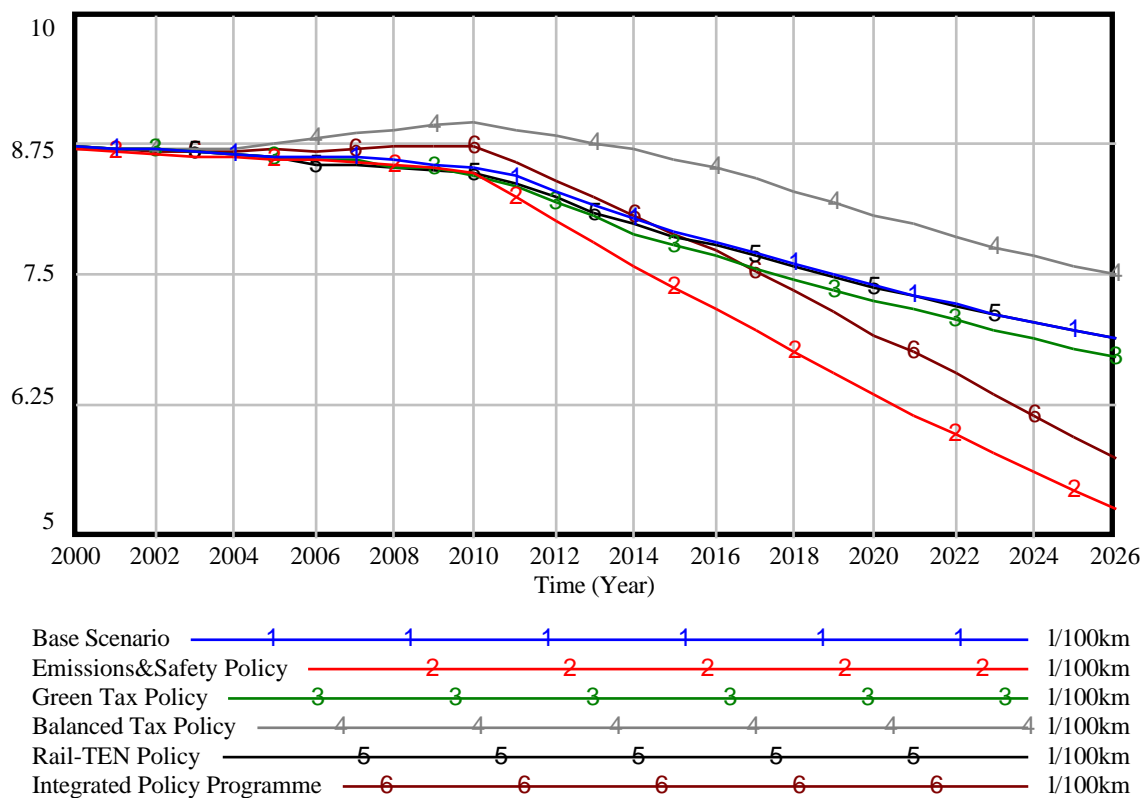


Figure 123: Average fuel consumption of gasoline cars in region 1 (A, D)

In figure 124 the yearly transport CO₂ emissions in EU15 countries are shown. The first observation is that the base scenario produces the highest quantity of CO₂ emissions. Nevertheless, three other policy packages IFT, BFT and Rail-TEN also produce continuously growing transport CO₂ emissions of nearly the same quantity. Besides this high emission level group there is another group with ISE and IPP (curve 2 and 6) that shows more or less stable emissions at the 1990 level. For these policy packages it seems that the growth in transport is compensated by the taken measures in terms of emissions. It should be mentioned that the IPP produces the “low” emission quantities mainly since the ISE is part of its measures.

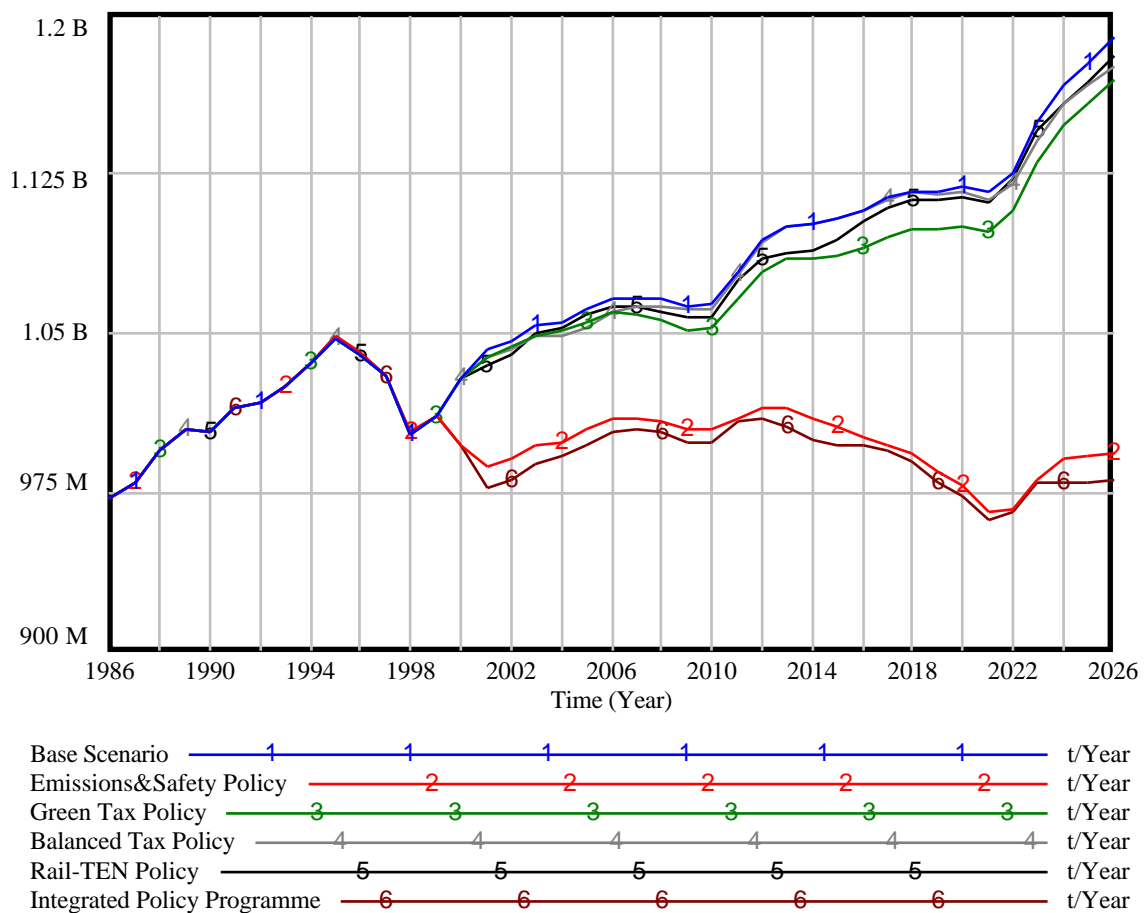


Figure 124: Yearly transport CO₂ emissions in EU15 countries

The curves in the following figure 125 presenting the percentage of transport externalities on GDP for region 1 (A, D) show a similar structure into two groups as in the previous figure. The group with the higher level again includes the base scenario, IFT, BFT and Rail-TEN while the group with the better performance in this case includes ISE and IPP. For all policy packages the percentage of externalities on GDP is reducing. However, this does not mean that absolute externalities are reduced over time. The reason for the decrease of the percentage is that GDP grows faster than transport externalities. The two packages with the worst situation in the final decade of the simulation are BFT and Rail-TEN. However, the reasons are different. For BFT the economic performance is poorest such that the baseline for the relative percentage (GDP) is smaller. For the Rail-TEN economic performance is quite well compared with the other packages but the growth in transport performance is highest driving also the externalities.

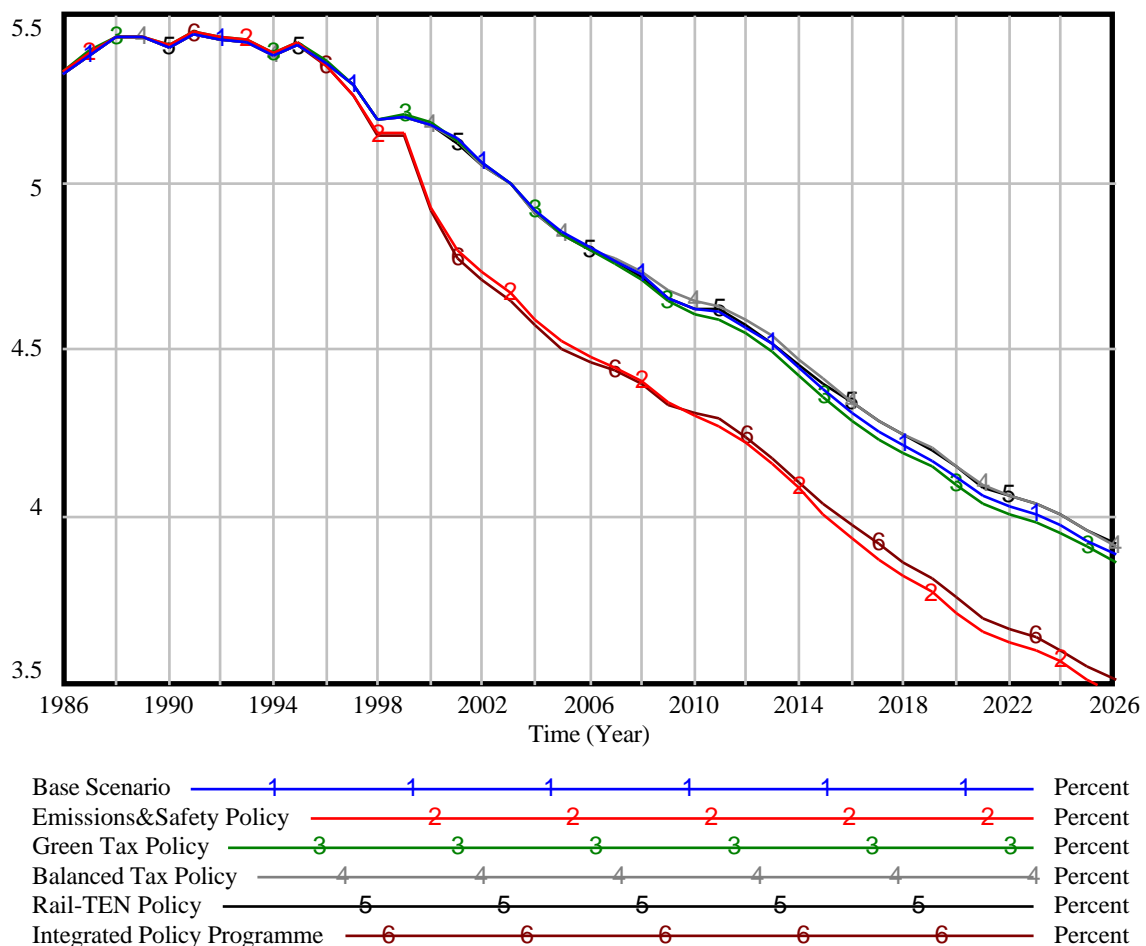


Figure 125: Percentage of transport externalities on GDP for region 1 (A, D)

Summarising, the results for the different macro regions are in general similar than for the whole EU15. However, regional differences of the single policy packages can be observed. For instance in terms of GDP three regions 1, 2 and 4 have the highest growth with the integrated

policy programme, while for region 3 this is realised with the All-TEN policy package. A ranking for the economically best policy is shown in table 54.

Table 54: Ranking of policies for the different regions

	Region 1 (A, D)	Region 2 (B, F, L, NL)	Region 3 (E, GR, I, P)	Region 4 (DK, FIN, IRL, S, UK)
Based on GDP				
First best policy	IPP	IPP	All-TEN	IPP
Second best policy	ISE	All-TEN	IPP	All-TEN
Third best policy	All-TEN	ISE	Rail-TEN	ISE
Based on accumulated CO2 emissions				
First best policy	IPP	IPP	IPP	IPP
Second best policy	ISE	ISE	ISE	ISE
Third best policy	IFT	IFT	IFT	IFT

Additionally in table 54 the ranking in terms of accumulated CO₂ emissions over the period 1986 to 2026 is shown. It has to be stated that this ranking is the same for all policy packages.

