Tourism's impact on climate change and its mitigation challenges
How can tourism become 'climatically sustainable'?

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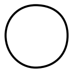
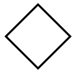
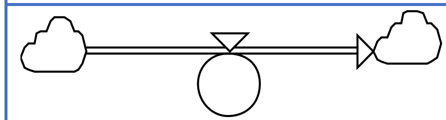
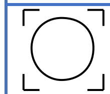
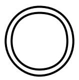
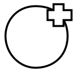
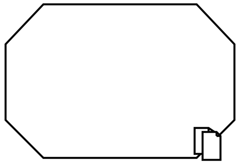
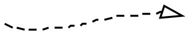
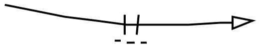
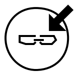
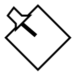
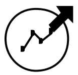
ANNEX IV. FULL DESCRIPTION OF GTTM^{DYN}

Introduction

This annex provides all details of the GTTM^{dyn}. Per Model Unit, a layout print is given, showing all variables and their links, and a table describing all variables in alphabetic order provining the dimension (that is the name of index definition for arrays), the physical unit, the kind of number (real, interger, logic), the equation or fixed value and comments providing some information. All 23 model units/submodels are covered plus some input and output organising units and a list of units, dimensions and connections to external databases. Powersim™ Studio 10 uses following conventions:

Symbol	Description
	Auxiliary. A variable that contains calculations based on other variables.
	Constant. A variable that contains calculations based on other variables.
	Level. A variable that accumulates changes. Influenced by flows.
	Continuous flow (plus rate variable and two clouds). A connector that influences levels. A flow is controlled by a variable connected by an information link (or attached directly) to the valve. A cloud is a symbol illustrating an undefined source or outlet for a flow to or from a level. The cloud symbol, also referred to as the source or sink or a flow, indicates the model's outer limits.
	Variable shortcut. A shortcut refers to a variable and provides easy access to this variable in a diagram when defining other variables. A shortcut is useful when the variable is located far away or when it is not present in the diagram. The variable that a shortcut refers to is called its source variable. Visually a shortcut is like a variable symbol with an extra set of corners.
	Array variable. A variable symbol with double frames indicates that the variable it represents is an array.

	Public variable. A public variable inside a submodel is indicated by a cross in the upper right corner. A public variable can be created connection points for in the diagram of the parent variable, can be referred to by variables outside the submodel, and itself refer to variables outside the submodel.
	Submodel. A variable that contains child variables. A submodel variable has no definition (value), data type, or unit. A document indicator indicates that the variable has diagrams. Any variable can have its own diagrams and child variables.
	Information link. A connector that provides information to auxiliaries about the value of other variables.
	Reference link. A connector that indicates that the two connected variables share the same value memory.
	Initialization link. A connector that provides start-up (initial) information to variables (both auxiliaries and levels) about the value of other variables.
	Delayed link. A connector that provides delayed information to auxiliaries about the value of other variables at an earlier stage in the simulation.
	Constant directly connected to an excelsheet cell value
	Variable with transfer direction set to in. A variable symbol with an arrow in the upper right corner pointing inwards, indicates that the variable has its transfer direction set to in. This implies that values are imported to the variable via datasets.
	Permanent variable. A variable that contains calculations based on other variables.
	Variable with transfer direction set to out. A variable symbol with an arrow in the upper right corner pointing outwards, indicates that the variable has its transfer direction set to out. This implies that values from the variable is exported from the model via datasets (in GTTM an Excel file).

Furthermore, I have tried to be consequent in colouring variables and backgrounds in the following way:

Main model units colouring schemes
Calculation models
Global models for trips and PV utility
Global output models
Global input models
Policy models

Variable colouring schemes
Exogenous user inputs
Exogenous excel data inputs
Endogenous PS sub-model inputs
Endogenous PS sub-model outputs
Own functions
GUI Policy inputs/outputs
Variables with unsure contents (purple and/or red line)
Redundant test variables
Test GUI inputs
Exogenous outputs
Analysis variables
Calibration variables
Endogenous other variables

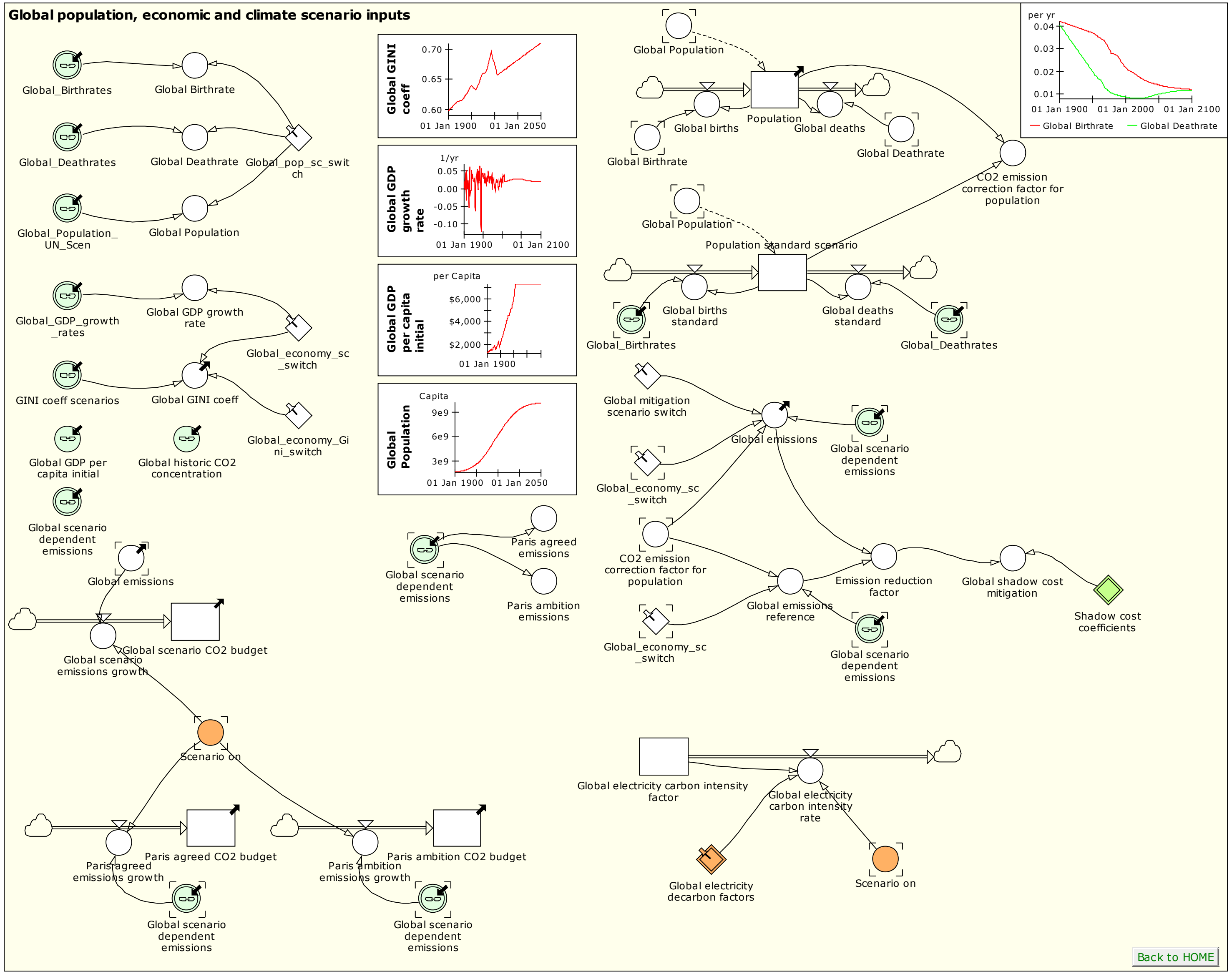
When you install the free Powersim Cockpit software and download the model from www.cstt.nl/userdata/documents/Peeters-PhD2017-GTTMdyn-model-software-data.zip (see instructions in Annex III) you will also be able to run the model and try policies and context scenarios and to look into GTTM^{dyn} and see the values for variables.

Global population, economic and climate scenario input

Description/task: Read main background data from excel files based on user contextual scenario input

Main inputs: Economic, pop and CO2 emission

Main outputs: Scenario specific GDP, pop, GINI



Global population, economic and climate scenario inputs
Global_Birthrates
Global Birthrate
Global_Deathrates
Global Deathrate
Global_pop_sc_switch
Global_Population_UN_Scen
Global Population
Global_GDP_growth_rates
Global GDP growth rate
Global_economy_sc_switch
GINI coeff scenarios
Global GINI coeff
Global_economy_Gini_switch
Global GDP per capita initial
Global historic CO2 concentration
Global scenario dependent emissions
Global emissions
Global scenario emissions growth
Global scenario CO2 budget
Scenario on
Paris agreed emissions growth
Paris agreed CO2 budget
Paris ambition emissions growth
Paris ambition CO2 budget
Global GINI coeff
0.70
0.65
0.60
01 Jan 1900
01 Jan 2050
Global GDP growth rate
1/yr
0.05
0.00
-0.05
-0.10
01 Jan 1900
01 Jan 2100
Global GDP per capita initial
per Capita
$6,000
$4,000
$2,000
01 Jan 1900
Global Population
Capita
9e9
6e9
3e9
01 Jan 1900
01 Jan 2050
Paris agreed emissions
Paris ambition emissions
Population
Global births
Global deaths
Global Birthrate
Global Deathrate
CO2 emission correction factor for population
Population standard scenario
Global births standard
Global deaths standard
Global mitigation scenario switch
Emission reduction factor
Global shadow cost mitigation
Shadow cost coefficients
Global emissions reference
Global electricity carbon intensity factor
Global electricity carbon intensity rate
Global electricity decarbon factors
per yr
0.04
0.03
0.02
0.01
01 Jan 1900
01 Jan 2000
01 Jan 2100
Global Birthrate
Global Deathrate
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
CO2 emission correction factor for population			Real	Population/Population standard scenario	
Emission reduction factor			Real	(Global emissions reference-Global emissions)/Global emissions reference	
GINI coeff scenarios	Global_GINI_scenarios		Real	{0,0,0,0,0,0,0,0}	The GINI coefficient has been scaled between 1900 and 1992 based on the value for 1992 given by (Korzeniewicz & Moran, 1996) and including a trend of increase from 1900 (but taking 0.7 as the value for 1900, an arbitrary guestimate). After 1992 we used the decline as found using data from Worldbank (see global gini data.xls).
Global Birthrate		yr^-1	Real	Global_Birthrates[INDEX(Global_pop_sc_switch)]	
Global births		Capita/yr	Real	Global Birthrate*Population	
Global births standard		Capita/yr	Real	Global_Birthrates[INDEX(3)]*Population standard scenario	
Global Deathrate		yr^-1	Real	Global_Deathrates[INDEX(Global_pop_sc_switch)]	
Global deaths		Capita/yr	Real	Global Deathrate*Population	
Global deaths standard		Capita/yr	Real	Global_Deathrates[INDEX(3)]*Population standard scenario	
Global electricity carbon intensity factor			Real	1	
Global electricity carbon intensity rate				IF(Scenario on, Global electricity carbon intensity factor* (Global electricity carbon intensity factor-Global electricity decarbon factors[Policy goal])/ Global electricity carbon intensity factor, 0)*Global electricity decarbon factors[Policy change factor]*1<<1/yr>>	
Global electricity decarbon factors	Policy_ecar_share_transition		Real	{.5,.1}	These two parameters define the exponential rate of decarbonisation of global electricity production. The policy goal factor is with respect to 2015 emission factor. The default reduction path is down to 50% (that is the per MJ

Name	Dimensions	Unit	Type	Definition	Documentation
					emission factor reduction) at a default pace factor of 0.1.
Global emissions		GtCO2	Real	CO2 emission correction factor for population* Global scenario dependent emissions[INDEX(Global_economy_sc_switch), INDEX(Global mitigation scenario switch)]	
Global emissions reference		GtCO2	Real	CO2 emission correction factor for population* Global scenario dependent emissions[INDEX(Global_economy_sc_switch), INDEX(1)]	Reduction is per unlimited mitigation reference because that is where global mitigation scenarios will get the shadow costs from.
Global GDP growth rate		1/yr	Real	Global_GDP_growth_rates[INDEX(Global_economy_sc_switch)]	
Global GDP per capita initial		USD/ Capita	Real	0	
Global GINI coeff			Real	IF(Global_economy_Gini_switch=0, GINI coeff scenarios[INDEX(Global_economy_sc_switch)], GINI coeff scenarios[INDEX(Global_economy_Gini_switch)])	
Global historic CO2 concentration		ppmv	Real	1<<ppmv>>	
Global mitigation scenario switch			Integer	1	Global mitigation scenario switch: 1 unlimited 2 moderate (3.5) 3 Paris Goal (2.0) 4 Paris Ambition (1.5)
Global Population		Capita	Real	Global_Population_UN_Scen[INDEX(Global_pop_sc_switch)]	
Global scenario CO2 budget		GtCO2	Real	0<<kg>>	
Global scenario dependent emissions	Global_GDP_scenarios,Global mitigation scenarios	GtCO2	Real	1<<GtCO2>>	
Global scenario emissions growth				IF(Scenario on,1,0)* Global emissions*1<<1/yr>>	
Global shadow cost mitigation		USD/ton	Real	(Shadow cost coefficients[f_a]+ Shadow cost coefficients[f_b]*Emission reduction factor+	f_a + f_b*B30 + f_c*f_d^B30

Name	Dimensions	Unit	Type	Definition	Documentation
				Shadow cost coefficients[f_c]* Shadow cost coefficients[f_d]^Emission reduction factor)*1<<USD/ton>>	
Global_Birthrates	Global_pop_scenarios	1/yr	Real	0	Based on UN data for 1950-2100 ((United Nations, 2011)) and the 1900 point from Limits to Growth: Meadows, D. H., Meadows, D. L. & Randers, J. (2004) Limits to Growth. The 30-year update. London: Earthscan Publications Ltd.
Global_Deathrates	Global_pop_scenarios	1/yr	Real	0	Ibid.
Global_economy_Gini_switch			Integer	0	Global United nations scenarios (4), plus a flat rate scenario for testing.
Global_economy_sc_switch			Integer	3	Global United nations scenarios (4), plus a flat rate scenario for testing. Default is Baseline (B1).
Global_GDP_growth_rates	Global_GDP_scenarios	1/yr	Real	0	
Global_pop_sc_switch			Integer	3	Global United nations scenarios (4), plus a flat rate scenario for testing.
Global_Population_UN_Scen	Global_pop_scenarios	Capita	Real	0	[see Global_Birthrates]
Paris agreed CO2 budget		GtCO2	Real	0<<kg>>	
Paris agreed emissions		GtCO2	Real	Global scenario dependent emissions[SRES_A1,Paris Agreed]* 1//'CO2 emission correction factor for population'	
Paris agreed emissions growth				IF(Scenario on,1,0)* Global scenario dependent emissions[SRES_A1,Paris Agreed]*1<<1/yr>>	
Paris ambition CO2 budget		GtCO2	Real	0<<kg>>	
Paris ambition emissions		GtCO2	Real	Global scenario dependent emissions[SRES_A1,Paris Ambition]* 1//'CO2 emission correction factor for population'	
Paris ambition emissions growth				IF(Scenario on,1,0)* Global scenario dependent emissions[SRES_A1,Paris Ambition]*1<<1/yr>>	
Population		Capita	Real	Global Population	

Name	Dimensions	Unit	Type	Definition	Documentation
Population standard scenario		Capita	Real	Global Population	
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	
Shadow cost coefficients	Shadow cost coeff		Real	{-0.00012058, 151.23, 0.00012058, 2690000}	

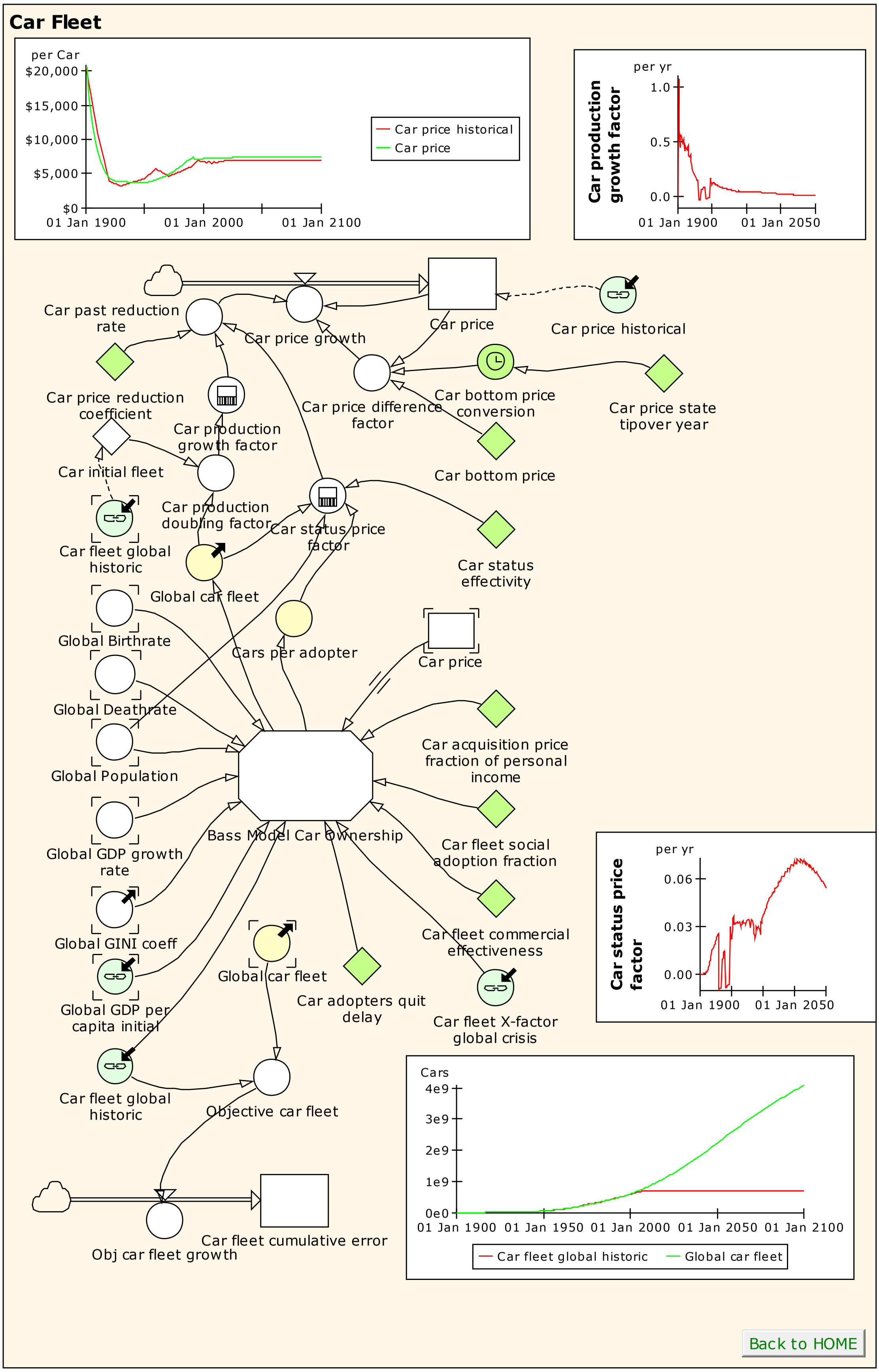
Car Fleet

Description/task: Estimate global car fleet size

Main inputs: Some constants

Main outputs: Car price

Car Fleet



per Car
$20,000
$15,000
$10,000
$5,000
$0
01 Jan 1900
01 Jan 2000
01 Jan 2100
Car price historical
Car price
Car production growth factor
per yr
1.0
0.5
0.0
01 Jan 1900
01 Jan 2050
Car past reduction rate
Car price growth
Car price
Car price historical
Car price reduction coefficient
Car price difference factor
Car bottom price conversion
Car price state tipover year
Car production growth factor
Car initial fleet
Car bottom price
Car production doubling factor
Car status price factor
Car fleet global historic
Car status effectivity
Global car fleet
Global Birthrate
Cars per adopter
Car price
Global Deathrate
Car acquisition price fraction of personal income
Global Population
Bass Model Car Ownership
Global GDP growth rate
Car fleet social adoption fraction
Global GINI coeff
Car fleet commercial effectiveness
Global car fleet
Car adopters quit delay
Global GDP per capita initial
Car fleet X-factor global crisis
Car fleet global historic
Objective car fleet
Obj car fleet growth
Car fleet cumulative error
Car status price factor
per yr
0.06
0.03
0.00
01 Jan 1900
01 Jan 2050
Cars
4e9
3e9
2e9
1e9
0e0
01 Jan 1900
01 Jan 1950
01 Jan 2000
01 Jan 2050
01 Jan 2100
Car fleet global historic
Global car fleet
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Car Ownership					
Car acquisition price fraction of personal income			Real	1.276918421	First based on a fit of data and the 0.81 from (Lescaroux, 2010, p. 13), but optimised to current higher value.
Car adopters quit delay		yr	Real	2	Own guestimate, assuming that an economic recession will not immediately cause people to get rid of their cars, but take some time (2 years we guessed).
Car bottom price		USD/ Car	Real	7000	based on Grubler and the time series for car cost up to 2010 using USA indexes.
Car bottom price conversion		1/yr	Real	IF(YEAR(TIME)>Car price state tipover year,1<<1/yr>>,0<<1/yr>>)	
Car fleet commercial effectiveness		1/yr	Real	0.006660203	Optimalisation for run from 1900.
Car fleet cumulative error			Real	0	
Car fleet global historic		Cars	Real	0	
Car fleet social adoption fraction		1/yr	Real	0.039991067	Optimalisation for run from 1900.
Car fleet X-factor global crisis			Real	0	This variable controls all other factors (X) like the effective anti-car use campaign in the USA during the WW-II, that caused people to stop driving (see (Gilbert & Perl, 2008, pp. 27-29). Also eventual production capacity problems could be part of this variable.
Car initial fleet		Car	Real	Car fleet global historic	
Car past reduction rate				(Car price reduction coefficient^(Car production growth factor*1<<yr>>)-1)/1<<yr>>+Car status price factor	Now we use the mathcad equation as given by (Grübler et al., 1999) (but made without unit), to calculate the growth factor over one time step. Furthermore we add the growth factor due to status.
Car price		USD/ Car	Real	Car price historical	

Name	Dimensions	Unit	Type	Definition	Documentation
Car price difference factor		USD/(yr*Car)	Real	Car bottom price conversion*(Car bottom price-Car price)	
Car price growth				Car past reduction rate*Car price+Car price difference factor	
Car price historical		USD/Car	Real	GRAPHCURVE(YEAR(),1900,10,{27196, 14375, 5148, 4177, 4954, 5634, 7479, 6119, 7090, 8367, 9430, 9076,10076}<<USD/Car>>)	Based on information given by (Grübler et al., 1999) for 1900-1980 and price indexes given by http://www.census.gov/compendia/statab/2012/tables/12s0737.xls for 1990-2010
Car price reduction coefficient			Real	0.84	Ibid.
Car price state tipover year			Real	1990	At some moment in time the car cost development has levelled off to about 7000-8000 (2000$); we assume that after 1990 the level of costs becomes a constant of about 7000 (1990$).
Car production doubling factor			Real	LOG(Global car fleet/ Car initial fleet,2)	
Car production growth factor		yr^-1	Real	DERIVN(Car production doubling factor,1)	We take the derivative with respect to time to calculate the annual change factor for cost.
Car status effectivity			Real	20	Guestimated to get the best fit.
Car status price factor				Car status effectivity*DERIVN(Global car fleet/Global Population/Cars per adopter)	The idea is based on (Grübler et al., 1999) and (Hopkins & Kornienko, 2006) and assumes that the change in car ownership is directly relating to its status and that status will increase the cost of cars (or better the willingness to pay extra fro status).
Cars per adopter		Cars/Capita	Real	Bass Model Car Ownership.Cars per adopter	
Global Birthrate				Global_Birthrates[INDEX(Global_pop_sc_switch)]	
Global car fleet		Car	Real	Bass Model Car Ownership.Car Adopters*Bass Model Car Ownership.Cars per adopter	
Global Deathrate				Global_Deathrates[INDEX(Global_pop_sc_switc	

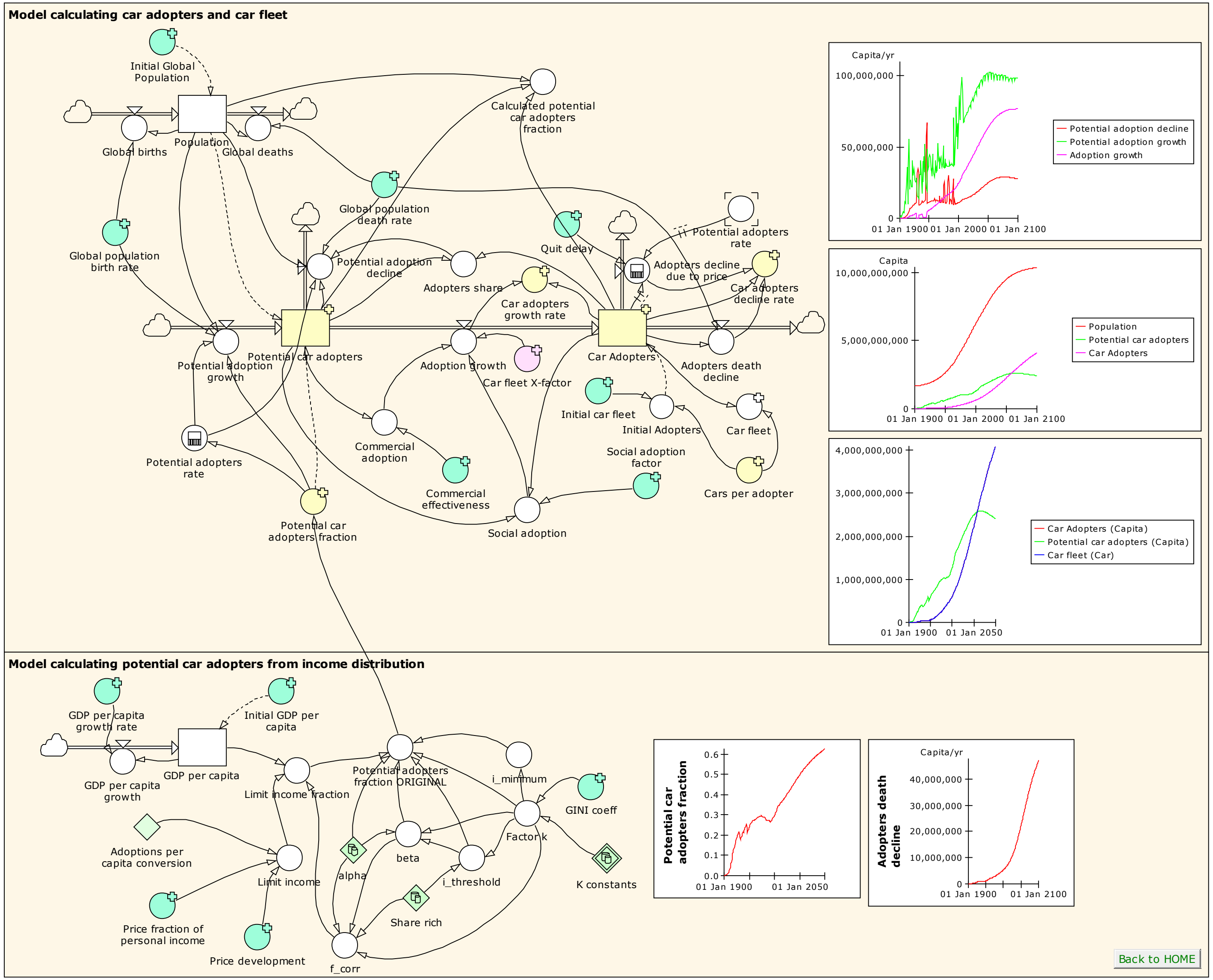
Name	Dimensions	Unit	Type	Definition	Documentation
				h)]	
Global GDP growth rate		1/yr		Global_GDP_growth_rates[INDEX(Global_economy_sc_switch)]	
Global GDP per capita initial		USD/Capita	Real	0	
Global GINI coeff				IF(Global_economy_Gini_switch=0, GINI coeff scenarios[INDEX(Global_economy_sc_switch)], GINI coeff scenarios[INDEX(Global_economy_Gini_switch)]])	
Global Population				Global_Population_UN_Scen[INDEX(Global_pop_sc_switch)]	
Obj car fleet growth		yr^-1	Real	Objective car fleet^2*1<<1/yr>>	
Objective car fleet			Real	(Global car fleet-Car fleet global historic)/Car fleet global historic	
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	

Bass Model Car Ownership

Description/task: Estimate adopters of car ownership

Main inputs: GDP, population, GINI

Main outputs: No. of cars



Model calculating car adopters and car fleet
Initial Global Population
Population
Global births
Global deaths
Calculated potential car adopters fraction
Global population death rate
Global population birth rate
Potential adoption decline
Adopters share
Quit delay
Potential adopters rate
Adopters decline due to price
Car adopters decline rate
Car adopters growth rate
Potential car adopters
Car Adopters
Potential adoption growth
Adoption growth
Car fleet X-factor
Adopters death decline
Initial car fleet
Initial Adopters
Car fleet
Potential adopters rate
Commercial adoption
Commercial effectiveness
Social adoption factor
Cars per adopter
Potential car adopters fraction
Social adoption
Capita/yr
100,000,000
50,000,000
0
01 Jan 1900
01 Jan 2000
01 Jan 2100
Potential adoption decline
Potential adoption growth
Adoption growth
Capita
10,000,000,000
5,000,000,000
Population
Potential car adopters
Car Adopters
4,000,000,000
3,000,000,000
2,000,000,000
1,000,000,000
01 Jan 2050
Car Adopters (Capita)
Potential car adopters (Capita)
Car fleet (Car)
Model calculating potential car adopters from income distribution
GDP per capita growth rate
Initial GDP per capita
GDP per capita
GDP per capita growth
Limit income fraction
Potential adopters fraction ORIGINAL
i_minimum
GINI coeff
Factor k
Adoptions per capita conversion
Limit income
alpha
beta
i_threshold
K constants
Share rich
Price fraction of personal income
Price development
f_corr
Potential car adopters fraction
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Adopters death decline
40,000,000
30,000,000
20,000,000
10,000,000
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Adopters death decline				//reduction from death rate// Global population death rate*Car Adopters	
Adopters decline due to price				//delayed quit rate from reduced potential share// MAX(DELAYINF(-Potential adopters rate*Car Adopters,Quit delay,3),0<<Capita/yr>>)	
Adopters share				Car Adopters/(Car Adopters+Potential car adopters)	
Adoption growth				(Commercial adoption +Social adoption) *Car fleet X-factor	
Adoptions per capita conversion		Car/ Capita	Real	1	
alpha			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R3C2")	The value of alpha is found to differ rather widely: • 2.0-2.3 for the UK wealth ((Drăgulescu & Yakovenko, 2001)) • 1.7 for the US wealth ((Drăgulescu & Yakovenko, 2001)) • Between 2.3 and 2.9 for the UK based on income ((Atkinson, 2005)) • Between 2.64 and 3.75 (which is an outlier above 3.14) for GDP/capita in Brazil ((Figueira et al., 2011)) • Rather variation of between 2.4 and 3.7 for Indian household and personal income and or rural and urban communities ((Ghosh et al., 2011)). • 2.34 and 2.63 for income for the USA ((Banerjee & Yakovenko, 2010)).
beta				(-(i_threshold^alpha))*(LN((i_threshold*(EXP(Factor k)-1))/Factor k)/Factor k-1)	
Calculated potential car adopters fraction				(Car Adopters+Potential car adopters)/Population	
Car Adopters		Capita		Initial Adopters	
Car adopters decline rate				(Adopters decline due to price+Adopters death decline)/Car Adopters	
Car adopters growth rate				Adoption growth/ Car Adopters	
Car fleet				Car Adopters*Cars per adopter	
Car fleet X-factor				Car fleet X-factor global crisis	