7.3.8 Example for Sensitivity Results

Besides the demonstration examples additional sensitivity checks with the ASP have been executed to test and validate the model reactions. For this purpose parameters of major importance for the model or with a certain degree of uncertainty about their values have been chosen. Two sensitivity checks and their outcome are explained in the following.

The first sensitivity check tests the influence of the following three parameters:

- Fuel price development influenced by tax changes after the year 2000,
- Share of fuel cost on perceived costs for private short distance car trips (< 40km),
- Share of fuel cost on perceived costs for private long distance car trips (> 40km).

In the sensitivity check the fuel tax for diesel and gasoline is varied from 50% of the base scenario tax to 500% of the base scenario with increments of 10%. At the same time the values for the share of fuel on perceived cost for short distance private car trips (base scenario = 90%) and long distance private car trips (base scenario = 78%) are altered from 30% to

100% also with increments of 10%. So, in total about 2600 simulation runs are performed to test the sensitivity of model results to these three parameters.

The results of the sensitivity checks can be presented in graphs showing different confidence bounds for model variables. The confidence bound e.g. 50% confidence indicates that this proportion of sensitivity runs keeps the results within the shown limits. Four confidence bounds with 0-50%, 50%-75%, 75%-95% and 95% - 100% and the curve for the base scenario are presented in the following sensitivity figures.

The first sensitivity figure 126 presents the confidence bounds of the yearly fuel tax revenues in region 1 (A, D). It can be observed that the base scenario (red curve) is near the border of the lower 50-75% confidence bound. The structure of the tax increase with adding the tax change of the sensitivity check over the 5-years period from 2000 to 2005 can be identified in the figure. It is chosen to add the sensitivity tax increase not in total at one point of time but in equal portions over the 5-years period to avoid frictions or oscillations because of a sudden shock by adding it in total. However, it can be realised that first after 2005 the tax revenues in the upper confidence bounds greater than 75% decrease, because of a consumers reaction to drive less considering the extremely increased fuel price. This reaction can not be found in the lower confidence bounds.

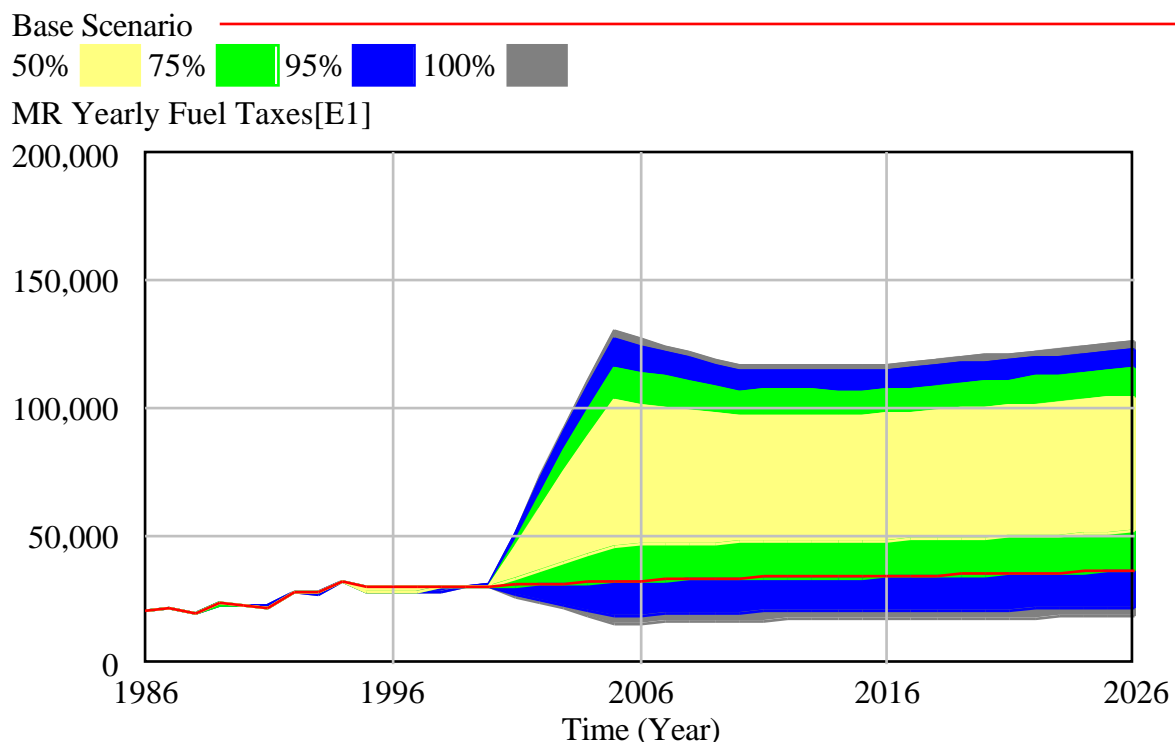


Figure 126: Fuel tax revenues in region 1 (A, D) with sensitivity testing

The following figures present how other interesting variables react on these changes of the yearly fuel taxes. First of all in figure 127 the reaction of GDP is depicted. In both regions the base scenario belongs to the upper 12.5 % of all possible developments calculated within the

2600 simulations. This can also be realised from the histogram in figure 128 showing the distribution of results for GDP in region 1 over 10 clusters. The value of 4499 Bill EURO belongs to the third highest cluster very close to the border of the second highest cluster, which is at 5000 Bill EURO. In general, it can be stated that economic development and growth is slowed down by very high fuel tax rates, but that it is not prevented. The results are similar also for the other regions not presented in the figures.

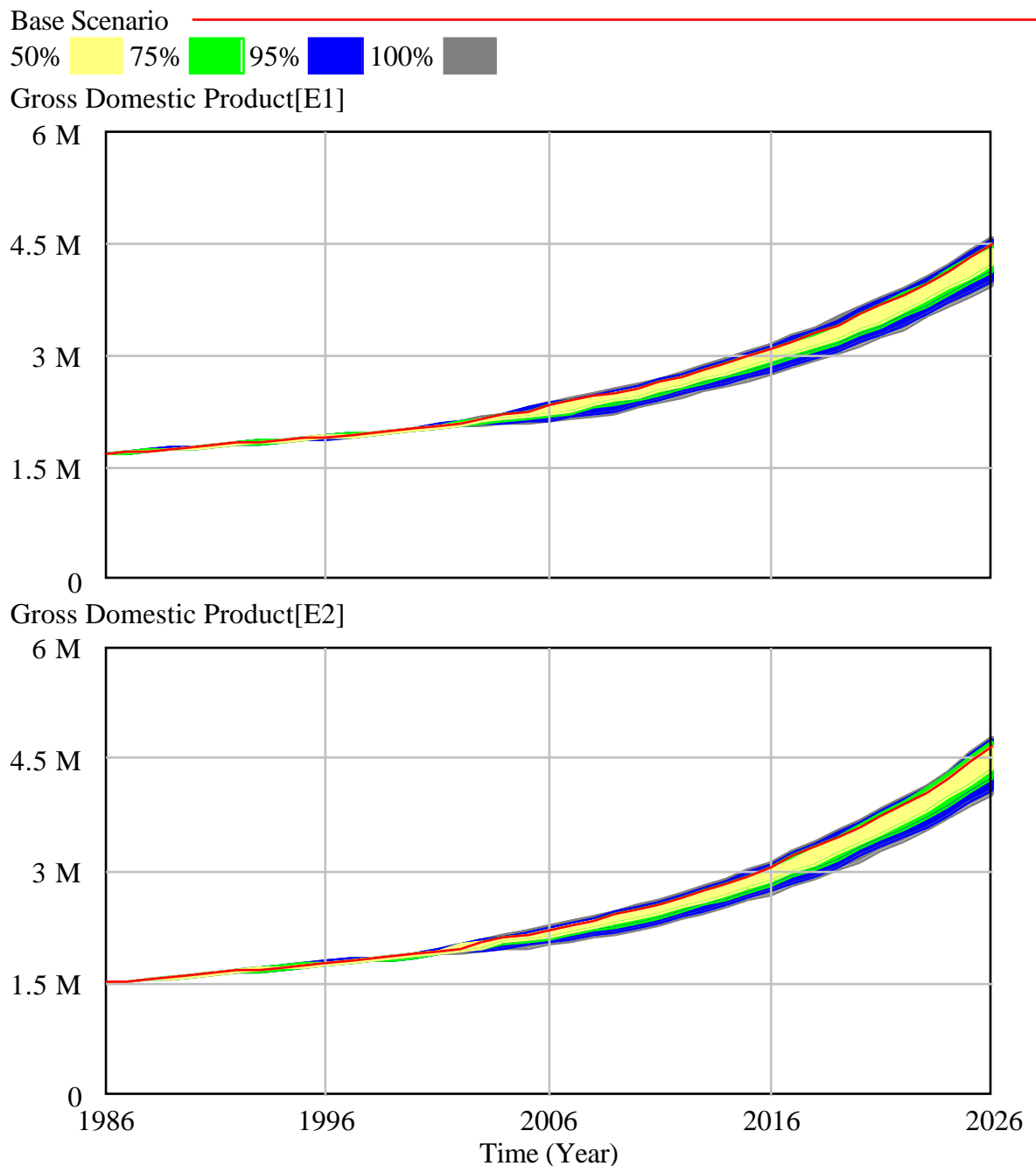


Figure 127: Reaction of GDP in region 1 (A, D) and region 2 (B, F, L, NL) to fuel price variation

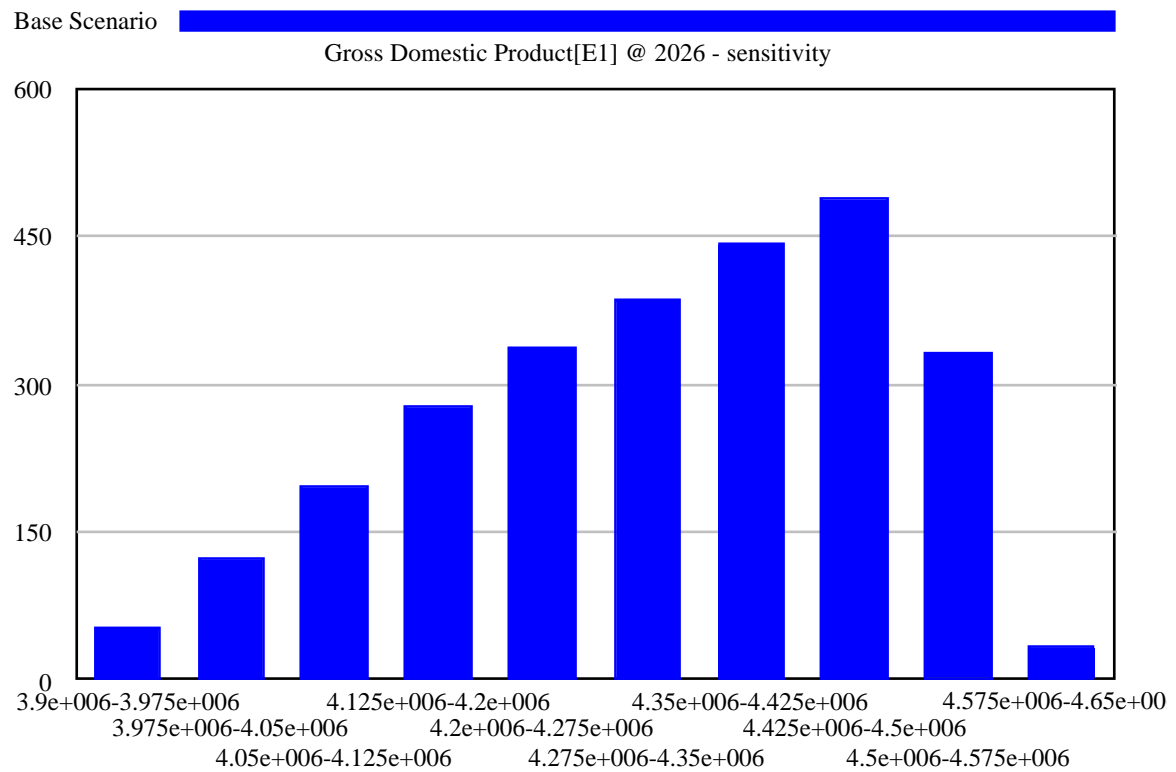


Figure 128: Histogram of sensitivity tests for GDP in region 1

Figure 129 presents the sensitivity results for employment in region 3 (E, GR, I, P). Again the base scenario result belongs to the upper 12.5% for most of the forecasting period. In general the development of employment is slightly positive, which can be seen from the yellow area. For the final 8 years it is interesting to see that the upper 87.5% of all runs follow the same development of employment. The reason seems to be that the maximum employment level limited by total possible working population and base unemployment is reached. In this case further economic growth on the supply side is either depending on increases in capital stock but – and this is even more important – further increase in labour productivity.