Name	Dimensions	Unit	Type	Definition	Documentation
Cars per adopter		Cars/ Capita	Real	1	This value is assumed to be one, though some people have more than one car.
Commercial adoption				Commercial effectiveness*Potential car adopters	
Commercial effectiveness		1/yr		Car fleet commercial effectiveness	
f_corr				(Share rich*alpha*EXP((LN(beta/Share rich)/alpha))/(alpha-1)+(EXP(Factor k)*EXP(-Share rich*Factor k)-1)/(EXP(Factor k)-1))	
Factor k				(K constants[a]+K constants[b]*GINI coeff+ K constants[c]*GINI coeff^2 +K constants[d]*GINI coeff^3)/ (K constants[e]+K constants[f]*GINI coeff+GINI coeff^2)	
GDP per capita		USD/ Capita		Initial GDP per capita	Because the GDP/capita is only available historically, we have constructed this model to use the growth figures from scenarios and reconstruct GDP/capita from that. Results equal during historical runs.
GDP per capita growth				GDP per capita*GDP per capita growth rate	
GDP per capita growth rate		1/yr		Global GDP growth rate	
GINI coeff				Global GINI coeff	The GINI coefficient has been scaled between 1900 and 1992 based on the value for 1992 given by (Korzeniewicz & Moran, 1996) and including a trend of increase from 1900 9but taking 0.7 as the value for 1900, an arbitrary guestimate). After 1992 we used the decline as found using data from Worldbank (see global gini data.xls).
Global births				Global population birth rate*Population	
Global deaths				Global population death rate*Population	
Global population birth rate		1/yr	Real	Global Birthrate	
Global population death rate		1/yr		Global Deathrate	
i_minimum				Factor k/(EXP(Factor k)-1)	

Name	Dimensions	Unit	Type	Definition	Documentation
i_threshold				(Factor k*(EXP(-Factor k*(Share rich-1)))/(EXP(Factor k)-1))	Based on mathcad file Chotikapanig Lorenz solution_NEW_13.xmcd
Initial Adopters		Capita		Initial car fleet/Cars per adopter	
Initial car fleet		Cars		Car fleet global historic	
Initial GDP per capita		USD/ Capita		Global GDP per capita initial	
Initial Global Population		Capita		Global Population	
K constants	k_constants		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R4C3:R9C3")	See the fitted curve as given in Mathcad - Chotikapanig Lorenz solution_13.xmcd and Findgraph solution given there.
Limit income				Price development/Price fraction of personal income*Adoptions per capita conversion	
Limit income fraction				Limit income/GDP per capita*f_corr	
Population		Capita		Initial Global Population	
Potential adopters fraction ORIGINAL				IF(Limit income fraction<i_minimum,1, IF(Limit income fraction<i_threshold, 1-LN(Limit income fraction*(EXP(Factor k)-1)/Factor k)/Factor k, beta/(Limit income fraction^alpha)))	
Potential adopters rate				DERIVN(Potential car adopters fraction)	
Potential adoption decline				Global population death rate*Potential car adopters +IF(Potential adopters rate<0<<1/yr>>, -Potential adopters rate*Population*(1-Adopters share), 0<<Capita/yr>>)	
Potential adoption growth				Global population birth rate*Population*Potential car adopters fraction +IF(Potential adopters rate>0<<1/yr>>,Potential adopters rate*Population,0<<Capita/yr>>)	
Potential car adopters				Population*Potential car adopters fraction	
Potential car				Potential adopters fraction ORIGINAL	

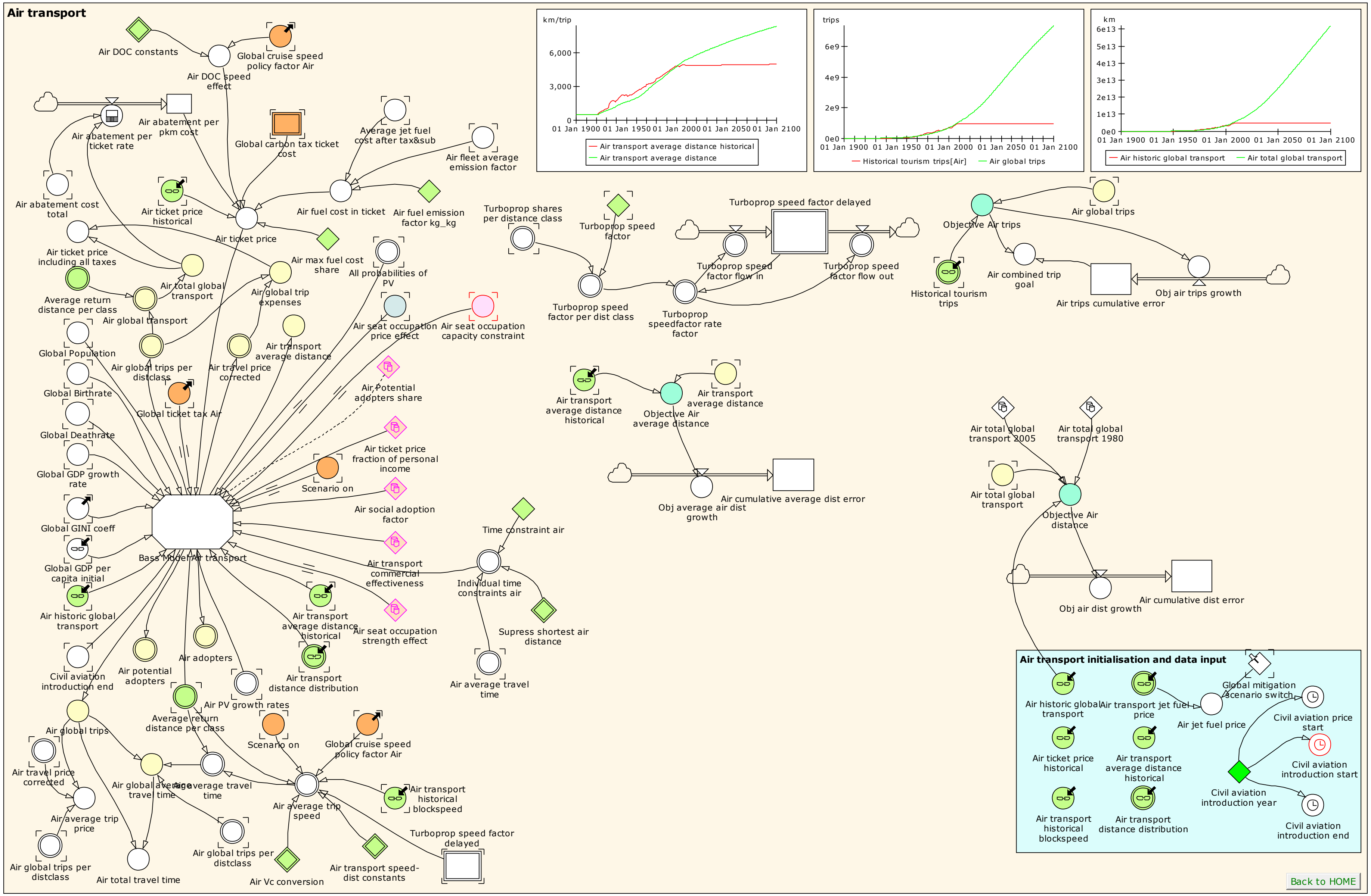
Name	Dimensions	Unit	Type	Definition	Documentation
adopters fraction					
Price development				REF(Car price)	Based on information given by (Grübler et al., 1999) for 1900-1980 and price indexes given by http://www.census.gov/compendia/statab/2010/tables/10s0721.xls for 1990-2010
Price fraction of personal income				Car acquisition price fraction of personal income	Base this on motorization rate, annual cost for the car, car lifetime; see (Schäfer, 1998)
Quit delay		yr		Car adopters quit delay	
Share rich			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R2C2")	
Social adoption				Social adoption factor*Potential car adopters* Car Adopters/(Car Adopters+Potential car adopters)	
Social adoption factor		1/yr		Car fleet social adoption fraction	

Air transport

Description/task: Prepare data for the Bass model

Main inputs: Fuel cost, fleet composition

Main outputs: Ticket price, travel time


Air transport
Air DOC constants
Global cruise speed policy factor Air
Air DOC speed effect
Air abatement per pkm cost
Air abatement per ticket rate
Global carbon tax ticket cost
Average jet fuel cost after tax&sub
Air fleet average emission factor
Air abatement cost total
Air ticket price historical
Air fuel cost in ticket
Air fuel emission factor kg_kg
Air ticket price
Air ticket price including all taxes
Air max fuel cost share
All probabilities of PV
Air total global transport
Average return distance per class
Air global trip expenses
Air global transport
Air seat occupation price effect
Air seat occupation capacity constraint
Global Population
Air global trips per distclass
Air travel price corrected
Air transport average distance
Global Birthrate
Global ticket tax Air
Air Potential adopters share
Global Deathrate
Global GDP growth rate
Air ticket price fraction of personal income
Scenario on
Air social adoption factor
Global GINI coeff
Global GDP per capita initial
Bass Model Air transport
Air transport commercial effectiveness
Air historic global transport
Air transport average distance historical
Air seat occupation strength effect
Air transport distance distribution
Civil aviation introduction end
Air potential adopters
Air adopters
Air PV growth rates
Air global trips
Average return distance per class
Scenario on
Global cruise speed policy factor Air
Air travel price corrected
Air global average travel time
Air average travel time
Air average trip price
Air average trip speed
Air transport historical blockspeed
Air global trips per distclass
Turbopropspeed factor delayed
Air global trips per distclass
Air total travel time
Air Vc conversion
Air transport speed-dist constants
Time constraint air
Individual time constraints air
Supress shortest air distance
Air average travel time
Turboprop shares per distance class
Turboprop speed factor
Turboprop speed factor delayed
Turboprop speed factor flow in
Turboprop speed factor flow out
Turboprop speed factor per dist class
Turboprop speedfactor rate factor
Air transport average distance historical
Objective Air average distance
Air transport average distance
Obj average air dist growth
Air cumulative average dist error
Objective Air trips
Air global trips
Historical tourism trips
Air combined trip goal
Air trips cumulative error
Obj air trips growth
Air total global transport 2005
Air total global transport 1980
Air total global transport
Objective Air distance
Obj air dist growth
Air cumulative dist error
km/trip
6,000
3,000
0
01 Jan 1900
01 Jan 1950
01 Jan 2000
01 Jan 2050
01 Jan 2100
Air transport average distance historical
Air transport average distance
trips
6e9
4e9
2e9
0e0
Historical tourism trips[Air]
Air global trips
km
6e13
5e13
4e13
3e13
2e13
1e13
0e0
Air historic global transport
Air total global transport
Air transport initialisation and data input
Air historic global transport
Air transport jet fuel price
Global mitigation scenario switch
Air jet fuel price
Civil aviation price start
Air ticket price historical
Air transport average distance historical
Civil aviation introduction start
Civil aviation introduction year
Air transport historical blockspeed
Air transport distance distribution
Civil aviation introduction end
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Name	Dimensions	Unit	Type	Definition	Documentation
Air abatement cost total				Air abatement average cost*Air global emissions*MU_Air*(1DIVZ0(1-MU_Air)-1)	
Air abatement per pkm cost		USD/km	Real	0<<USD/km>>	
Air abatement per ticket rate				DERIVN(Air abatement cost total/Air total global transport)	
Air adopters				Bass Model Air transport.Adopters	
Air average travel time				IF(Air average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Air average trip speed)	Return time in hours
Air average trip price				IF(Air global trips<.001<<trips>>,1<<USD/trip>>, ARRSUM(Air global trips per distclass*Air travel price corrected)/Air global trips)	
Air average trip speed				1/Turboprop speed factor delayed* FOR(i=DIM(Average return distance per class,1)| IF(Scenario on,1+Global cruise speed policy factor Air/(-0.15)* ((Air Vc conversion[Vc_b]-1)*Average return distance per class[i]*1<<trip/km>>/ (Air Vc conversion[Vc_c]+Average return distance per class[i]*1<<trip/km>>)) ,1)* MIN(Air transport historical blockspeed*Air transport speed-dist constants[Block_max_conversion]/Turboprop speed factor delayed[i], Air transport speed-dist constants[C_v]* (Average return distance per class[i]/1<<km/trip>>)^Air transport speed-dist constants[B1_exp]*1<<km/hr>>))	The formula is based on the MONS data for the Netherlands as cited in (Peeters & Landré, 2012, p. 49). The constants are valid for 2010 and are corrected for the average block speed historical and future as given in the global time series excel input file times a correction factor to reach the (Peeters & Landré, 2012, p. 49) given maximum of 800 km/hr at 2010.
Air combined trip goal				Air trips cumulative error*Objective Air trips	
Air cumulative average dist error			Real	0	
Air cumulative dist error			Real	0	
Air DOC constants	1..3		Real	{5.5272, -9.0915, 4.5643}	The relationship between DOC and deviation from the optimum DOC speed (as fraction of) for the whole fleet is based on B737-400, B747-400, B767-200 and B767-300ER data as

Name	Dimensions	Unit	Type	Definition	Documentation
					shown in file Overview speed restrictions.xlsx based on (Peeters, 2000).
Air DOC speed effect				Air DOC constants[1]+ Air DOC constants[2]*(1+Global cruise speed policy factor Air)+ Air DOC constants[3]*(1+Global cruise speed policy factor Air)^2	
Air fleet average emission factor				Air global emissions/Air total global transport	
Air fuel cost in ticket				Air fleet average emission factor* Average jet fuel cost after tax&sub/ Air fuel emission factor kg_kg	
Air fuel emission factor kg_kg			Real	3.157<<kg/kg>>	Based on ICAO calculator (ICAO, 2014)
Air global average travel time				IF(Air global trips<0.0001<<trips>>,1<<hr/trip>>, ARRSUM(Air average travel time*Air global trips per distclass)/Air global trips)	return travel time
Air global transport				Average return distance per class*Air global trips per distclass	
Air global trip expenses				ARRSUM(Air global trips per distclass*Air travel price corrected)	
Air global trips				ARRSUM(Bass Model Air transport.Trips)	
Air global trips per distclass				Bass Model Air transport.Adopters*Bass Model Air transport.Trips per adoption	
Air historic global transport		km	Real	0	
Air jet fuel price		USD/kg	Real	Air transport jet fuel price[INDEX(Global mitigation scenario switch)]	
Air max fuel cost share			Real	0.35	This value is based on just less then 35% of fuel cost in ticket cost as shown by for instance (Rutherford & Zeinali, 2009) showing max of just over 30% between . 1970 and 2009.
Air potential adopters				Bass Model Air transport.Potential adopters	This variable acts in initializing the nr of potential adopters at the start of aviation.
Air Potential adopters share			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input	This factor determines the share of real adopters in calculating the average income of the travelling population. The remainder is the average for all distance classes of potential

Name	Dimensions	Unit	Type	Definition	Documentation
				/Analyses variables input.xlsx", "Decision_values", "R7C3")	adopters
Air PV growth rates				All growth rates[Air]	
Air seat occupation capacity constraint				Transport capacity submodel.Air seat occupation capacity constraint	
Air seat occupation price effect				SLIDINGAVERAGE(Transport capacity submodel.Air seat occupation growth price effect ,9<<yr>>)	Keep the sliding average as is to avoid the oscillations when reducing airport capacity.
Air seat occupation strength effect			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R59C3")	
Air social adoption factor			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R9C3")	
Air ticket price				Air DOC speed effect* IF(Air fuel cost in ticket/Air ticket price historical>Air max fuel cost share, (Air fuel cost in ticket/Air ticket price historical-Air max fuel cost share+1)*Air ticket price historical, Air ticket price historical)+ Air abatement per pkm cost+ Global carbon tax ticket cost[Air]	Adds the basic historical and future ticket price plus abatement cost plus carbon tax. Additionally there is an assumption that when fuel cost to basic ticket price gets a higher share than 35% of ticket cost, it will bring up the price to maintain this share.
Air ticket price fraction of personal income			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R10C3")//	Based on a fit of data and the 0.81 from (Lescaroux, 2010, p. 13).
Air ticket price historical		USD/km	Real	GRAPHCURVE(YEAR(),1900,10,{27196, 14375, 5148, 4177, 4954, 5634, 7479, 6119, 7090, 8367, 9430, 9076,10076}<<USD/km>>)	Based on information given by (Grübler et al., 1999) for 1900-1980 and price indexes given by http://www.census.gov/compendia/statab/20

Name	Dimensions	Unit	Type	Definition	Documentation
					12/tables/12s0737.xls for 1990-2010
Air ticket price including all taxes				Air global trip expenses/Air total global transport	
Air total global transport				ARRSUM(Air global transport)	
Air total global transport 1980		km	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Global timeseries data.xlsm", "Air transport pkm", "R82C2")<<km>>	
Air total global transport 2005		km	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Global timeseries data.xlsm", "Air transport pkm", "R107C2")<<km>>	
Air total travel time		yr		Air global average travel time*Air global trips	
Air transport average distance				Bass Model Air transport.Overall average distance	
Air transport average distance historical		km/trip	Real	0	
Air transport commercial effectiveness			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R11C3")	
Air transport distance distribution	Dist_class		Real	0	Fraction of adopters per distance class, set to follow a power law with -2.3 coefficient and delivering the average trip distance. Fine tuned by setting lowest class to 0, adjusting second class to between 0 and 1.0 and leaving classes with more than 24 hours our of the equation (zero trips, though there of course were some).

Name	Dimensions	Unit	Type	Definition	Documentation
Air transport historical blockspeed		km/hr	Real	0	
Air transport jet fuel price	Global mitigation scenarios	USD/kg	Real	1<<USD/kg>>	
Air transport speed-dist constants	Speed_dist_constants		Real	{1.303,10.484,0.447}	The first factor gives the block versus maximum speed ratio (see Aviation data.xls), the two others are taken from the underlying data based on MONS (see (Peeters & Landré, 2012)). The idea is that the air transport historic block speed is related with the first constant to historic maximum speed and that the maximum speed and first constant of the equation from (Peeters & Landré, 2012) are related in a constant ratio.
Air travel price corrected				Bass Model Air transport.Air travel price corrected	
Air trips cumulative error			Real	0	
Air Vc conversion	Air Vcruise conversion		Real	{0.85,3991}	These factors are used in an equation to translate a change in cruise speed to a change in trip speed based on analysis in Speed graphes MON.xlsx.
All probabilities of PV				Individual time constraints all* EXP(All PV constrained) /ARRSUM(Individual time constraints all*EXP(All PV constrained))	
Average jet fuel cost after tax&sub				ARRSUM(Biofuel shares Plus*Biofuel_plus prices after tax)	
Average return distance per class	Dist_class	km/trip	Real	{75,112.5,150,200,262.5,350,462.5,600,787.5,1037.5,1362.5,1787.5,2337.5,3075,4050,5312.5,6975,9175,12062.5,15850}*2<<km/trip>>	These are now the metric averages, but this should be updated with GTTD measured averages for the whole database.
Bass Model Air transport					
Civil aviation introduction end			Logical	IF(YEAR(TIME)>Civil aviation introduction year+1,TRUE,FALSE)	This variable triggers the introduction of civil air transport at the year set in the linked

Name	Dimensions	Unit	Type	Definition	Documentation
					constant. This is necessary because of the fact that before a certain year civil air transport has not been on offer.
Civil aviation introduction start			Logical	IF(YEAR(TIME)>Civil aviation introduction year-1,TRUE,FALSE) //For fleet reproduction set at -1 year.	This variable triggers the introduction of civil air transport at the year set in the linked constant. This is necessary because of the fact that before a certain year it civil air transport has not been on offer.
Civil aviation introduction year			Real	1920	This year defines the moment that serious supply of air transport is introduced into the market; before this date the model keeps air transport and adopters at zero. It is connected to two events: 'Civil aviation start' triggering civil aviation supply and 'Civil aviation cost start', which runs one year ahead and avoids the cost trigger to heavily and inadvertently affect air transport volume.
Civil aviation price start			Logical	IF(YEAR(TIME)>Civil aviation introduction year-1,TRUE,FALSE)	This year triggers the cost of air transport calculation, 1 year ahead of the start of air transport in the model, because otherwise the triggering itself would strongly affect the transport volume in the wrong way.
Global Birthrate				Global_Birthrates[INDEX(Global_pop_sc_switch)]	
Global carbon tax ticket cost	Modes	USD/km	Real	0<<USD/km>>	
Global cruise speed policy factor Air				IF(Scenario on,1,0)* GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy cruise speed factor Air)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Global Deathrate				Global_Deathrates[INDEX(Global_pop_sc_switch)]	
Global GDP growth rate		1/yr		Global_GDP_growth_rates[INDEX(Global_economy_sc_switch)]	
Global GDP per capita initial		USD/Capita	Real	0	
Global GINI coeff				IF(Global_economy_Gini_switch=0, GINI coeff scenarios[INDEX(Global_economy_sc_switch)], GINI	

Name	Dimensions	Unit	Type	Definition	Documentation
				coeff scenarios[INDEX(Global_economy_Gini_switch)])	
Global mitigation scenario switch			Integer	1	Global mitigation scenario switch: 1 unlimited 2 moderate (3.5) 3 Paris Goal (2.0) 4 Paris Ambition (1.5)
Global Population				Global_Population_UN_Scen[INDEX(Global_pop_sc_switch)]	
Global ticket tax Air				IF(Scenario on, GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global ticket tax Air),0)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Historical tourism trips	Transport modes	trip	Real	0<<trips>>	
Individual time constraints air	Dist_class			FOR(i=DIM(Air average travel time)| Supress shortest air distance[i]* MAX(0,MIN(1,1.25*Time constraint air/(1.25*Time constraint air-Time constraint air) +Air average travel time[i]/(Time constraint air-1.25*Time constraint air))))	
Obj air dist growth				Objective Air distance*1<<1/yr>>	
Obj air trips growth				Objective Air trips*1<<1/yr>>	
Obj average air dist growth				Objective Air average distance*1<<1/yr>>	
Objective Air average distance				SQRT(((Air transport average distance-Air transport average distance historical)/ Air transport average distance historical)^2)	The error is relative to the final 2005 figure as to give emphasis tot the latest years of the cumulative error (the first years errors are much smaller as total mobility is then much smaller). This helps to find data that are close to the 2005 known situation and avoids an emphasis on fit to early data that are not too reliable anyway.
Objective Air distance				SQRT(IF(YEAR(STOPTIME)=1980, (IF(Air total global transport 1980=0<<km>>,0, (Air total global transport-Air historic global transport)/ Air total global transport 1980))^2, (IF(Air total global transport 2005=0<<km>>,0, (Air total global transport-Air historic global transport)/ Air total	Ibid.

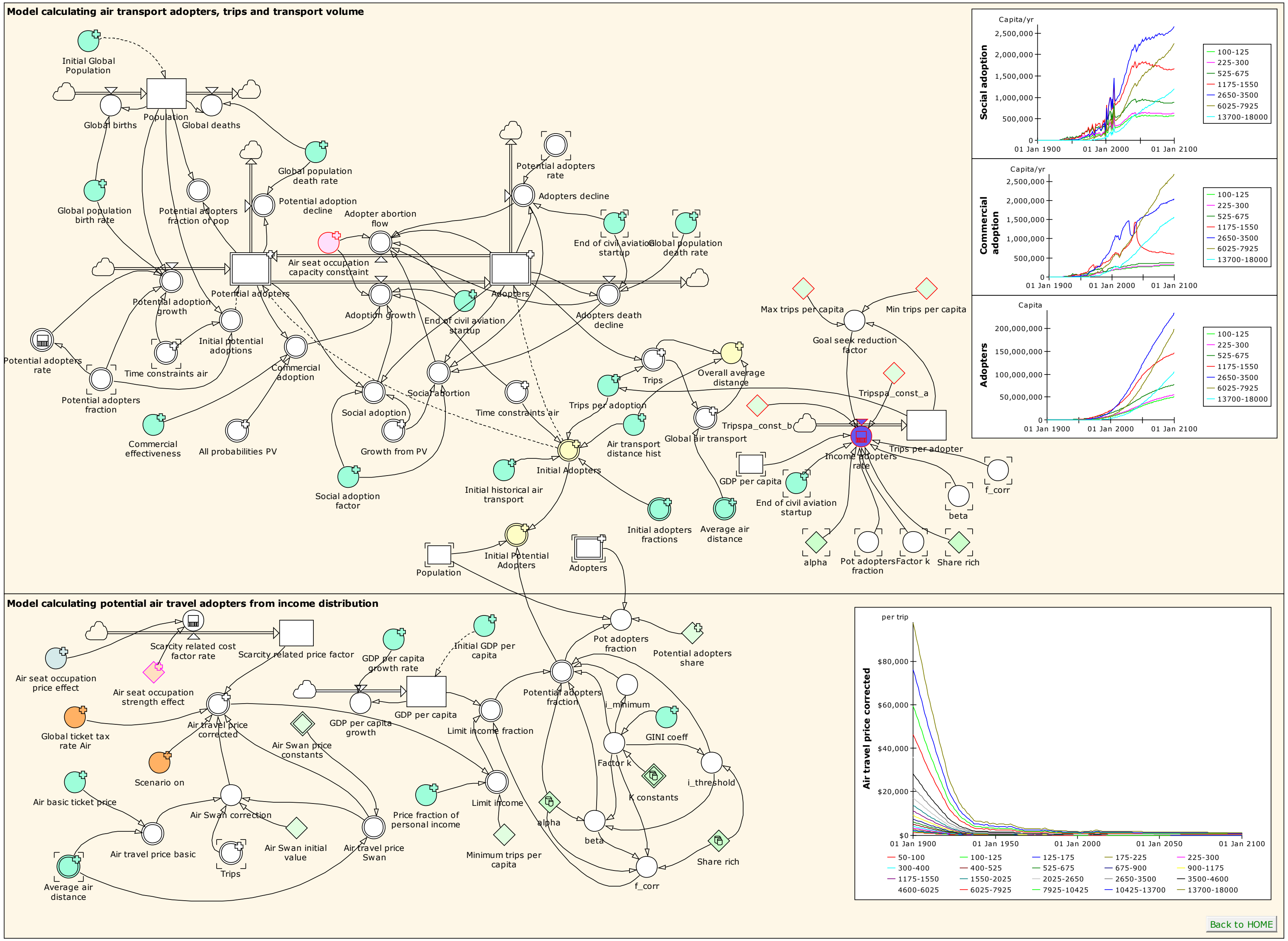
Name	Dimensions	Unit	Type	Definition	Documentation
				global transport 2005))^2))	
Objective Air trips				IF(Air global trips=0<<trips>>, 0, SQRT(((Air global trips-Historical tourism trips[Air])/Air global trips)^2))	Ibid.
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	
Supress shortest air distance	Dist_class		Real	{0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1}	
Time constraint air		hr/trip	Real	52<<hr/trip>>	The assumption is based on data from CVO file ravel time return frequency 2010.spv and assumes that growth is reduced from the beginning of the last bin before the first zero bin linearly until 25% of the initial travel time.
Turboprop shares per distance class				Turboprop global capacity per dist classDIVZ0 Air global transport capacity	
Turboprop speed factor			Real	1-0.5*(1-300/500)	Based on the cruise speed difference of 300 mph for turboprops and 500 for regional jets given in (ATR, 2014). Then taken half of the disadvantage because LTO, taxying, etc. is the same.
Turboprop speed factor delayed	Dist_class		Real	0	
Turboprop speed factor flow in				FOR(i=DIM(Turboprop speedfactor rate factor)| IF(Turboprop speedfactor rate factor[i]>0,Turboprop speedfactor rate factor[i]*1<<1/yr>>,0<<1/yr>>))	
Turboprop speed factor flow out				FOR(i=DIM(Turboprop speedfactor rate factor)| IF(Turboprop speedfactor rate factor[i]<0,-Turboprop speedfactor rate factor[i]*1<<1/yr>>,0<<1/yr>>))	
Turboprop speed factor per dist class				1/(1+(Turboprop speed factor-1)*Turboprop shares per distance class)	
Turboprop speedfactor rate factor				Turboprop speed factor per dist class-Turboprop speed factor delayed	