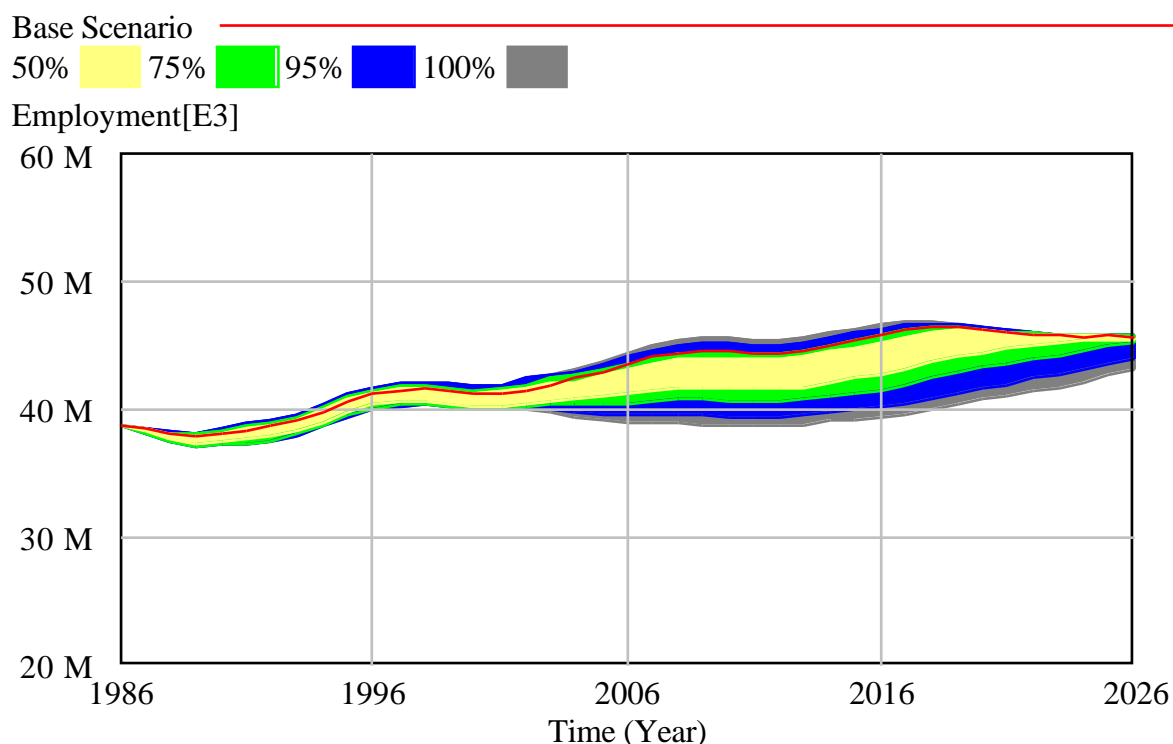


Figure 129: Sensitivity results for employment in region 3

On the transport side the modal-split should be varying significantly between the different sensitivity simulations. Figure 130 presents the modal-split share of car and train in longer distance passenger transport (>40 km). It can be seen that in the first ten years of the simulation there is also a bandwidth for the variables, which is due to the variations in share of fuel on total costs of car trips. However, the bandwidth diminishes near to zero after this period. The reason is that a certain type of model variables that is calibrated according to the initial development of the base scenario starts to oscillate if the initial development is changed without recalibration. However, these oscillations are calmed down over time to a reasonable development. As in the first years only the share of fuel on total (perceived) costs is varied this figure 130 also reflects that the share of fuel on total (perceived) costs is not of zero importance but of minor importance compared with the increase in fuel price for the sensitivity tests.

Looking at the year 2000 in which now the increase of the fuel prices commences one can observe that modal-split in the longer distance band can be changed significantly. Halving the fuel tax would lead to 3-4% increase in share of car transport, while raising the tax level by 400% decreases it by about 17% at the maximum. However, over time the effect diminishes reaching finally about 10% at maximum. On the other hand rail transport gains at maximum 4.5% diminishing to about 2% at the end of the time horizon.

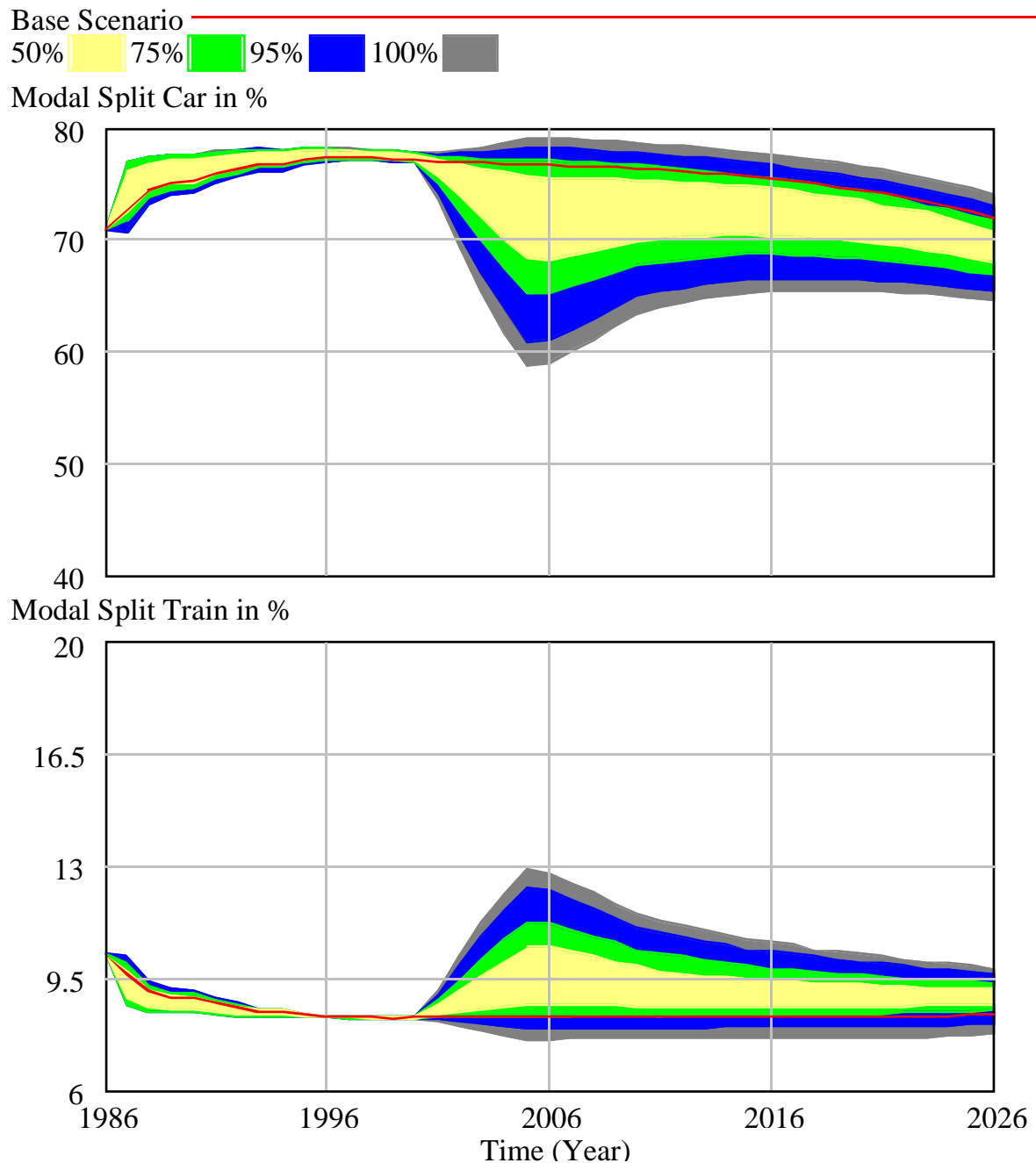


Figure 130: Modal-split of non-local passenger transport based on trip volumes for car and train

Also the development of environmental indicators can reasonably be investigated with the sensitivity tests. Considering the important discussions about the contribution of transport to the greenhouse effect by the emissions of CO₂ figure 131 indicates for region 3 that the base scenario belongs to the upper 12.5% of simulations, which in this case are the most negative results. Looking at the most optimistic results in 2026 it seems that a stabilisation on the 1985 level seems to be possible, which in the long-run would not be enough to reach sustainability, if one considers e.g. the findings of the OECD project on environmentally sustainable transport (EST) where a reduction of 80% in 2030 compared to the 1990 level should be reached.

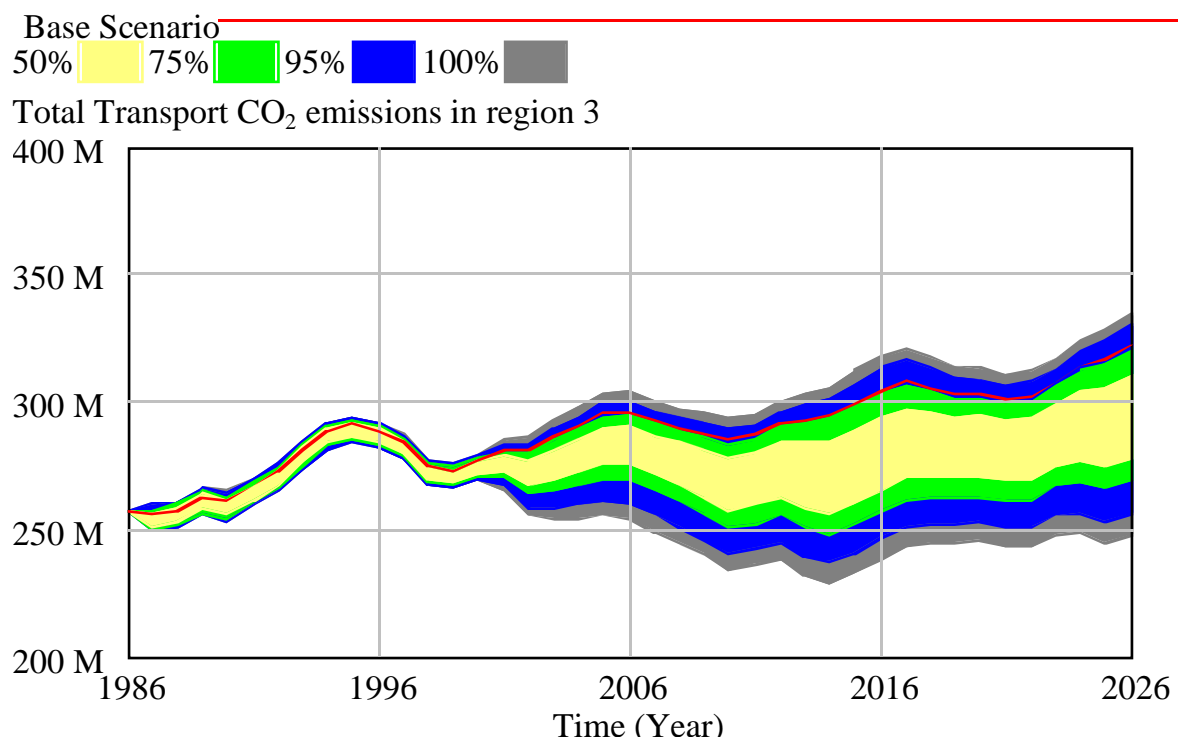


Figure 131: Sensitivity results for total CO₂ emissions of transport in region 3

The fuel price is also one of the influencing factors for the development of the passenger car fleet. Figure 132 shows for region 4 that between the highest and the lowest tax level the gap in the car fleet is about 10 million passenger cars. In this case the difficulty in the model could be that such strong changes of fuel prices happening between 2000 and 2005 in the extreme cases of the sensitivity simulations are without any example in reality. That means the risk that the applied elasticities over- or underestimate the reactions of demand exists. Nevertheless the fuel price increase in the beginning of the year 2000 showed that customers in Germany do react by decreasing demand for cars in the short-run. In the long-run this might be compensated by increased demand for very fuel-efficient cars, when these are offered more widespread.