Bass Model Air transport

Description/task: Calculate the number of adopters per distance class

Main inputs: GDP, pop., GINI, ticket price, PV rates

Main outputs: Air trips, travel time per distance class


Model calculating air transport adopters, trips and transport volume
Initial Global Population
Population
Global births
Global deaths
Global population death rate
Global population birth rate
Potential adopters fraction of pop
Potential adoption decline
Adopter abortion flow
Potential adopters rate
Adopters decline
End of civil aviation startup
Global population death rate
Air seat occupation capacity constraint
Potential adopters
Adopters
Potential adoption growth
Adoption growth
End of civil aviation startup
Adopters death decline
Initial potential adoptions
Commercial adoption
Social abortion
Potential adopters rate
Time constraints air
Potential adopters fraction
Social adoption
Time constraints air
Commercial effectiveness
All probabilities PV
Growth from PV
Social adoption factor
Trips
Overall average distance
Trips per adoption
Air transport distance hist
Global air transport
Initial Adopters
Initial historical air transport
Initial adopters fractions
Average air distance
Initial Potential Adopters
Population
Adopters
Max trips per capita
Min trips per capita
Goal seek reduction factor
Tripspa_const_a
Tripspa_const_b
Income adopters rate
Trips per adopter
GDP per capita
End of civil aviation startup
f_corr
beta
alpha
Pot adopters fraction
Factor k
Share rich
Social adoption
Commercial adoption
Adopters
Capita/yr
Capita
01 Jan 1900
01 Jan 2000
01 Jan 2100
100-125
225-300
525-675
1175-1550
2650-3500
6025-7925
13700-18000
Model calculating potential air travel adopters from income distribution
Scarcity related cost factor rate
Scarcity related price factor
Air seat occupation price effect
Air seat occupation strength effect
GDP per capita growth rate
Initial GDP per capita
Pot adopters fraction
Potential adopters share
Global ticket tax rate Air
Air travel price corrected
GDP per capita growth
GDP per capita
Limit income fraction
Potential adopters fraction
i_minimum
GINI coeff
Air Swan price constants
Scenario on
Factor k
i_threshold
K constants
Air basic ticket price
Air Swan correction
Limit income
Price fraction of personal income
Air Swan initial value
alpha
Air travel price basic
Air travel price Swan
Minimum trips per capita
beta
Share rich
Trips
Average air distance
f_corr
Air travel price corrected
per trip
$80,000
$60,000
$40,000
$20,000
$0
01 Jan 1900
01 Jan 1950
01 Jan 2000
01 Jan 2050
01 Jan 2100
50-100
100-125
125-175
175-225
225-300
300-400
400-525
525-675
675-900
900-1175
1175-1550
1550-2025
2025-2650
2650-3500
3500-4600
4600-6025
6025-7925
7925-10425
10425-13700
13700-18000
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Air transport.Adopter abortion flow				IF(End of civil aviation startup,1,0)* MIN(Adopters*1<<1/yr>>-Adopters death decline-Adopters decline, Social abortion+ Air seat occupation capacity constraint*Adopters)	
Bass Model Air transport.Adopters		Capita		Initial Adopters	
Bass Model Air transport.Adopters death decline				//reduction from death rate// IF(End of civil aviation startup,1,0)* Global population death rate*Adopters	
Bass Model Air transport.Adopters decline				//delayed quit rate from reduced potential share// IF(End of civil aviation startup,1,0)* FOR(i=DIM(Adopters,1)| MAX(-Potential adopters rate[i]*Adopters[i],0<<Capita/yr>>))	
Bass Model Air transport.Adoption growth				IF(Air seat occupation capacity constraint>0<<1/yr>>,0,1)* Time constraints air*IF(End of civil aviation startup,1,0)* (Commercial adoption+Social adoption)	
Bass Model Air transport.Air basic ticket price				Parent~Air ticket price	
Bass Model Air transport.Air seat occupation capacity constraint				REF(Parent~Air seat occupation capacity constraint)	
Bass Model Air transport.Air seat occupation price effect				REF(Parent~Air seat occupation price effect)	This standard function creates a multiplicator that sigmoidally reduces from 1 to zero (and is to be used to multiply growth with) for any ratio of a value/goal between a 'reduced growth limit ratio' (giving 1.0) and ratio 1 (giving 0.0). This function is inspired by section 8.5 in (Sterman, 2000). The workout for this purpose is in files Goal seeking growth form.xls and Goal seeking growth function.fgr. The

Name	Dimensions	Unit	Type	Definition	Documentation
					latter function was for a reduction between 0.75 and 1.0, but has been simplified to give a reduction functin for the whole 0-1 range and than using a condition to scale the x between the 'reduced growth limit ratio' and the ratio 1.0.
Bass Model Air transport.Air seat occupation strength effect			Real	REF(Parent~Air seat occupation strength effect)	
Bass Model Air transport.Air Swan correction				IF(ARRSUM(Trips)=0<<trips>>,Air Swan initial value, ARRAVERAGE(Air travel price basic*Trips) /ARRAVERAGE(Air travel price Swan*Trips))	Correction to the average ticket cost calculated with Grubler method. used delayed trips to be able to average weighted. The start value is the one of this factor calculated at aviation start when running from 1900.
Bass Model Air transport.Air Swan initial value			Real	23.75	
Bass Model Air transport.Air Swan price constants	Swan_cost_constants		Real	{0.348186946,-0.25,0.090500851,-0.088}	these constants are based on (Swan & Adler, 2006, p. 113), where the seat capacity is standardised to 130 for short haule and 290 for long haul, which results in a continuous function from SH to LH at 4000 km stage length.
Bass Model Air transport.Air transport distance hist		km/trip	Real	Parent~Air transport average distance historical	
Bass Model Air transport.Air travel price basic				Air basic ticket price*Average air distance	
Bass Model Air transport.Air travel price corrected				IF(Scenario on, (1+Global ticket tax rate Air) ,1)* Scarcity related price factor* Air travel price Swan*Air Swan correction	

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Air transport.Air travel price Swan	Dist_class	USD/trip	Real	FOR(i=DIM(Average air distance,1)| Average air distance[i]*IF(Average air distance[i]<4000 <<km/trip>>, Air Swan price constants[C_SH]*(Average air distance[i]/1<<km/trip>>)^Air Swan price constants[E_SH], Air Swan price constants[C_LH]*(Average air distance[i]/1<<km/trip>>)^Air Swan price constants[E_LH]))* 1<<USD/km>>	Here the (Swan & Adler, 2006, p. 113) equations are applied; due to the power function the distance first has been made unitless and the whole function been made to have the right units (USD/trip).
Bass Model Air transport.All probabilities PV				Parent~All probabilities of PV	
Bass Model Air transport.alpha			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R3C2")	The value of alpha is found to differ rather widely: • 2.0-2.3 for the UK wealth ((Drăgulescu & Yakovenko, 2001)) • 1.7 for the US wealth ((Drăgulescu & Yakovenko, 2001)) • Between 2.3 and 2.9 for the UK based on income ((Atkinson, 2005)) • Between 2.64 and 3.75 (which is an outlier above 3.14) for GDP/capita in Brazil ((Figueira et al., 2011)) • Rather variation of between 2.4 and 3.7 for Indian household and personal income and or rural and urban communities ((Ghosh et al., 2011)). • 2.34 and 2.63 for income for the USA ((Banerjee & Yakovenko, 2010)).
Bass Model Air transport.Average air distance	Dist_class	km/trip	Real	Parent~Average return distance per class	
Bass Model Air transport.beta				(-(i_threshold^alpha))*(LN((i_threshold*(EXP(Factor k)-1))/Factor k)/Factor k-1)	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Air				Commercial effectiveness* Potential adopters* All	

Name	Dimensions	Unit	Type	Definition	Documentation
transport.Commercial adoption				probabilities PV[Air,*]/1<<yr>>	
Bass Model Air transport.Commercial effectiveness			Real	Parent~Air transport commercial effectiveness	
Bass Model Air transport.End of civil aviation startup			Logical	Parent~Civil aviation introduction end	
Bass Model Air transport.f_corr				(Share rich*alpha*EXP((LN(beta/Share rich)/alpha))/(alpha-1)+(EXP(Factor k)*EXP(-Share rich*Factor k)-1)/(EXP(Factor k)-1))	
Bass Model Air transport.Factor k				(K constants[a]+K constants[b]*GINI coeff+ K constants[c]*GINI coeff^2 +K constants[d]*GINI coeff^3)/ (K constants[e]+K constants[f]*GINI coeff+GINI coeff^2)	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Air transport.GDP per capita		USD/ Capita	Real	Initial GDP per capita	Because the GDP/capita is only avialable historically, we have constructed this model to use the growth figures from scenarios and reconstruct GDP/capita from that. Results equal during historical runs.
Bass Model Air transport.GDP per capita growth				GDP per capita*GDP per capita growth rate	
Bass Model Air transport.GDP per capita growth rate		1/yr		Parent~Global GDP growth rate	
Bass Model Air transport.GINI coeff				Parent~Global GINI coeff	The GINI coefficient has been scaled between 1900 and 1992 based on the value for 1992 given by (Korzeniewicz & Moran, 1996) and including a trend of increase from 1900 (but taking 0.7 as the value for 1900, an arbitrary guestimate). After 1992 we used

Name	Dimensions	Unit	Type	Definition	Documentation
					the decline as found using data from Worldbank (see global gini data.xls).
Bass Model Air transport.Global air transport				Average air distance*Trips	
Bass Model Air transport.Global births				Global population birth rate*Population	
Bass Model Air transport.Global deaths				Global population death rate*Population	
Bass Model Air transport.Global population birth rate		1/yr	Real	Parent~Global Birthrate	
Bass Model Air transport.Global population death rate		1/yr		Parent~Global Deathrate	
Bass Model Air transport.Global ticket tax rate Air				REF(Parent~Global ticket tax Air)	
Bass Model Air transport.Goal seek reduction factor			Real	(1-TANH(Trips per adopter/(Max trips per capita-Min trips per capita)*6- (Min trips per capita+Max trips per capita)*3/(Max trips per capita-Min trips per capita)))/2	X-min and x-max prioivide the range over x you want the S-shape reduction from 1 to 0. Replace the X-value variable with your real X. See also S-curve mechanism.xlsx.
Bass Model Air transport.Growth from PV				Parent~Air PV growth rates	
Bass Model Air transport.i_minimum				Factor k/(EXP(Factor k)-1)	see Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd
Bass Model Air transport.i_threshold				(Factor k*(EXP(-Factor k*(Share rich-1)))/ (EXP(Factor k)-1))	Based on mathcad file Chotikapanig Lorenz solution_NEW_13.xmcd
Bass Model Air transport.Income adopters rate				IF(End of civil aviation startup,1,0)* Goal seek reduction factor* DERIVN(Tripspa_const_a*GDP per capita*f_corr* IF(Pot adopters fraction<Share rich,(beta/Pot adopters fraction)^(1/alpha), (Factor k*EXP(-Factor k*(Pot adopters fraction-1))/(EXP(Factor k)-1)))/1000 +Tripspa_const_b,1)	As the trip per capita depends on adopters it was necessary to insert a level by taking the first derivative and integrating again. The calculation is based on the equation 7 in sup. file 2 of (Peeters, 2013) by

Name	Dimensions	Unit	Type	Definition	Documentation
					solving it for population share and average income.
Bass Model Air transport.Initial Adopters				Time constraints air* Initial historical air transport/Air transport distance hist *Initial adopters fractions/Trips per adoption	This variable is required for the initialisation of adopters and potential adopters after factual introduction of air transport suplly (in a somewhat substantial way). This is necessary due to the match of historical and calculated data. for a new transport mode like space toursm it should not be necessary. also for car and rai it is not necessary as these existed aready in 1900.
Bass Model Air transport.Initial adopters fractions	Dist_class		Real	Parent~Air transport distance distribution	
Bass Model Air transport.Initial GDP per capita		USD/ Capita	Real	Parent~Global GDP per capita initial	
Bass Model Air transport.Initial Global Population		Capita		Parent~Global Population	
Bass Model Air transport.Initial historical air transport		km	Real	Parent~Air historic global transport	
Bass Model Air transport.Initial Potential Adopters				Population*Potential adopters fraction-Initial Adopters	This auxiliary just helps to set the potential adopters afte start of civil aviation year.
Bass Model Air transport.Initial potential adoptions				Time constraints air*Potential adopters fraction*Population	
Bass Model Air transport.K constants	k_constants		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R4C3:R9C3")	See the fitted curve as given in Mathcad - Chotikapanig Lorenz solution_13.xmcd and Findgraph solution given there.

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Air transport.Limit income				Air travel price corrected/Price fraction of personal income*Minimum trips per capita	
Bass Model Air transport.Limit income fraction				Limit income/GDP per capita *f_corr	
Bass Model Air transport.Max trips per capita		trips/ Capita	Real	3	As there is a maximum to global nr of trips and as most travellers are one-mode only we have taken a slightly lower max per mode.
Bass Model Air transport.Min trips per capita		trips/ Capita	Real	2.5	Bit arbitrary taken somewhat lower tha max.
Bass Model Air transport.Minimum trips per capita		trip/ Capita	Real	1<<trips/Capita>>	
Bass Model Air transport.Overall average distance				IF(ARRSUM(Trips)<.0001<<trips>>,Air transport distance hist, ARRSUM(Global air transport)/ARRSUM(Trips))	1-way distance (actually per flight....)
Bass Model Air transport.Population		Capita		Initial Global Population	
Bass Model Air transport.Pot adopters fraction				Potential adopters share*ARRAVERAGE(Potential adopters fraction) +(1-Potential adopters share)*ARRSUM(Adopters)/Population	The adopters fraction is used to calculate the average income of the partly potential adopters population.
Bass Model Air transport.Potential adopters		Capita		Initial potential adoptions-Initial Adopters	
Bass Model Air transport.Potential adopters fraction				IF(Limit income fraction<i_minimum,1, IF(Limit income fraction<i_threshold, 1-LN(Limit income fraction*(EXP(Factor k)-1)/Factor k)/Factor k, beta/(Limit income fraction^alpha)))	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Air transport.Potential adopters fraction of pop				Potential adopters/Population	
Bass Model Air transport.Potential				DERIVN(Potential adopters fraction)	

Name	Dimensions	Unit	Type	Definition	Documentation
adopters rate					
Bass Model Air transport.Potential adopters share			Real	Parent~Air Potential adopters share	This factor determines the share of real adopters in calculating the average income of the travelling population. The remainder is the average for all dist classes of potential adopters
Bass Model Air transport.Potential adoption decline				(Global population death rate*Potential adopters)	
Bass Model Air transport.Potential adoption growth				Time constraints air* (Global population birth rate*Population*Potential adopters fraction//follow population growth// +Potential adopters rate*Population)//follow potential fraction growth and decline//	
Bass Model Air transport.Price fraction of personal income			Real	Parent~Air ticket price fraction of personal income	
Bass Model Air transport.Scarcity related cost factor rate				Air seat occupation strength effect* DERIVN(MAX(1,1DIVZ1(Air seat occupation price effect)))	
Bass Model Air transport.Scarcity related price factor			Real	1	
Bass Model Air transport.Scenario on				REF(Parent~Scenario on)	
Bass Model Air transport.Share rich			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R2C2")	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Air transport.Social abortion				FOR(i=DIM(Growth from PV)| MIN(Adopters[i]*1<<1/yr>>-Adopters death decline[i]-Adopters decline[i], IF(Growth from PV[i]<0<<1/yr>>, -Growth from PV[i],0<<1/yr>>)*Adopters[i]*Social adoption factor))	
Bass Model Air				FOR(i=DIM(Growth from PV)| IF(Growth from	

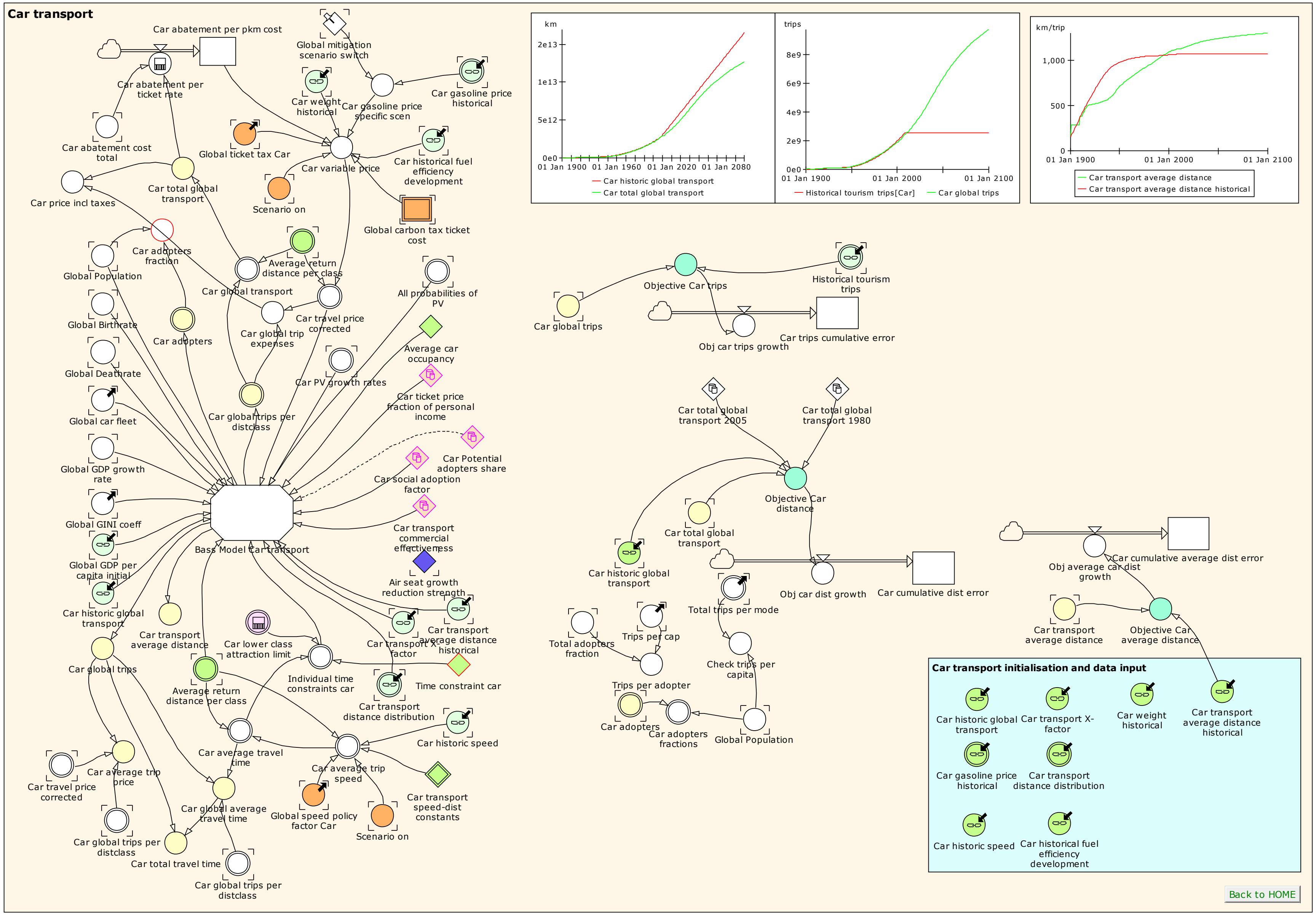
Name	Dimensions	Unit	Type	Definition	Documentation
transport.Social adoption				PV[i]<0<<1/yr>>,0<<1/yr>>,Growth from PV[i])* Potential adopters[i]*Adopters[i]*Social adoption factor DIVZ0(Adopters[i]+Potential adopters[i]))	
Bass Model Air transport.Social adoption factor			Real	Parent~Air social adoption factor	
Bass Model Air transport.Time constraints air	Dist_class			Parent~Individual time constraints air	
Bass Model Air transport.Trips				Adopters*Trips per adoption	
Bass Model Air transport.Trips per adopter		trips/ Capita	Real	2.75	
Bass Model Air transport.Trips per adoption		trips/ Capita	Real	Trips per adopter	
Bass Model Air transport.Tripspa_const_a		trips/USD	Real	0.0902	see CVO trips per capita per mode.xlsx
Bass Model Air transport.Tripspa_const_b		trips/ Capita	Real	1.809	Ibid.

Car transport

Description/task: Prepare data for the Bass model

Main inputs: Fuel cost, fleet composition

Main outputs: Ticket price, travel time



Car transport
Car abatement per pkm cost
Global mitigation scenario switch
Car abatement per ticket rate
Car weight historical
Car gasoline price specific scen
Car gasoline price historical
Car abatement cost total
Global ticket tax Car
Car historical fuel efficiency development
Car variable price
Car total global transport
Scenario on
Car price incl taxes
Global carbon tax ticket cost
Car adopters fraction
Average return distance per class
Global Population
Car global transport
All probabilities of PV
Global Birthrate
Car global trip expenses
Car travel price corrected
Car adopters
Average car occupancy
Global Deathrate
Car PV growth rates
Car ticket price fraction of personal income
Global car fleet
Car global trips per distclass
Car Potential adopters share
Global GDP growth rate
Car social adoption factor
Global GINI coeff
Car transport commercial effectiveness
Bass Model Car transport
Global GDP per capita initial
Air seat growth reduction strength
Car historic global transport
Car transport average distance
Car lower class attraction limit
Car transport X-factor
Car transport average distance historical
Car global trips
Individual time constraints car
Time constraint car
Average return distance per class
Car transport distance distribution
Car historic speed
Car average travel time
Car average trip speed
Car travel price corrected
Car average trip price
Car transport speed-dist constants
Global speed policy factor Car
Car global average travel time
Scenario on
Car global trips per distclass
Car total travel time
Car global trips per distclass
km
2e13
1e13
5e12
0e0
01 Jan 1900
01 Jan 1960
01 Jan 2020
01 Jan 2080
Car historic global transport
Car total global transport
trips
8e9
6e9
4e9
2e9
0e0
01 Jan 1900
01 Jan 2000
01 Jan 2100
Historical tourism trips[Car]
Car global trips
km/trip
1,000
500
0
01 Jan 1900
01 Jan 2000
01 Jan 2100
Car transport average distance
Car transport average distance historical
Objective Car trips
Historical tourism trips
Car global trips
Car trips cumulative error
Obj car trips growth
Car total global transport 2005
Car total global transport 1980
Objective Car distance
Car total global transport
Car historic global transport
Car cumulative dist error
Obj car dist growth
Total trips per mode
Obj average car dist growth
Car cumulative average dist error
Total adopters fraction
Trips per cap
Check trips per capita
Car transport average distance
Objective Car average distance
Trips per adopter
Car adopters
Car adopters fractions
Global Population
Car transport initialisation and data input
Car historic global transport
Car transport X-factor
Car weight historical
Car transport average distance historical
Car gasoline price historical
Car transport distance distribution
Car historic speed
Car historical fuel efficiency development
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Name	Dimensions	Unit	Type	Definition	Documentation
All probabilities of PV				Individual time constraints all* EXP(All PV constrained) /ARRSUM(Individual time constraints all*EXP(All PV constrained))	
Average car occupancy		Capita/ Car	Real	2.208	See average from global tourism as used in (UNWTO-UNEP-WMO, 2008) and calculated in WTOUNEPWMO2008_figures_02_Final.xls sheet 'Transport World' cell L22.
Average return distance per class	Dist_class	km/trip	Real	{75,112.5,150,200,262.5,350,462.5,600,787.5,1037.5,1362.5,1787.5,2337.5,3075,4050,5312.5,6975,9175,12062.5,15850}*2<<km/trip>>	These are now the metric averages, but this should be updated with GTTD measured averages for the whole database.
Bass Model Car transport					
Car abatement cost total				Car electric abatement cost total+Car fossil abatement cost total	
Car abatement per pkm cost		USD/km	Real	0<<USD/km>>	
Car abatement per ticket rate				DERIVN(Car abatement cost total/Car total global transport)	
Car adopters				Bass Model Car transport.Adopters	
Car adopters fraction				ARRSUM(Car adopters)/Global Population	
Car adopters fractions				Car adopters/Global Population	
Car average travel time				IF(Car average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Car average trip speed)	return travel time
Car average trip price				ARRSUM(Car global trips per distclass*Car travel price corrected)/Car global trips	
Car average trip speed				IF(Scenario on,1+Global speed policy factor Car,1)* FOR(i=DIM(Average return distance per class,1)| MIN(Car historic speed*Car transport speed-dist constants[Block_max_conversion], Car transport speed-dist constants[C_v]* (Average return distance per class[i]/1<<km/trip>>)^Car transport speed-dist	The formula is based on the MONS data for the Netherlands as cited in (Peeters & Landré, 2012, p. 49). The constants are valid for 2010(?) only and need to be corrected for the average blockspeed.

				constants[B1_exp]*1<<km/hr>>))	
Car cumulative average dist error			Real	0	
Car cumulative dist error			Real	0	
Car gasoline price historical	Global mitigation scenarios	USD/kg	Real	0<<USD/kg>>	from file Global time series data.xlsm
Car gasoline price specific scen		USD/kg	Real	Car gasoline price historical[INDEX(Global mitigation scenario switch)]	Added after implementing the global mitigation scenario dependent fuel price.
Car global average travel time				ARRSUM(Car average travel time*Car global trips per distclass)/ IF(Car global trips=0<<trips>>,1<<trips>>,Car global trips)	return overall average travel time
Car global transport				Average return distance per class*Car global trips per distclass	
Car global trip expenses				ARRSUM(Car global trips per distclass*Car travel price corrected)	
Car global trips				ARRSUM(Bass Model Car transport.Trips)	
Car global trips per distclass				Bass Model Car transport.Adopters*Bass Model Car transport.Trips per adoption	
Car historic global transport		km	Real	0	Data from file Global time series data.xlsm
Car historic speed		km/hr	Real	120	Data from file Global time series data.xlsm
Car historical fuel efficiency development		kg/km/kg	Real	0	data from file Global time series data.xlsm
Car lower class attraction limit	Dist_class		Real	{DELAYINF(IF(YEAR()<1940,1,1),10<<yr>>,3),1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1}	This variable reduces the first short distance class as it makes the average distance impossible to reach that was historically measured, (see world trends input file, from
Car Potential			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_	This factor determines the share of real

adopters share			Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R13C3")	adopters in calculating the average income of the travelling population. The remainder is the average for all distance classes of potential adopters
Car price incl taxes			Car global trip expenses/Car total global transport	
Car PV growth rates			All growth rates[Car]	
Car social adoption factor		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R15C3")	
Car ticket price fraction of personal income		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R16C3")	Based on a fit of data and the 0.81 from (Lescaroux, 2010, p. 13).
Car total global transport			ARRSUM(Car global transport)	
Car total global transport 1980	km	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Global timeseries data.xlsm", "Car transport pkm", "R82C2")<<km>>	
Car total global transport 2005	km	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Global timeseries data.xlsm", "Car transport pkm", "R107C2")<<km>>	
Car total travel time	yr		Car global average travel time*Car global trips	Multiply with 2 as all times are one-way.
Car transport average distance			Bass Model Car transport.Overall average distance	
Car transport average distance historical	km/trip	Real	0<<km/trip>>	return distance

Car transport commercial effectiveness			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R17C3")	
Car transport distance distribution	Dist_class		Real	0.1	Data from file Global time series data.xlsm
Car transport speed-dist constants	Speed_dist_constants		Real	{1,12.78,0.411}	The first factor gives the operational versus maximum speed ratio (set at 1 as only relevant for air transport), the two others are taken from the underlying data based on MONS (see (Peeters & Landré, 2012)).
Car transport X-factor			Real	1	This variable controls all other factors (X) like the effective anti-car use campaign in the USA during the WW-II, that caused people to stop driving (see (Gilbert & Perl, 2008, pp. 27-29). Also eventual production capacity problems could be part of this variable. Data from file Global time series data.xlsm
Car travel price corrected				Car variable price*Average return distance per class	
Car trips cumulative error			Real	0	
Car variable price				IF(Scenario on,1+Global ticket tax Car,1)* (Car gasoline price specific scen*Car historical fuel efficiency development*Car weight historical+ Car abatement per pkm cost+ Global carbon tax ticket cost[Car])	
Car weight historical		kg	Real	0<<kg>>	Input from file Global time series data.xlsm
Check trips per capita				ARRSUM(Total trips per mode)/Global Population	
Global Birthrate				Global_Birthrates[INDEX(Global_pop_sc_switch)]	
Global car fleet				Bass Model Car Ownership.Car Adopters*Bass Model Car	

				Ownership.Cars per adopter	
Global carbon tax ticket cost	Modes	USD/km	Real	0<<USD/km>>	
Global Deathrate				Global_Deathrates[INDEX(Global_pop_sc_switch)]	
Global GDP growth rate		1/yr		Global_GDP_growth_rates[INDEX(Global_economy_sc_switch)]	
Global GDP per capita initial		USD/ Capita	Real	0	
Global GINI coeff				IF(Global_economy_Gini_switch=0, GINI coeff scenarios[INDEX(Global_economy_sc_switch)], GINI coeff scenarios[INDEX(Global_economy_Gini_switch)])	
Global mitigation scenario switch			Integer	1	Global mitigation scenario switch: 1 unlimited 2 moderate (3.5) 3 Paris Goal (2.0) 4 Paris Ambition (1.5)
Global Population				Global_Population_UN_Scen[INDEX(Global_pop_sc_switch)]	
Global speed policy factor Car				GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global speed policy factor Car)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Global ticket tax Car				GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global ticket tax Car)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Historical tourism trips	Transport modes	trip	Real	0<<trips>>	
Individual time constraints car	Dist_class			FOR(i=DIM(Car average travel time)| Car lower class attraction limit[i]* MAX(0,MIN(1,1.25*Time constraint car/(1.25*Time constraint car-Time constraint car) +Car average travel time[i]/(Time constraint car-1.25*Time constraint car))))	
Obj average car dist growth				Objective Car average distance*1<<1/yr>>	
Obj car dist growth				Objective Car distance*1<<1/yr>>	
Obj car trips growth				Objective Car trips*1<<1/yr>>	

Objective Car average distance				SQRT(((Car transport average distance-Car transport average distance historical)/ Car transport average distance historical)^2)	The error is relative to the final 2005 figure as to give emphasis tot the latest years of the cumulative error (the first years errors are much smaller as total mobility is then much smaller). This helps to find data that are close to the 2005 known situation and avoids an emphasis on fit to early data that are not too reliable anyway.
Objective Car distance				SQRT(IF(YEAR(STOPTIME)=1980, (IF(Car total global transport 1980=0<<km>>,0, (Car total global transport-Car historic global transport)/ Car total global transport 1980))^2, (IF(Car total global transport 2005=0<<km>>,0, (Car total global transport-Car historic global transport)/ Car total global transport 2005))^2))	Ibid.
Objective Car trips				IF(Car global trips=0<<trips>>, 0, SQRT(((Car global trips-Historical tourism trips[Car])/ Car global trips)^2))	Ibid.
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	
Time constraint car		hr/trip	Real	52<<hr/trip>>	The assumption is based on data from CVO file ravel time return frequency 2010.spv and assumes that growth is reduced from the beginning of the last bin before the first zero bin linearly until 25% of the initial travel time.
Total adopters fraction				Total adopters/Global Population	
Total trips per mode	Transport modes			{Air global trips,Car global trips,Other global trips}	
Trips per adopter				Trips per cap/Total adopters fraction	
Trips per cap				Global travel inclination policy factor* Pop at max frac*Max glob trips p cap +IF(Pop at max frac<Share rich, alpha*(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap) *(Share rich*(beta/Share rich)^(1/alpha)-Pop at max frac*(beta/Pop at max frac)^(1/alpha)) /(alpha-1) +(EXP(Factor k)*EXP(-	Based on the GINI procedure.