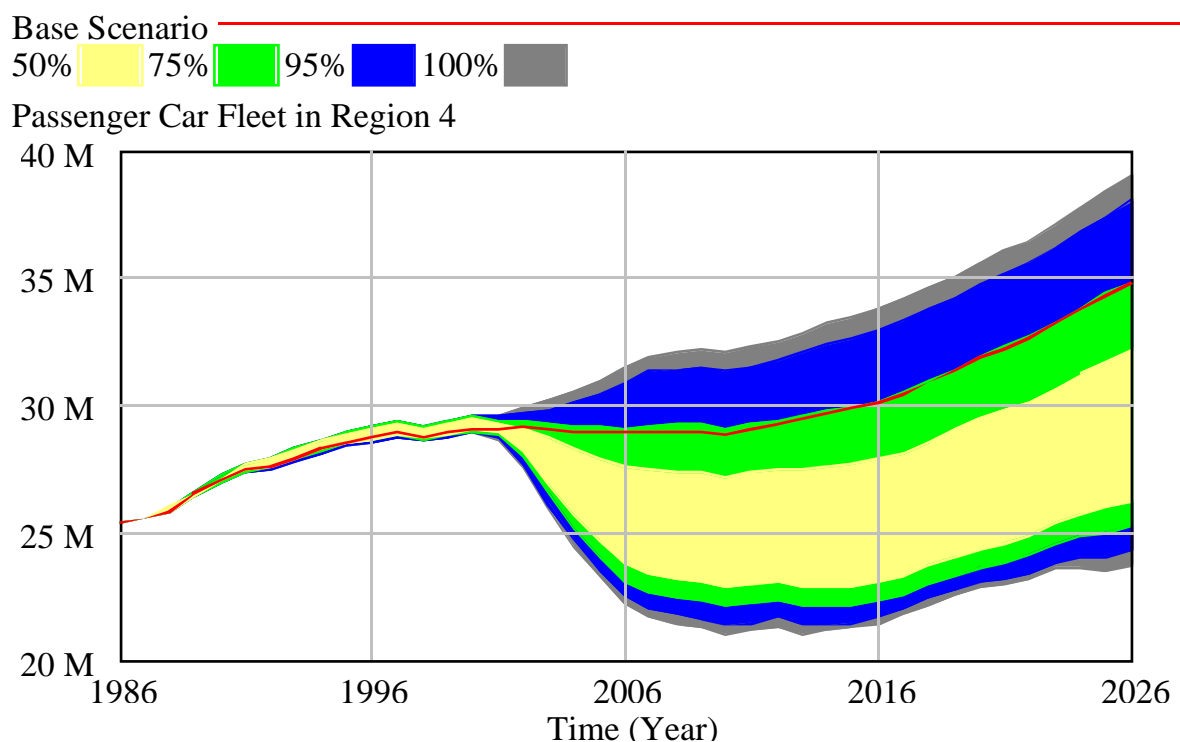


Figure 132: Results for passenger car fleet in region 4 with sensitivity testing

The second example of a sensitivity test is focused on the development of the value of time, which is of importance for the transport model as it influences the generalised time respectively cost variables. The model differentiates the value of time of local and non-local business transport, of private and tourism transport for passenger and of bulk, semi-bulk and unitised goods transport for freight. In the base scenario besides for bulk goods transport the value of time increases with a rate of 2.6% a year. Alternatively the increase can be adjusted to the growth of GDP, which is reasonable as it can be argued that the value of time grows with the development of (material) welfare. For the second sensitivity test the yearly growth rate for the value of time is varied from 0% to 10% with an increment of 0.01%.

The following figures present a small selection of results for the sensitivity test of the value of time. Figure 133 shows the modal-split shares based on trip volumes for passenger trips by car and by plane. In the period 1996 to 2006 it seems that growth-rates for the value of time below 2.6% do not have an influence on the car share as the base scenario, and the upper 25% of sensitivity runs have the same value. After 2006 lower growth rates would lead to slightly higher share of car transport. On the other hand with extreme growth rates of value of time (which are not realistic as average values but might already be true for some top managers and politicians who always use the plane) the share of car shrinks to zero after about 2016.

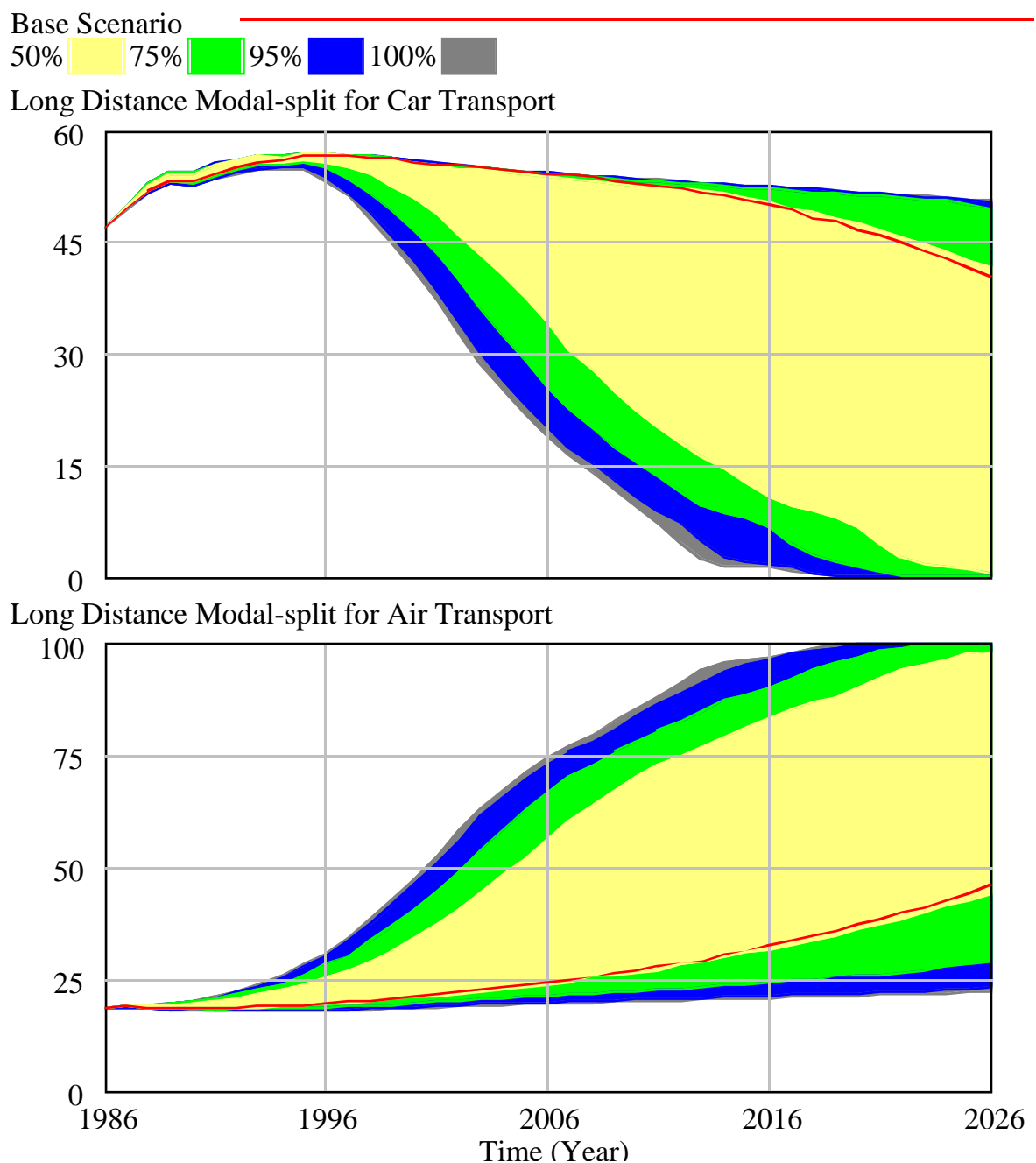


Figure 133: Long-distance modal-split (>160km) for car and air transport based on trip volumes (results of sensitivity test)

Considering the share of air transport in figure 133 it can be realised that it is very much mirroring the development of car transport. That means the losses of car transport become gains of air transport. However, as air transport share reaches 100% after about 2020 also train and bus transport share would be zero, such that everybody would take the plane for long distance trips in case of the very high value of the value of time. Nevertheless the very high growth rates should be seen as an academic example and not as a possibility in reality.

Figure 134 presents the results for the transport performance of passenger modes with extreme yearly growth rate of 10% for the value of time. From the beginning bus mode loses users, while car mode gains demand until about 1998 but then suddenly starts to lose demand. It seems that a certain threshold of value-of-time exists above which a break in trend of the attractiveness of car mode occurs. A similar but smoothed behaviour is observed for rail mode with a turning point at about 2010. Air mode starts to grow very rapidly at about 1994. However, it should be reminded that this is an extremely high growth rate, which could be beyond the confidence bounds of the model reactions, such that these results should be handled with care.

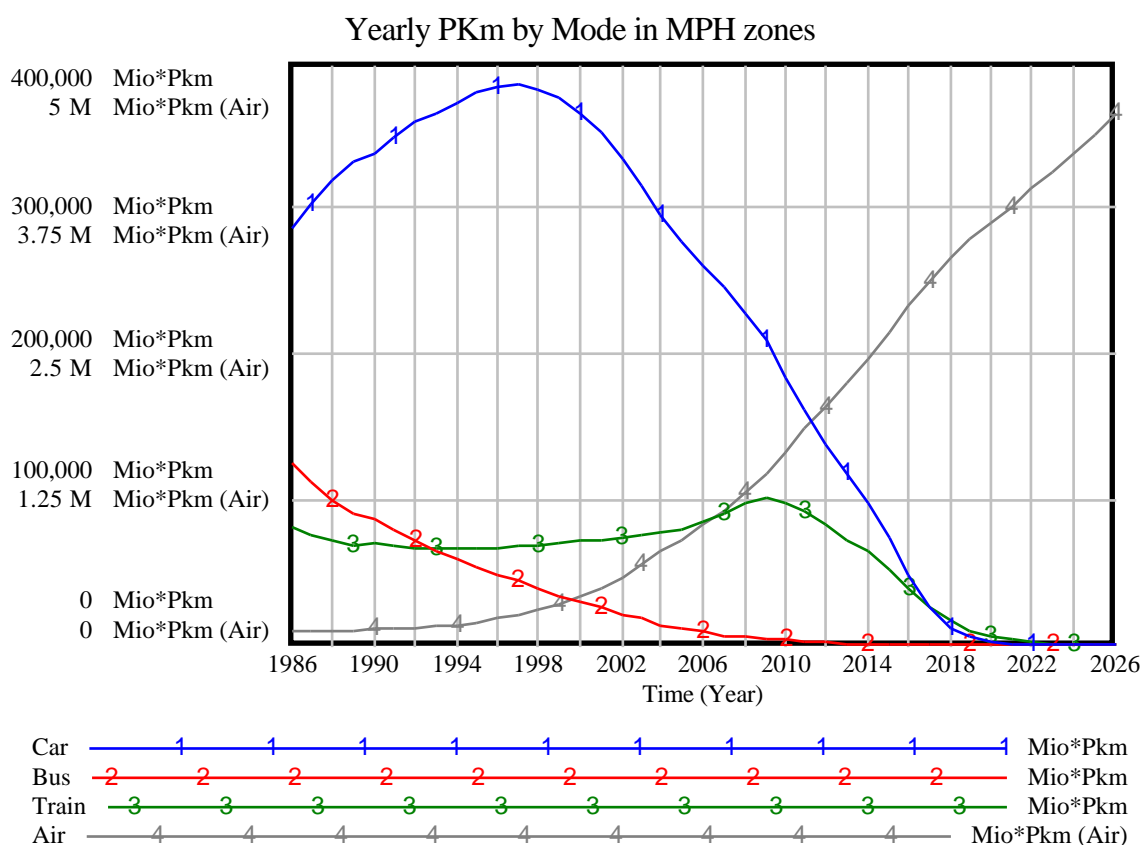


Figure 134: Long-distance (>160km) transport performance of passenger modes in metropolitan areas plus hinterland (MPH) with growth rate for value of time of 10%

8 ASTRA-TIP

8.1 Introduction

ASTRA – TIP, the viewing **T**ool for **I**mplementation of **P**olicies, was designed to provide the user an easy-to-use platform to display and to compare the ASTRA model results for the five ASTRA policy packages. The following chapters will show how to use the TIP. For comprehensive explanation some screen shots are presented. Names of elements of the ASTRA-TIP are written in *italics*.

8.2 Basic Usage

Opening the ASTRA-TIP from the Windows Program Manager or the MacIntosh Finder leads to the *welcome screen* (figure 135). By pressing the *start button* in the bottom right corner of the *welcome screen*, the *result screen* is opened (figure 136). When the result screen is opened the first time by default it presents the *base scenario screen*.

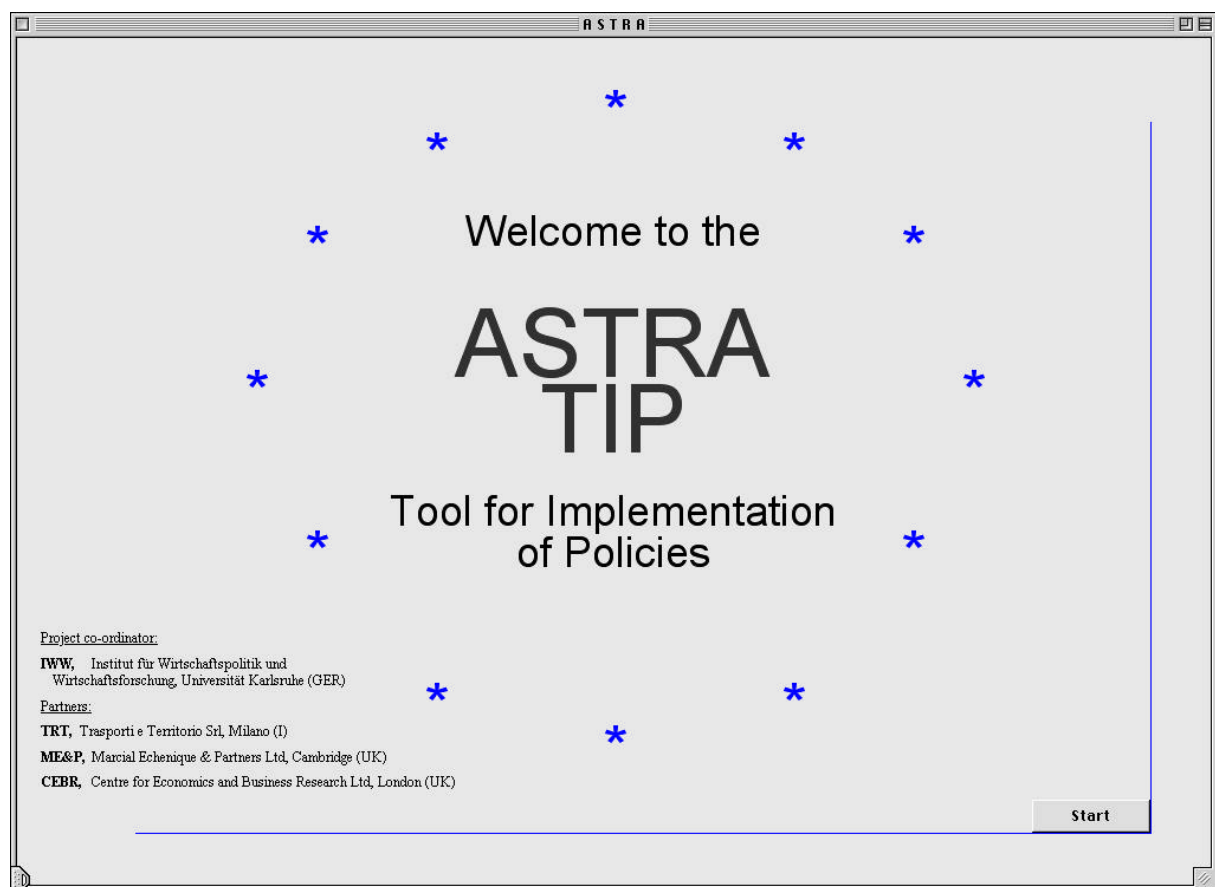


Figure 135: Welcome screen of ASTRA-TIP

The structure of the *base scenario screen* and the five policy packages is the same as they are all of type *result screen* presented in the following figure.

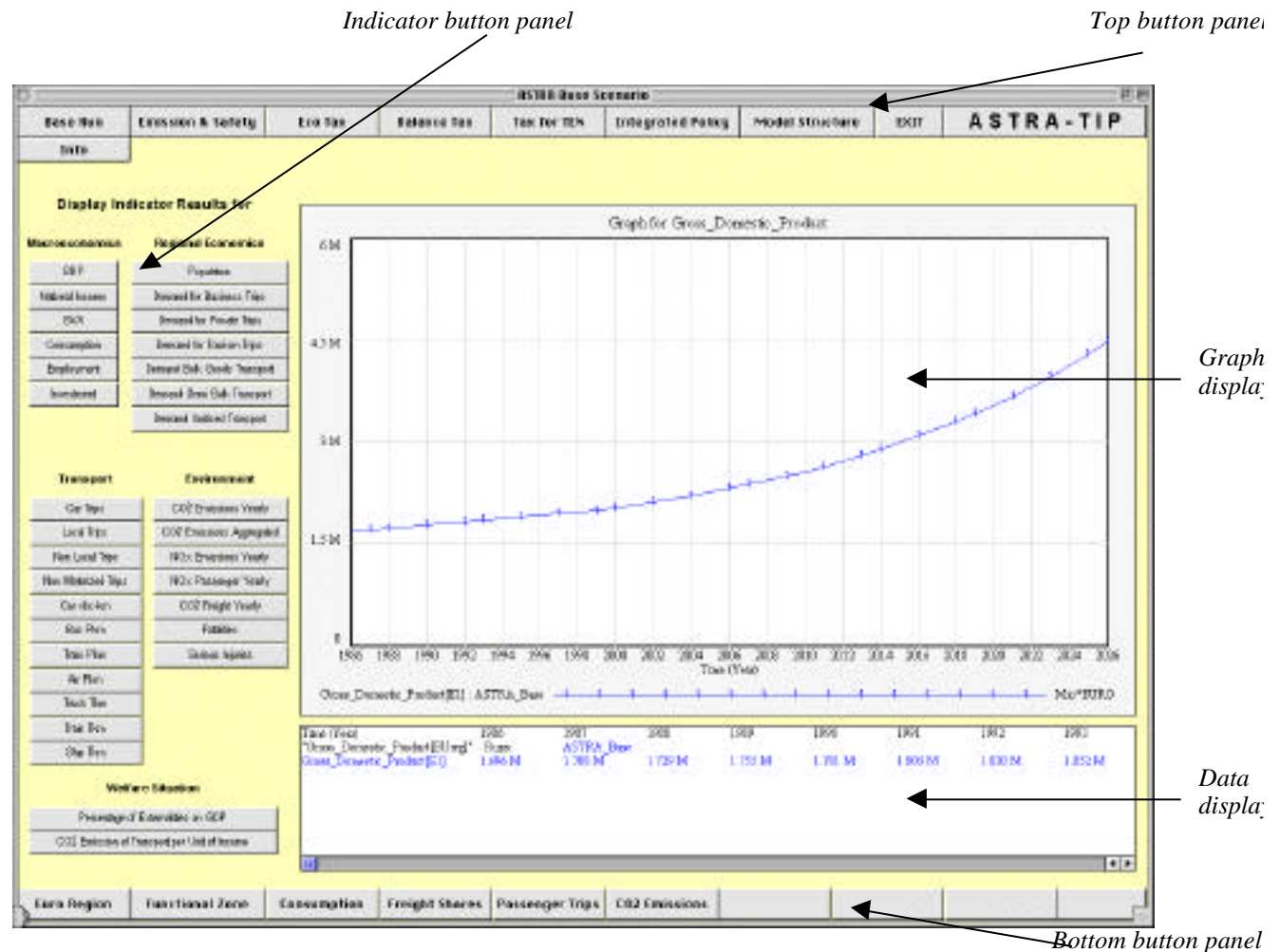


Figure 136: General structure of result screens

On a *result screen* one finds the *top button panel* that contains the buttons to switch between the different *result screens* for the base scenario and all policy packages. Furthermore there is a button to view the model structure and to exit the ASTRA-TIP. If one of the packages is active there is an *info button* below the corresponding top button that briefly explains the scenario (e.g. its baseline idea).

On the left side of the screen there is the *indicator button panel*. It contains buttons to display the results of major indicators in the ASTRA model. The available indicators are divided into five groups:

1. Macroeconomics,
2. Regional Economics,
3. Transport,
4. Environment and
5. Welfare Situation

Right hand to the *indicator button panel* there are the result display tools: *graph display* and *data display*. Both display the results for the active indicator that is chosen by pressing one of the buttons on the *indicator button panel*.

On the bottom of the result screen the *bottom button panel* is arranged. The first two buttons from the left are used to choose the spatial location for which spatially differentiated indicators should be displayed. The *button Euro Region* enables to switch between the four macro regions (E1 = A, D; E2 = B, F, L, NL; E3 = E, GR, I, P; E4 = DK, FIN, IRL, S, UK; see figure 137). After confirming the dialog box by *Close*, the result screen will be updated with the new options.