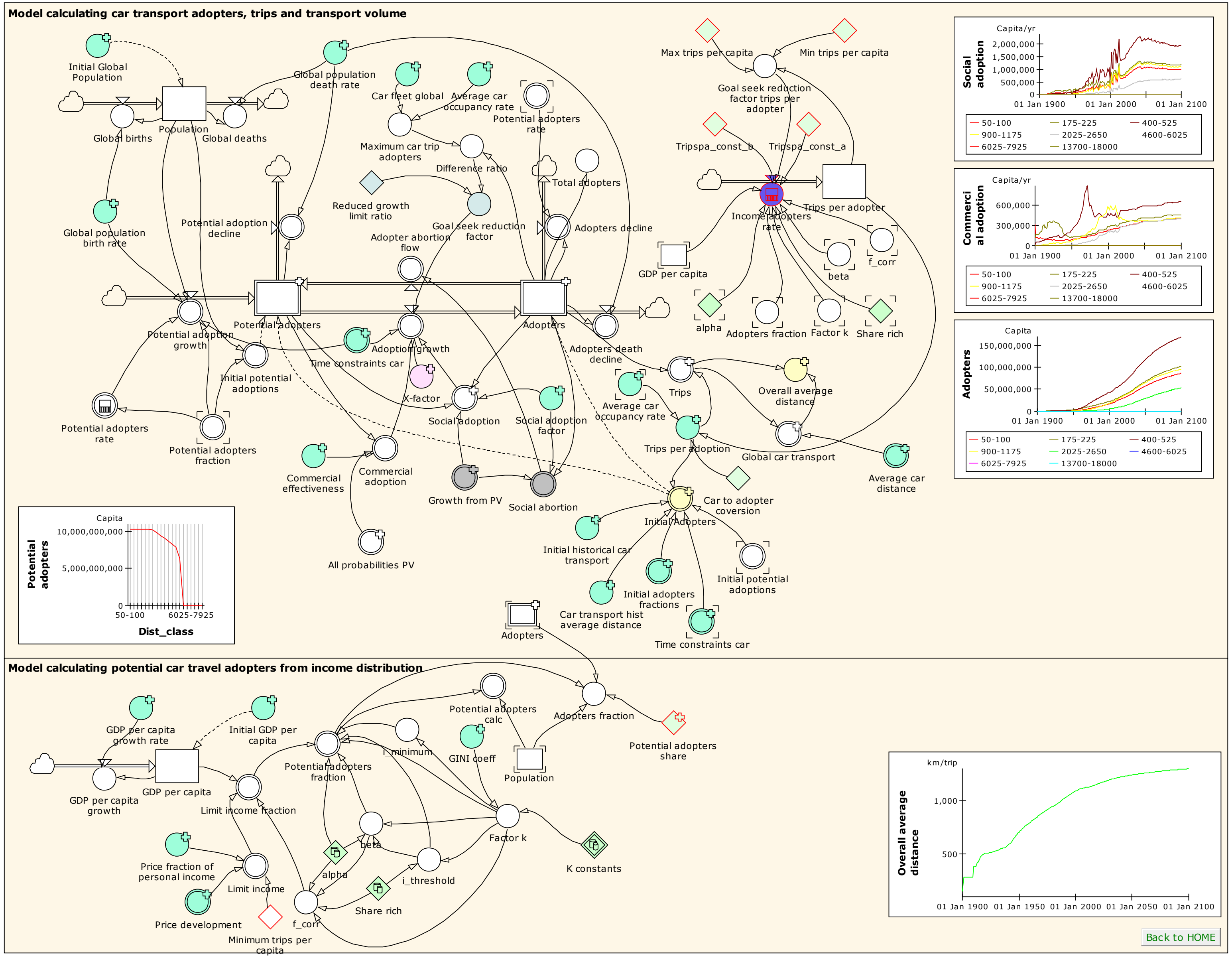
	Share rich*Factor k)-1) *(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap) /(EXP(Factor k)-1), (EXP(Factor k)*EXP(-Pop at max frac*Factor k)-1) *(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap)/(EXP(Factor k)-1))

Bass Model Car transport

Description/task: Calculate the number of adopters per distance class

Main inputs: GDP, pop., GINI, variable cost, PV rates

Main outputs: Car trips, travel time per distance class


Model calculating car transport adopters, trips and transport volume
Initial Global Population
Global population death rate
Car fleet global
Average car occupancy rate
Potential adopters rate
Population
Global births
Global deaths
Maximum car trip adopters
Difference ratio
Total adopters
Reduced growth limit ratio
Goal seek reduction factor
Potential adoption decline
Adopters decline
Adopter abortion flow
Global population birth rate
Potential adopters
Adopters
Potential adoption growth
Adoption growth
Adopters death decline
Time constraints car
Initial potential adoptions
X-factor
Social adoption
Social adoption factor
Potential adopters rate
Potential adopters fraction
Commercial effectiveness
Commercial adoption
Growth from PV
Social abortion
All probabilities PV
Max trips per capita
Min trips per capita
Goal seek reduction factor trips per adopter
Tripspa_const_b
Tripspa_const_a
Income adopters rate
Trips per adopter
GDP per capita
beta
f_corr
alpha
Adopters fraction
Factor k
Share rich
Trips
Overall average distance
Average car occupancy rate
Trips per adoption
Global car transport
Average car distance
Car to adopter coversion
Initial Adopters
Initial historical car transport
Initial adopters fractions
Initial potential adoptions
Car transport hist average distance
Time constraints car
Adopters
Social adoption
Capita/yr
2,000,000
1,500,000
1,000,000
500,000
0
01 Jan 1900
01 Jan 2000
01 Jan 2100
50-100
175-225
400-525
900-1175
2025-2650
4600-6025
6025-7925
13700-18000
Commercial adoption
Capita/yr
600,000
300,000
0
Adopters
Capita
150,000,000
100,000,000
50,000,000
0
Potential adopters
Capita
10,000,000,000
5,000,000,000
0
50-100
6025-7925
Dist_class
Model calculating potential car travel adopters from income distribution
GDP per capita growth rate
Initial GDP per capita
Potential adopters calc
Adopters fraction
i_minimum
GINI coeff
Population
Potential adopters share
GDP per capita growth
GDP per capita
Potential adopters fraction
Limit income fraction
beta
Factor k
K constants
Price fraction of personal income
Limit income
alpha
i_threshold
Share rich
Price development
f_corr
Minimum trips per capita
Overall average distance
km/trip
1,000
500
01 Jan 1900
01 Jan 1950
01 Jan 2000
01 Jan 2050
01 Jan 2100
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Car transport.Adopter abortion flow				Social abortion	
Bass Model Car transport.Adopters		Capita		Initial Adopters	
Bass Model Car transport.Adopters death decline				//reduction from death rate// Global population death rate*Adopters	
Bass Model Car transport.Adopters decline	Dist_class			FOR(i=DIM(Adopters,1)| MAX(-Potential adopters rate[i]*Adopters[i],0<<Capita/yr>>))	
Bass Model Car transport.Adopters fraction				Potential adopters share*ARRAVERAGE(Potential adopters fraction) +(1-Potential adopters share)*ARRSUM(Adopters)/Population	The adopters fraction is used to calculate the average income of the partly potential adopters population.
Bass Model Car transport.Adoption growth				Time constraints car*(((Commercial adoption+Social adoption) *X-factor))//reduces (or increases) growth in special times like global crises// *Goal seek reduction factor//to avoid more adopters than car owners to use cars	
Bass Model Car transport.All probabilities PV				Parent~All probabilities of PV	
Bass Model Car transport.alpha			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R3C2")	The value of alpha is found to differ rather widely: • 2.0-2.3 for the UK wealth ((Drăgulescu & Yakovenko, 2001)) • 1.7 for the US wealth ((Drăgulescu & Yakovenko, 2001)) • Between 2.3 and 2.9 for the UK based on income ((Atkinson, 2005)) • Between 2.64 and 3.75 (which is an outlier above 3.14) for GDP/capita in Brazil ((Figueira et al., 2011)) • Rather variation of between 2.4 and 3.7 for Indian household and personal income and or rural and urban communities ((Ghosh et al., 2011)). • 2.34 and 2.63 for income for the USA ((Banerjee & Yakovenko, 2010)).

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Car transport.Average car distance	Dist_class	km/trip	Real	Parent~Average return distance per class	
Bass Model Car transport.Average car occupancy rate		Capita/Car	Real	Parent~Average car occupancy	
Bass Model Car transport.beta				(-(i_threshold^alpha))*(LN((i_threshold*(EXP(Factor k)-1))/Factor k)/Factor k-1)	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Car transport.Car fleet global		Cars		Parent~Global car fleet	
Bass Model Car transport.Car to adopter coversion		Car/Capita	Real	1	
Bass Model Car transport.Car transport hist average distance		km/trip	Real	Parent~Car transport average distance historical	
Bass Model Car transport.Commercial adoption				Commercial effectiveness* Potential adopters* All probabilities PV[Car,*]/1<<yr>>	
Bass Model Car transport.Commercial effectiveness			Real	Parent~Car transport commercial effectiveness	
Bass Model Car transport.Difference ratio				ARRSUM(Adopters)/Maximum car trip adopters	
Bass Model Car transport.f_corr				(Share rich*alpha*EXP((LN(beta/Share rich)/alpha))/(alpha-1)+(EXP(Factor k)*EXP(-Share rich*Factor k)-1)/(EXP(Factor k)-1))	
Bass Model Car transport.Factor k				(K constants[a]+K constants[b]*GINI coeff+ K constants[c]*GINI coeff^2 +K constants[d]*GINI coeff^3)/ (K constants[e]+K constants[f]*GINI coeff+GINI coeff^2)	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Car transport.GDP per capita		USD/ Capita	Real	Initial GDP per capita	Because the GDP/capita is only available historically, we have constructed this model to use the growth figures from scenarios and reconstruct GDP/capita from that. Results equal during historical runs.
Bass Model Car transport.GDP per capita growth				GDP per capita*GDP per capita growth rate	
Bass Model Car transport.GDP per capita growth rate		1/yr		Parent~Global GDP growth rate	
Bass Model Car transport.GINI coeff				Parent~Global GINI coeff	The GINI coefficient has been scaled between 1900 and 1992 based on the value for 1992 given by (Korzeniewicz & Moran, 1996) and including a trend of increase from 1900 9but taking 0.7 as the value for 1900, an arbitrary guestimate). After 1992 we used the decline as found using data from Worldbank (see global gini data.xls).
Bass Model Car transport.Global births				Global population birth rate*Population	
Bass Model Car transport.Global car transport				Average car distance*Trips	
Bass Model Car transport.Global deaths				Global population death rate*Population	
Bass Model Car transport.Global population birth rate		1/yr	Real	Parent~Global Birthrate	
Bass Model Car transport.Global population death rate		1/yr		Parent~Global Deathrate	
Bass Model Car transport.Goal seek				MAX(0, 1+(-.003872-1)* (1-EXP(-((1.98555*(IF(Difference ratio<Reduced growth	This standard function creates a multiplier that reduces sigmoidal from 1 to zero (and is to be

Name	Dimensions	Unit	Type	Definition	Documentation
reduction factor				limit ratio, 0, (Difference ratio-Reduced growth limit ratio)/(1-Reduced growth limit ratio))))^2.5))))	used to multiply growth with) for any ratio of a value/goal between a 'reduced growth limit ratio' (giving 1.0) and ratio 1 (giving 0.0). This function is inspired by section 8.5 in (Sterman, 2000). The workout for this purpose is in files Goal seeking growth form.xls and Goal seeking growth function.fgr. The latter function was for a reduction between 0.75 and 1.0, but has been simplified to give a reduction function for the whole 0-1 range and than using a condition to scale the x between the 'reduced growth limit ratio' and the ratio 1.0.
Bass Model Car transport.Goal seek reduction factor trips per adopter			Real	(1-TANH(Trips per adopter/(Max trips per capita-Min trips per capita)*6- (Min trips per capita+Max trips per capita)*3/(Max trips per capita-Min trips per capita)))/2	X-min and x-max provide the range over x you want the S-shape reduction from 1 to 0. Replace the X-value variable with your real X. See also S-curve mechanism.xlsx.
Bass Model Car transport.Growth from PV				Parent~Car PV growth rates	
Bass Model Car transport.i_minimum				Factor k/(EXP(Factor k)-1)	see Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd
Bass Model Car transport.i_threshold				(Factor k*(EXP(-Factor k*(Share rich-1)))/(EXP(Factor k)-1))	Based on mathcad file Chotikapanig Lorenz solution_NEW_13.xmcd
Bass Model Car transport.Income adopters rate				Goal seek reduction factor trips per adopter* DERIVN(Tripspa_const_a*GDP per capita*f_corr* IF(Adopters fraction<Share rich,(beta/Adopters fraction)^(1/alpha), (Factor k*EXP(-Factor k*(Adopters fraction-1))/(EXP(Factor k)-1)))/1000 +Tripspa_const_b,1)	As the trip per capita depends on adopters it was necessary to insert a level by taking the first derivative and integrating again. The calculation is based on the equation 7 in sup. file 2 of (Peeters, 2013) by solving it for population share and average income.
Bass Model Car transport.Initial Adopters				Time constraints car* MIN(Initial historical car transport/Car transport hist average distance *Initial adopters fractions/Trips per adoption, Initial potential adoptions)	This variable is required for the initialisation of adopters and potential adopters after factual introduction of air transport supply (in a somewhat substantial way). This is necessary due to the match of historical and calculated data. for a new transport mode like space tourism it should not be necessary. Also for car

Name	Dimensions	Unit	Type	Definition	Documentation
					and rail it is not necessary as these existed already in 1900.
Bass Model Car transport.Initial adopters fractions	Dist_class		Real	Parent~Car transport distance distribution	
Bass Model Car transport.Initial GDP per capita		USD/ Capita	Real	Parent~Global GDP per capita initial	
Bass Model Car transport.Initial Global Population		Capita		Parent~Global Population	
Bass Model Car transport.Initial historical car transport		km	Real	Parent~Car historic global transport	
Bass Model Car transport.Initial potential adoptions				Potential adopters fraction*Population//ARRSUM('Potential adopters fraction')	
Bass Model Car transport.K constants	k_constants		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R4C3:R9C3")	See the fitted curve as given in Mathcad - Chotikapanig Lorenz solution_13.xmcd and Findgraph solution given there.
Bass Model Car transport.Limit income				Price development/Price fraction of personal income*Minimum trips per capita	
Bass Model Car transport.Limit income fraction				Limit income/GDP per capita*f_corr	
Bass Model Car transport.Max trips per capita		trips/ Capita	Real	3	As there is a maximum to global nr of trips and as most travellers are one-mode only we have taken a slightly lower max per mode.
Bass Model Car transport.Maximum car trip adopters				Average car occupancy rate*Car fleet global	

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Car transport.Min trips per capita		trips/ Capita	Real	2.5	Bit arbitrary taken somewhat lower than max.
Bass Model Car transport.Minimum trips per capita		trip/ Capita	Real	1<<trips/Capita>>	
Bass Model Car transport.Overall average distance				IF(ARRSUM(Trips)<.0001<<trips>>,1<<km/trip >>, ARRSUM(Global car transport)/ARRSUM(Trips))	Average one-way distances.
Bass Model Car transport.Population		Capita		Initial Global Population	
Bass Model Car transport.Potential adopters		Capita		Initial potential adoptions -Initial Adopters	
Bass Model Car transport.Potential adopters calc				Population*Potential adopters fraction	
Bass Model Car transport.Potential adopters fraction				IF(Limit income fraction<i_minimum,1, IF(Limit income fraction<i_threshold, 1-LN(Limit income fraction*(EXP(Factor k)-1)/Factor k)/Factor k, beta/(Limit income fraction^alpha)))	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Car transport.Potential adopters rate				DERIVN(Potential adopters fraction)	
Bass Model Car transport.Potential adopters share			Real	Parent~Car Potential adopters share	This factor determines the share of real adopters in calculating the average income of the travelling population. The remainder is the average for all distance classes of potential adopters
Bass Model Car transport.Potential adoption decline				(Global population death rate*Potential adopters)	
Bass Model Car transport.Potential adoption growth				Time constraints car* (Global population birth rate*Potential adopters fraction*Population//follow population growth// +Potential adopters	

Name	Dimensions	Unit	Type	Definition	Documentation
				rate*Population)//follow potential fraction growth and decline	
Bass Model Car transport.Price development				Parent~Car travel price corrected	Based on information given by (Grübler et al., 1999) for 1900-1980 and price indexes given by http://www.census.gov/compendia/statab/2010/tables/10s0721.xls for 1990-2010
Bass Model Car transport.Price fraction of personal income			Real	Parent~Car ticket price fraction of personal income	Based this on motorization rate, annual cost for the car, car lifetime; see (Schäfer, 1998)
Bass Model Car transport.Reduced growth limit ratio			Real	0.9	This variable defines the point where the function starts to reduce (set between 0 and 1)
Bass Model Car transport.Share rich			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R2C2")	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Car transport.Social abortion				FOR(i=DIM(Growth from PV)| IF(Growth from PV[i]<0<<1/yr>>, -Growth from PV[i],0<<1/yr>>)*Adopters[i]*Social adoption factor)	
Bass Model Car transport.Social adoption				FOR(i=DIM(Growth from PV)| IF(Growth from PV[i]<0<<1/yr>>,0<<1/yr>>, Growth from PV[i])*Potential adopters[i]*Adopters[i]*Social adoption factor /(Adopters[i]+Potential adopters[i]))	
Bass Model Car transport.Social adoption factor			Real	Parent~Car social adoption factor	
Bass Model Car transport.Time constraints car	Dist_class			Parent~Individual time constraints car	
Bass Model Car transport.Total adopters				ARRSUM(Adopters)	