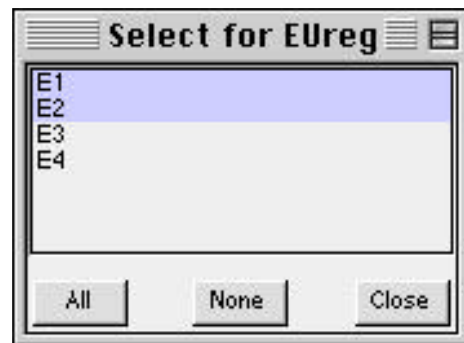
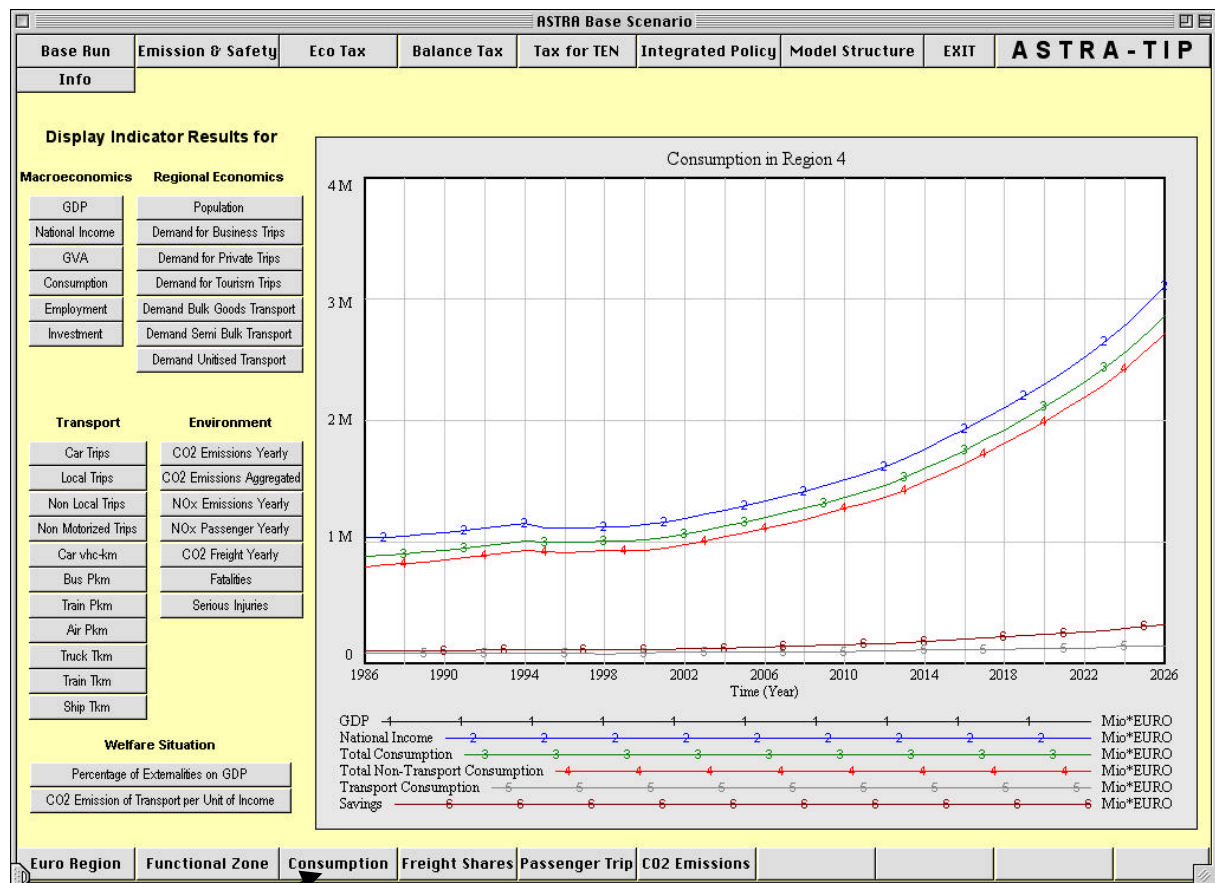


Figure 137: Selection dialog for spatial selection of Euro Region type indicators

The *button Functional Zone* effects the passenger model indicators to switch between the displayed functional zones (LSA = Large Stand Alone Metropolitan Centres; MPH = Metropolitan Areas plus Hinterlands; HDU = High Density Urbanised Areas; HDD = High Density Dispersed Areas; MDR = Medium Density Regions; LDR = Low Density Regions).

On the right hand side of the *bottom button panel* is the *?-button* that displays important information for the user e.g. names of the macro regions. The remaining buttons in the panel change their names and functionality in dependency of the chosen policy package presented on the result screen. If one presses these buttons then on the graph display a *predefined graph* showing a set of indicators is presented e.g. for the consumption variables e.g. total consumption, consumption for transport purposes (figure 138).

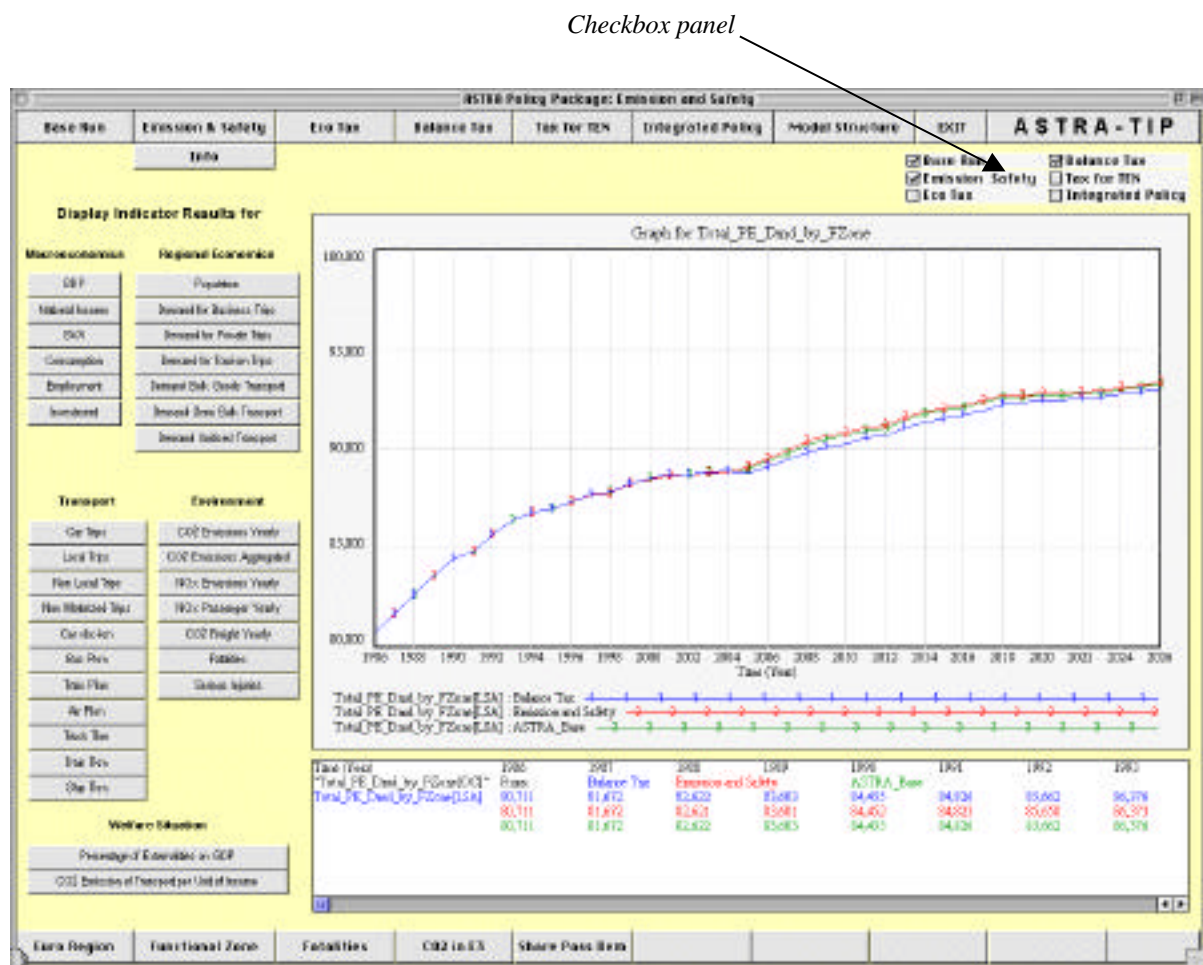


Pre-defined graph button

Figure 138: Pre-defined graph for consumption in region 4

8.3 The Policy Packages

By changing the active policy package on the *top button panel*, the loaded datasets will be changed to display results for the new active policy. The windows for the policy packages vary from the *base scenario screen* by the possibility to display results for different runs simultaneously. For this purpose six checkboxes are presented on the *checkbox panel* in the right top corner of the window. Initially selecting a new policy package on the *result screen* only the checkbox for this policy package is selected and the displayed results belong to this policy. Selecting further policy packages by clicking checkboxes and pressing one of the indicator buttons invokes the display of the results for this indicator for all selected policies (figure 139).



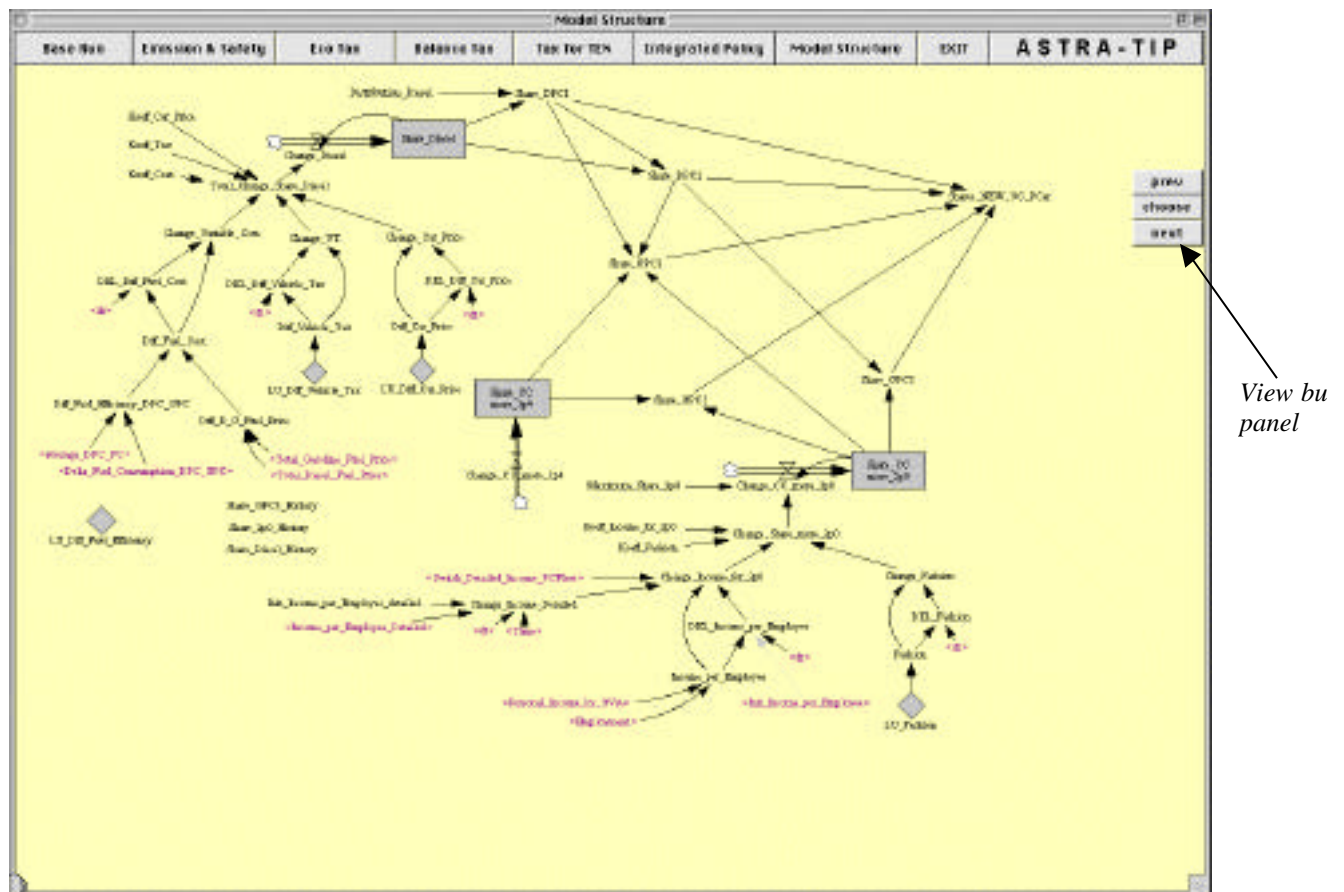


Figure 140: Example of a model structure screen

The model structure is described in about 100 views that can be scrolled by using the *next* and *prev* buttons on the *view button panel*. *choose* will show a dialog from which the desired view can be selected directly (figure 141).

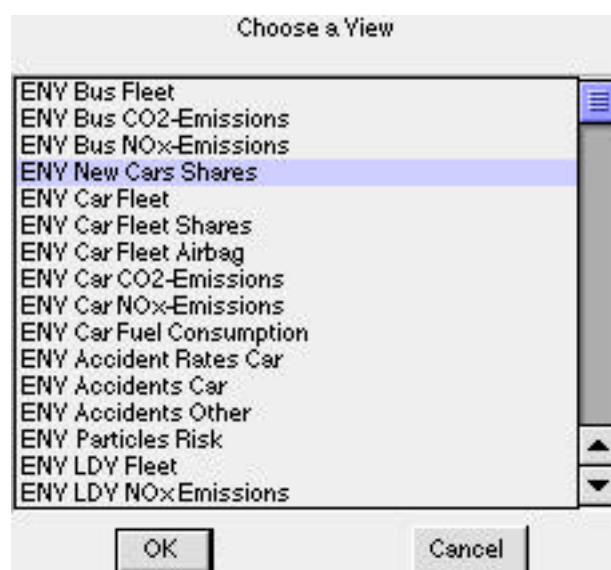


Figure 141: Dialog to choose a view presenting a part of the model structure

8.5 Technical Requirements

For running ASTRA-TIP one needs the Vensim application software, the ASTRA-TIP file and ASTRA model files (12 files). The Vensim application software has to be purchased for a small charge by Ventana Systems or by national distributors (for both see <http://www.vensim.com/>). An IBM PC version or a MacIntosh version are available. The hardware should be up-to-date and equipped with sufficient RAM. Free hard disk space of about 80 MB is required, if all datasets are stored on the hard disk.

9 Outlook

As the ASTRA project has reached its final stage now and the model development, calibration and demonstration examples are completed it makes sense to provide an outlook on future use and improvements of the model. The baseline for initiating the ASTRA project was to develop more a feasibility study than a fully operable model. Nevertheless, the final output of the ASTRA project is an operable model for the given spatial representation with which further policies and policy packages of the prototypes presented in the demonstration examples could be tested.

What concerns the improvements and further developments the modelling team created during the model development several fruitful ideas about additional feedbacks and interrelationships that could be tested for their feasibility for modelling and their importance. This will be the task of usual scientific development e.g. at the University of Karlsruhe with diploma or dissertation theses.

However, there are also more concrete improvements to be made. The first one can be seen in increased spatial differentiation into EU countries instead of macro regions including accession countries. Also, the sectoral categorisation into 12 economic sectors could be adjusted to 25 economic sectors according to EUROSTAT classification. These tasks will be part of the TIPMAC project soon starting in the EU 5th FP.

Two further task in the EU 5th FP currently at the level of proposals could cover other aspects. The first task would cover a more detailed consideration of information technologies and energy prices on transport and economy. The second task would extend the forecasting horizon until at least the year 2050 and would combine it with a backcasting approach describing desirable futures. As it has been shown in the OECD-EST project this combination of backcasting and forecasting provides synergies for policy design and assessment.

The ASTRA approach could also be transferred on a national level with only one country as the top spatial level. This will be tackled by a project of TRT in which an Italian ASTRA will be developed. For this project also some of the above mentioned improvements will be considered.

IWW intends either to integrate elements of the ESCOT model developed for the OECD-EST assessment (e.g. effects of technological progress) and to integrate ASTRA with models from further partners. For this purpose a co-operation with the Institute for Prospective Technological Studies (IPTS) will be established with the focus on linking ASTRA and POLES (SD world energy model) and the attempt of transferring ideas of ASTRA onto an urban level.

10 Conclusions

The first and most important conclusion is that despite all problems like reaching the size limits of the originally used software (ithink) the ASTRA project successfully comes to prospective conclusions providing the following achievements:

- An integrated system dynamics model is developed including the four sub-modules macroeconomics (MAC), regional economics and land use (REM), transport (TRA) and environment (ENV).
- A plausible base scenario is designed and five policy packages as well as an integrated policy programme have been implemented and tested as demonstration examples.
- The results of the demonstration examples reveal that the ASTRA approach reasonably can be applied for long-term assessment of the consequences of transport policy measures, policy packages or policy programmes.
- An easy-to-use interface is developed with the Vensim application software to make the main indicators easily accessible and to present a compact picture of the results of the demonstration examples.

In the ASTRA project conventional models are transformed into the system dynamics methodology. This can be done in several ways that can be distinguished by the degree of adaptation to the system dynamics methodology. A full adaptation would mean a transformation of all of the functionals into the system dynamics world, which implies a formulation of new functionals or a reformulation of the functionals as difference equations. On the other hand the conventional functionals of the key relationship can be copied directly into the ithink software without explicit transformation. Also, there are existing several intermediate stages with more or less adaptation to the system dynamics methodology. The ASTRA approach could be classified as more orientated towards the econometrically based sectoral models, which is related to the project approach to base the ASTRA model on these type of models. Nevertheless this approach demonstrates that it is feasible to start the system dynamics modelling process on the basis of the four applied models. Still there is enough space for improvements towards a better adaptation of the system dynamics methodology to sectoral modelling.

A second issue that has to be mentioned in relation to the system dynamics methodology is that in the general view these approaches have only few data requirements. However, in ASTRA emphasis was also put on the collection and use of a broad variety of data sources for instance to depict existing structures appropriately in the model e.g. regional car vehicle fleets. This supports to endogenise the development of real world systems instead of hypothesising an aggregated development e.g. of average car emission factors.

For long-term strategic assessment most often qualitative expert judgements are applied. The problem with these qualitative judgements is that they are hardly verifiable and the risk of a lack of consistency is existing e.g. in terms of the underlying framework of assumptions or the considered influences. With an integrated modelling framework given by a system dynamics model these problems are avoided as the models can be verified providing that the software tools are public and the documentation is sufficient. Consistency is secured by the consequent use of the integrated modelling framework. Furthermore, benefits for long-term assessment can be gained when forecasting and backcasting approaches are combined such that by a forecast with a system dynamics model the development path to the images of the future developed with backcasting can be shown.

The overall framework for assessment is the demand for a sustainable development with the three dimensions economy, ecology and society. For European transport policy this has been further detailed with the objectives of the CTP (1992), CTAP (1995), FPI (1998) and the documents on CTP and sustainable mobility (1999). For the assessment of all the mentioned sets of policy objectives a great variety of indicators is needed, which is often hampered by a lack of data. With ASTRA the data for the (most) indicators can be provided quite sophisticated as the model includes common indicators as GDP, employment, transport performance or CO₂ emissions as well as specific indicators like investments in vehicles for a certain mode, the number of gasoline cars with less than 1400 cc engines or the externalities of NO_x emissions. Based on this great variety of indicator data all kinds of assessment schemes e.g. MCA, CBA or the spider model developed by the SAMI project can be applied.

In ASTRA the model was used to test five policy packages (Improved Emission and Safety (ISE), Increased Fuel Tax (IFT), Balanced Fuel Tax (BFT), Rail-TEN, All-TEN and an integrated policy programme (IPP) against the development in the base scenario. Considering the economic effects in terms of changes in GDP the IPP is the most effective policy for EU15, which is also true for region 1 (A, D), region 2 (B, F, L, NL) and region 4 (DK, FIN, IRL, S, UK). But not for region 3 (E, GR, I, P), where the All-TEN policy package is most effective in economic terms. The variations for the second best and the third best policy package is even higher such that an important conclusion is that very similar policy packages taken in different regions can lead to regional different results. The reason for the difference then would be the different starting point or structure. Whereas in terms of CO₂ emissions, which is the most important environmental indicator, the ranking is identical for all regions with IPP and ISE lead to the best solution. Here one has to consider that ISE is part of the IPP and by this mitigates the latter policies environmental impacts.

In general the change of average yearly GDP growth rate over the 25(30-)-years policy simulation period is at maximum 0.2% between the best and the worst development. This seems to be a plausible range for the effect of transport policies that do not imply harsh changes of the societal and economic framework. For instance the recent increase in oil prices over about 8 months covered a similar or even higher percentage increase than in the ASTRA policy packages where the increase takes place over a much longer period. The real development in the first half of the year 2000 can be seen more as a kind of crisis or shock.

Concerning the other two dimensions of sustainability the picture is less optimistic or less well documented. The development of environmental effects is ambivalent. The NO_x emissions will be reduced coming at least very close to a sustainable level in the next decade. But the more important CO_2 emissions increase for the most policy packages continually. The most optimistic policy packages in terms of CO_2 emissions stabilise emissions at the 1990 level. However considering the Kyoto requirements or the longer term targets of the OECD-EST project this is not sufficient to reach the goals. Also for accidents including fatalities no significant improvement could be identified, such that to come closer to environmental sustainability stronger measures e.g. as described in the OECD-EST project would have to be taken.

In terms of social sustainability the ASTRA model provides only a short list of indicators. Currently, it seems to be difficult to extend this list as the scientific field still has to be developed further to be able to have a comprehensive social assessment. The major social indicator in ASTRA is the number of unemployed persons. This number will decrease strongly over time in the base scenario as well as in all policy packages. However, this is mainly caused by the demographic development with only a minor contribution of transport policy.

The future development respectively the effect of a taken policy package could also be expressed in terms of changes of the welfare position. The welfare position can on the one hand in ASTRA be described with simple indicators like private consumption or externalities of emissions. On the other hand intensity indicators or cost-effectiveness indicators can be constructed easily. An example for an intensity indicator would be the quantity of transport CO_2 emissions per unit of GDP. Cost-effectiveness in terms of CO_2 reduction could be assessed with the reduction of CO_2 emissions that can be gained by a decrease of GDP (assuming for this example that the policy causes a decrease in GDP) both compared with their development in the base scenario. Using such techniques comprehensive assessments of the welfare consequences of policies can be performed.

An important single result of the demonstration examples concerns the consideration of reactions of air transport on changes of attractiveness for other modes. Air transport, which is already the fastest growing transport mode, is even significantly accelerating its growth in all policies that increased the price for road transport leaving the price for air transport unchanged respectively following the base scenario development. For instance this concerns the eco tax concepts increasing road fuel tax by yearly steps without implementing a kerosene tax. In this case at least a part of the environmental improvements will be compensated by the resulting increased air transport.

11 References

- ASTRA (1998): “Design and Specifications of a System Dynamics Model”, deliverable 2 of 4th framework research project ASTRA, Karlsruhe.
- ASTRA (1999): “The ASTRA System Dynamics Model Platform (ASP)”, deliverable 3 of 4th framework research project ASTRA, Karlsruhe.
- BAST (1975) Bundesanstalt für Straßenwesen: “Auswirkungen von Tempo 100 auf Verkehrsablauf und Unfallgeschehen”, (English: Effects of a Speed Limit of 100 km/h on Traffic Flow and Accidents), Köln.
- BAST (1978) Bundesanstalt für Straßenwesen: “Schutzwirkung von Sicherheitsgurten - Literaturanalyse”, (English: Protective Effect of Safety Belts - Literature Study), Vol. 2, Köln.
- BAST (1986) Bundesanstalt für Straßenwesen: “Untersuchung zur Auswirkung der vorübergehenden Anordnung von Tempo 100 auf Bundesautobahnstrecken im Rahmen des Abgas-Großversuchs auf das Unfallgeschehen” (English: Study on Effects on Accident Rates of Speed Limit 100 km/h on Motorways during the Emission Control Study), Bergisch Gladbach.
- BAST (1992) Bundesanstalt für Straßenwesen: “Mehr Verkehrssicherheit durch bessere Technik ?” (English: Higher Traffic Safety by Technical Improvements ?), Bergisch Gladbach.
- BAST (1996) Bundesanstalt für Straßenwesen: “Kontinuierliche Erhebungen zum Schutzverhalten von Verkehrsteilnehmern” (English: Continuous Statistics on Self Protection Behaviour of Transport Users), BAST Report not published, Karlsruhe.
- BUWAL; UBA; infras (1995): “Handbuch Emissionsfaktoren des Straßenverkehrs – Version 1.1”. (english: Handbook on Emission Factors of Road Transport Version 1.1), CD-Rom, Bern, Berlin.
- BUWAL; UBA; infras (1999): “Handbuch Emissionsfaktoren des Straßenverkehrs – Version 1.2”. (english: Handbook on Emission Factors of Road Transport Version 1.2), CD-Rom, Bern, Berlin.
- Cuhls, K.; Blind, K.; Grupp, H. (1998): “Delphi 98 – Zukunft nachgefragt - Studie zur globalen Entwicklung von Wissenschaft und Technik” (english: Delphi 98 – Future Investigated -Study on the Global Development of Science and Technology), Vol. 1&2, Fraunhofer Institut für Systemtechnik und Innovationsforschung (ISI), Karlsruhe.
- DETR (1997): “National Travel Survey 1994/96”, The Stationery Office, London.
- DETR (1998): “Focus on Personal Travel – 1998”, The Stationery Office, London

- DETR (1999): "Transport Statistics Great Britain – 1998", The Stationery Office, London.
- DGXVI (1999): "Sixth Periodic Report on the social and economic situation and development of the regions of the European Union", European Commission, Brussels.
- Dings, J.; Dijkstra W.; Wit R. (1997): "European Aviation Emissions: Trends and Attainable Reductions", financed by European Commission DG XI and others, Delft.
- ECMT (1998) European Conference of Ministers of Transport: "Statistical Trends in Transport 1965 - 1994", Paris.
- EEA (1997): "COPERT II – Methodology and Emission Factors". Final Draft Report by Ahlvik P. et al. for EEA European Topic Centre on Air Emission.
- ERSF (1998a) European Road Safety Foundation: "Every tenth crash caused by attack of illness", in: *European Road Safety News*, Vol. 11, Bertrange.
- ERSF (1998b) European Road Safety Foundation: "The raising of Speed Limits is Causing Concern", in: *European Road Safety News*, Vol. 12, Bertrange.
- ERSF (1998c) European Road Safety Foundation: "Eyesight Problems - a source of accidents - Results of a German Study", in: *European Road Safety News*, Vol. 12, Bertrange.
- EUFRANET (1999): "Study of long term flows scenarios", deliverable 3 of the EUFRANET project.
- European Commision (1997): "European Economy – 1996 Broad Economic Policy Guidelines", No.62 ISBN 0379-0991.
- EUROSTAT (1995): "Input-Output-Tables of Domestic Production for 1995 (R25, code 7)", can be ordered from EUROSTAT datashop: dslux@eurostat.datashop.lu, Luxembourg.
- EUROSTAT (1996): "Regions – Statistical Yearbook 1996", Luxembourg.
- EUROSTAT (1997a): "EU Transport in Figures", European Commission DG VII, Luxembourg.
- EUROSTAT (1997b): "Beyond the predictable: demographic changes in the EU up to 2050", Luxembourg.
- EUROSTAT (1997c): "Eurostat Jahrbuch '97", (english: EUROSTAT Statistical Yearbook 1997), Luxembourg.
- EUROSTAT (1998): "Demographic statistics Data 1995-96", Luxembourg.
- GDV (1998) Gesamtverband der Deutschen Versicherungswirtschaft: "Retrospektive Sicherheitsanalyse von PKW-Kollisionen mit Schwerverletzten", (Englisch: Retrospect

- Safety Analysis of Traffic Accidents with Serious Injuries), Institute for Vehicle Security at the GDV, München.
- Gühnemann, Astrid (1999): "Methods for Strategic Environmental Assessment of Transport Infrastructure Plans", dissertation thesis at IWW, Karlsruhe.
- Hayashi, Yoshitsugu (1998): "Implications of Car-related Tax Reform in Changing Peoples Mind to Purchase, Own and Use to lower CO₂ Emission", paper presented at the OECD EST conference in Ottawa.
- Hassel D., Weber F.-J. (1997): "Final Data Structure of Road Emission Factors – First Version", Deliverable 3 of the European project MEET, Köln.
- Hickman A.J., André M., Hammarström U., Kyriakis N. (1997): "Road Traffic Characteristics for Estimating Pollutant Emissions", deliverable 4 of 4th framework research project MEET.
- HPS (1997a): "ithink Analyst: Technical Documentation", Hanover.
- HPS (1997b): "ithink Analyst: An introduction to Systems Thinking", Hanover.
- IWW, IFEU, Kessel+Partner, Planungsgruppe Ökologie, PTV Consult (1998): "Entwicklung eines Verfahrens zur Aufstellung umweltorientierter Fernverkehrskonzepte als Beitrag zur Bundesverkehrswegeplanung" (english: Development of a Procedure for the Design of Environmentally Sustainable Transport Plans as a Contribution to Federal Transport Infrastructure Planning), Final Report from March 1998, on behalf of the Federal Environmental Agency of Germany, Karlsruhe.
- Johansson, Olof; Schipper, Lee (1997): "Measuring the Long-Run Fuel Demand of Cars", in: *Journal of Transport Economics and Policy*, Sep. 1997.
- Jorgenson, M.; Sorenson, S. (1997): "Estimating Emissions from Railway Traffic", deliverable 17 of 4th framework research project MEET, Lyngby.
- Kalivoda, Manfred; Kudrna, Monika; Fitzgerald, Pio (1998): "Methodologies for Estimating Emissions from Air Traffic: Future Emissions", deliverable 18 of 4th framework research project MEET and COST 319 Action, Vienna.
- Karsky, M.; Salini, P. (1999): "Prospective des Transports de Marchandises en France a l'Horizon 2020 – Le Modèle SIMTRANS", final report, financed under the PREDIT research programme, Paris.
- Keeling, C.D.; Whorf, T.P. (1998): "Atmospheric CO₂ Concentrations – Mauna Loa Observators, Hawaii", data set provided in electronic form, California.
- Keller, M.; Mauch, C.; Heeb, J. (1999): "MODUM: Model Umwelt – Mobilität", (english: MODUM: Model Environment - Mobility), 3rd interim report, research project of the Swiss NFP41 research programme, Bern.

- Knörr W., Höpfner U., Knisch H.; Lambrecht U., Nagel H.-J., Patyk A. (1997): "Daten- und Rechenmodell: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1980-2020". (english: Database and Calculation Scheme: Energy Consumption and Emissions of Motorized Transport in Germany 1980 - 2020), Research Project on behalf of the Federal Environmental Agency, Heidelberg.
- Koornstra, Matthijs; Bijleveld, Frits; Hagenzieker, Marjan (1997): "The Safety Effects of Daytime Running Lights", Leidschendam.
- Kuchenbecker, K. (1999): "Strategische Prognose und Bewertung von Verkehrsentwicklungen mit System Dynamics", (english: Strategic Forecast and Evaluation of Transport Developments with System Dynamics), dissertation thesis at IWW, Karlsruhe.
- LAI (1992): "Krebsrisiko durch Luftverunreinigungen", (english: Risk of Cancer caused by Air Pollution), report of the German Länderausschuß für Immissionsschutz, Düsseldorf.
- Lewis Dr. C. A. (1997): "Fuel and Energy Production Emission Factors". Deliverable 20 of the European project MEET.
- Litman, Todd (1998): "Transportation Cost Analysis: Techniques, Estimates and Implications", Victoria, Canada.
- Lohmeyer (1996): "Verfahren zur Abschätzung charakteristischer Luftschadstoffimmissionswerte für Ortsdurchfahrten im Rahmen des Bundesverkehrswegeplans", on behalf of Heusch-Boesefeldt, Karlsruhe.
- Mannan M. S., Ernvall T., Enberg A. (1998): "The effects of Sex, Accident Type and Car Characteristics Among Elderly Drivers in Finland", in: *IATSS Research*, Vol. 2.
- Müller, P.; Rothengatter, W. (1988): "Measuring the Relevance of Natural Resources for Production", in: *Jahrbücher für Nationalökonomie und Statistik*, Vol. 204, p.99-119, Stuttgart.
- National Road Traffic Forecasts (Great Britain) (1997)
- OECD (1996): "Environmental Criteria for Sustainable Transport", Report on Phase I of the Project on Environmentally Sustainable Transport (EST), Paris.
- OECD (2000): "Environmentally Sustainable Transport (EST) – Futures, Strategies and Best Practices", Synthesis Report of the Project on Environmentally Sustainable Transport (EST), Paris, Vienna.
- Ortuzar, J.; Willumsen, L.G. (1995): "Modelling Transport", 2nd Edition, John Wiley & Sons, Chichester.
- POSSUM (1998): "POSSUM – Final Report", 4th framework research project on behalf of DG VII, London, Brussels.

- Potter S. (1997): "Vital Travel Statistics", Landor, London.
- PROGNOS (1995): "Bedeutung und Umweltwirkungen von Schienen- und Luftverkehr", (english: Importance and Environmental Effects of Rail and Air Transport), Deutsches Verkehrsforum, Bonn.
- Robinson, J.B. (1996): "Life in 2030: Exploring a Sustainable Future for Canada", Vancouver.
- SCENARIOS (1998): "Global Reference Scenarios", deliverable C5, 4th framework research project on behalf of DG VII, Paris.
- Schade; B.; Rothengatter, W.; Schade, W. (1999): "Assessment of the BAU/EST Scenario with a Model for Economic Assessment of Sustainability Policies of Transport (ESCOT)", paper presented to the OECD-EST meeting on 8-10.10.1999 (final report in preparation), Paris.
- Schade B., Rothengatter W., Schade W. (2000): "Model for Economic Assessment of Sustainability poliCies Of Transport (ESCOT)", Paper Presented to the 3rd Biennial Conference of the European Society for Ecological Economics, Vienna.
- Schade, W.; Rothengatter, W. (1999): "Long-term Assessment of Transport Policies to Achieve Sustainability", paper presented at the 4th European System Science Conference in Valencia, Proceedings, Valencia.
- Statistisches Bundesamt (1997a): "Volkswirtschaftliche Gesamtrechnungen, Fachserie 18, Reihe 2: Input-Output-Tabellen 1993", (english: System of National Accounts FS18, R2: Input-Output Tables 1993), Metzler-Poeschel-Verlag, Stuttgart.
- Statistisches Bundesamt (1997b): "Statistisches Jahrbuch für das Ausland 1997", (english: Statistical Yearbook for Foreign Countries 1997), Metzler-Poeschel-Verlag, Stuttgart.
- STREAMS (1999): Final Deliverables 8 and 10, 4th framework research project on behalf of DG VII, Cambridge, Milan.
- Trozzi, Carlo; Vaccaro, Rita (1997): "Methodologies for Estimating Air Pollution Emissions from Ships", deliverable 19 of 4th framework research project MEET, Rom.
- UBA (1999): "Technische Optionen zur Verminderung der Verkehrsbelastungen: Brennstoffzellenfahrzeuge", (english: Technical Options for Reduction of Environmental Loads by Transport: Fuel Cell Cars), Final Report, Berlin.
- UK National Accounts (1997): "The Blue Book", London.
- UPI (1997) Umwelt- und Prognose-Institut: "Externe Gesundheitskosten des Verkehrs in der Bundesrepublik Deutschland". (english: Health Externalities of Transport in Germany), Heidelberg.

VS (1997a): “Vensim DSS: Reference Manual Version 3.0”, Harvard.

VS (1997b): “Vensim DSS: Modelling Guide”, Harvard.

WHO, ADEME, UVTEK, Austrian Federal Ministry of Environment, Youth and Family Affairs, Federal Environment Agency (1999): „Health Costs due to Road Traffic-related Air Pollution – Economic Evaluation“, World Health Organisation, Direction de L’Air et des Transports France, Federal Department of Environment, Transport, Energy and Communications, Bern.