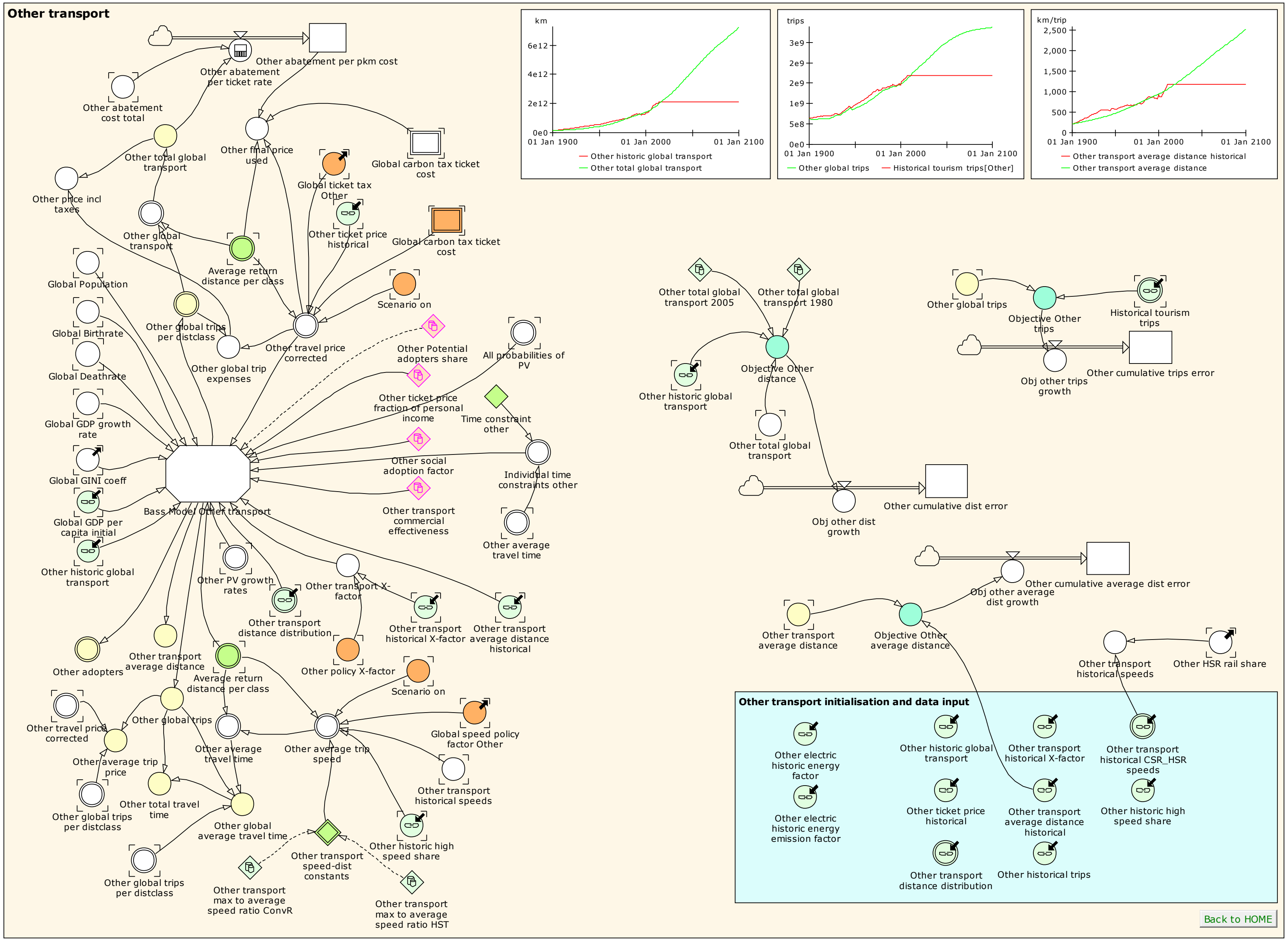
Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Car transport.Trips				Adopters*Trips per adoption	
Bass Model Car transport.Trips per adopter		trips/ Capita	Real	2.75	
Bass Model Car transport.Trips per adoption		trip/ Capita	Real	Average car occupancy rate*Trips per adopter*Car to adopter coversion	One trip is a return trip!
Bass Model Car transport.Tripspa_const_a		trips/USD	Real	0.0912	See CVO trips per capita per mode.xlsx
Bass Model Car transport.Tripspa_const_b		trips/ Capita	Real	1.552	Ibid.
Bass Model Car transport.X-factor			Real	Parent~Car transport X-factor	

Other transport

Description/task: Prepare data for the Bass model

Main inputs: Fuel cost, fleet composition

Main outputs: Ticket price, travel time


Other transport
Other abatement per pkm cost
Other abatement per ticket rate
Other abatement cost total
Other total global transport
Other final price used
Global carbon tax ticket cost
Global ticket tax Other
Other price incl taxes
Other global transport
Other ticket price historical
Global carbon tax ticket cost
Average return distance per class
Global Population
Scenario on
Global Birthrate
Other global trips per distclass
Other travel price corrected
Other global trip expenses
Other Potential adopters share
All probabilities of PV
Global Deathrate
Other ticket price fraction of personal income
Time constraint other
Global GDP growth rate
Other social adoption factor
Individual time constraints other
Global GINI coeff
Global GDP per capita initial
Bass Model Other transport
Other transport commercial effectiveness
Other average travel time
Other historic global transport
Other PV growth rates
Other transport X-factor
Other transport distance distribution
Other transport historical X-factor
Other transport average distance historical
Other adopters
Other transport average distance
Average return distance per class
Other policy X-factor
Scenario on
Other travel price corrected
Other global trips
Other average travel time
Other average trip speed
Global speed policy factor Other
Other average trip price
Other transport historical speeds
Other global trips per distclass
Other total travel time
Other global average travel time
Other transport speed-dist constants
Other historic high speed share
Other global trips per distclass
Other transport max to average speed ratio ConvR
Other transport max to average speed ratio HST
km
6e12
4e12
2e12
0e0
01 Jan 1900
01 Jan 2000
01 Jan 2100
Other historic global transport
Other total global transport
trips
3e9
2e9
2e9
1e9
5e8
0e0
01 Jan 1900
01 Jan 2000
01 Jan 2100
Other global trips
Historical tourism trips[Other]
km/trip
2,500
2,000
1,500
1,000
500
0
01 Jan 1900
01 Jan 2000
01 Jan 2100
Other transport average distance historical
Other transport average distance
Other total global transport 2005
Other total global transport 1980
Other global trips
Objective Other trips
Historical tourism trips
Objective Other distance
Obj other trips growth
Other cumulative trips error
Other historic global transport
Other total global transport
Obj other dist growth
Other cumulative dist error
Obj other average dist growth
Other cumulative average dist error
Other transport average distance
Objective Other average distance
Other transport historical speeds
Other HSR rail share
Other transport initialisation and data input
Other electric historic energy factor
Other historic global transport
Other transport historical X-factor
Other transport historical CSR_HSR speeds
Other electric historic energy emission factor
Other ticket price historical
Other transport average distance historical
Other historic high speed share
Other transport distance distribution
Other historical trips
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Name	Dimensions	Unit	Type	Definition	Documentation
All probabilities of PV				Individual time constraints all* EXP(All PV constrained) /ARRSUM(Individual time constraints all*EXP(All PV constrained))	
Average return distance per class	Dist_class	km/trip	Real	{75,112.5,150,200,262.5,350,462.5,600,787.5,1037.5,1362.5,1787.5,2337.5,3075,4050,5312.5,6975,9175,12062.5,15850}*2 <<km/trip>>	These are now the metric averages, but this should be updated with GTTD measured averages for the whole database.
Bass Model Other transport					
Car abatement cost total				Car electric abatement cost total+Car fossil abatement cost total	
Car PV growth rates				All growth rates[Car]	
Global Birthrate				Global_Birthrates[INDEX(Global_pop_sc_switch)]	
Global car fleet				Bass Model Car Ownership.Car Adopters*Bass Model Car Ownership.Cars per adopter	
Global carbon tax ticket cost	Modes	USD/km	Real	0<<USD/km>>	
Global Deathrate				Global_Deathrates[INDEX(Global_pop_sc_switch)]	
Global GDP growth rate		1/yr		Global_GDP_growth_rates[INDEX(Global_economy_sc_switch)]	
Global GDP per capita initial		USD/Capita	Real	0	
Global GINI coeff				IF(Global_economy_Gini_switch=0, GINI coeff scenarios[INDEX(Global_economy_sc_switch)], GINI coeff scenarios[INDEX(Global_economy_Gini_switch)])	
Global mitigation scenario switch			Integer	1	Global mitigation scenario switch: 1 unlimited 2 moderate (3.5) 3 Paris Goal (2.0) 4 Paris Ambition (1.5)
Global Population				Global_Population_UN_Scen[INDEX(Global_pop_sc_switch)]	
Global speed policy factor Car				GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global speed policy factor Car)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Global speed policy				GRAPHCURVE(YEAR(TIME),Scenario start year,	A 5 year delay has been added to avoid

Name	Dimensions	Unit	Type	Definition	Documentation
factor Other				(YEAR(STOPTIME)-Scenario start year)/4, Policy global speed policy factor Other)	a too strong impulses at the beginning of the measure.
Global ticket tax Car				GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global ticket tax Car)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Global ticket tax Other				GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global ticket tax Other)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Historical tourism trips	Transport modes	trip	Real	0<<trips>>	
Individual time constraints other	Dist_class			FOR(i=DIM(Other average travel time)| MAX(0,MIN(1,1.25*Time constraint other/(1.25*Time constraint other-Time constraint other) +Other average travel time[i]/(Time constraint other-1.25*Time constraint other))))	
Obj other average dist growth				Objective Other average distance*1<<1/yr>>	
Obj other dist growth				Objective Other distance*1<<1/yr>>	
Obj other trips growth				Objective Other trips*1<<1/yr>>	
Objective Other average distance				SQRT(((Other transport average distance-Other transport average distance historical)/ Other transport average distance historical)^2)	The error is relative to the final 2005 figure as to give emphasis tot the latest years of the cumulative error (the first years errors are much smaller as total mobility is then much smaller). This helps to find data that are close to the 2005 known situation and avoids an emphasis on fit to early data that are not too reliable anyway.
Objective Other distance				SQRT(IF(YEAR(STOPTIME)=1980, (IF(Other total global transport 1980=0<<km>>,0, (Other total global transport-Other historic global transport)/ Other total global transport 1980))^2, (IF(Other total global transport 2005=0<<km>>,0, (Other total global transport-Other historic global transport)/ Other total global transport 2005))^2))	Ibid.

Name	Dimensions	Unit	Type	Definition	Documentation
Objective Other trips				IF(Other global trips=0<<trips>>, 0, SQRT(((Other global trips-Historical tourism trips[Other])/ Other global trips)^2))	Ibid.
Other abatement cost total				(Other share electric* Other electric abatement average*MU_Other electric*(1DIVZ0(1-MU_Other electric)-1)+ (1-Other share electric)* Other non-electric abatement average*MU_Other non-electric*(1DIVZ0(1-MU_Other non-electric)-1)) *Other total emissions//)	
Other abatement per pkm cost		USD/ km	Real	0<<USD/km>>	
Other abatement per ticket rate				DERIVN(Other abatement cost total/Other total global transport)	
Other adopters				Bass Model Other transport.Adopters	
Other average travel time				IF(Other average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Other average trip speed)	return travel times
Other average trip price				IF(Other global trips<.001<<trips>>,1<<USD/trip>>, ARRSUM(Other global trips per distclass*Other travel price corrected)/Other global trips)	
Other average trip speed				//conventioal speed part// IF(Scenario on,1+Global speed policy factor Other,1)* //'Other policy speed factor'*// ((1-Other historic high speed share)* FOR(i=DIM(Average return distance per class,1)| MIN(Other transport historical speeds*Other transport speed-dist constants[ConvSpRail,Block_max_conversion], Other transport speed-dist constants[ConvSpRail,C_v]* (Average return distance per class[i]/1<<km/trip>>)^Other transport speed-dist constants[ConvSpRail,B1_exp]*1<<km/hr>>)) //high speed part// +Other historic high speed share* FOR(i=DIM(Average return distance per class,1)| MIN(Other transport historical speeds*Other transport speed-dist constants[HighSpRail,Block_max_conversion], Other transport speed-dist constants[HighSpRail,C_v]* (Average return distance per class[i]/1<<km/trip>>)^Other transport speed-dist constants[HighSpRail,B1_exp]*1<<km/hr>>)))	The formula is based on the MONS data for the Netherlands as cited in (Peeters & Landré, 2012, p. 49). The constants are valid for 2010 and were corrected for the average other speed as combined between conventional and high speed rail. Therefore the share of HSR is included in the equation to find the overall average speed.
Other cumulative average dist error			Real	0	

Name	Dimensions	Unit	Type	Definition	Documentation
Other cumulative dist error			Real	0	
Other cumulative trips error			Real	0	
Other electric historic energy emission factor		kg/MJ	Real	0	
Other electric historic energy factor		MJ/km	Real	0	
Other final price used				ARRAVERAGE(Other travel price corrected/Average return distance per class)+ Other abatement per pkm cost+ Global carbon tax ticket cost[Other]	
Other global average travel time				IF(Other global trips<0.0001<<trips>>,1<<hr/trip>>, ARRSUM(Other average travel time*Other global trips per distclass)/Other global trips)	return time
Other global transport				Average return distance per class*Other global trips per distclass	
Other global trip expenses				ARRSUM(Other global trips per distclass*Other travel price corrected)	
Other global trips				ARRSUM(Bass Model Other transport.Trips)	
Other global trips per distclass				Bass Model Other transport.Adopters*Bass Model Other transport.Trips per adoption	
Other historic global transport		km	Real	0	
Other historic high speed share			Real	0	
Other historical trips		trips	Real	0	
Other HSR rail share				Transport capacity submodel.Other HSR transport share	
Other policy X-factor			Real	0	
Other Potential adopters share			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model	This factor determines the share of real adopters in calculating the average

Name	Dimensions	Unit	Type	Definition	Documentation
				files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R23C3")	income of the travelling population. The remainder is the average for all distance classes of potential adopters
Other price incl taxes				Other global trip expenses/Other total global transport	
Other PV growth rates				All growth rates[Other]	
Other social adoption factor			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R25C3")	
Other ticket price fraction of personal income			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R26C3")	
Other ticket price historical		USD/ km	Real	GRAPHCURVE(YEAR(),1900,10,{27196, 14375, 5148, 4177, 4954, 5634, 7479, 6119, 7090, 8367, 9430, 9076,10076}<<USD/km>>)	Based on information given by (Grübler et al., 1999) for 1900-1980 and price indexes given by http://www.census.gov/compendia/statab/2012/tables/12s0737.xls for 1990-2010
Other total global transport				ARRSUM(Other global transport)	
Other total global transport 1980		km	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Global timeseries data.xlsm", "Other transport pkm", "R82C2")<<km>>	
Other total global transport 2005		km	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Global timeseries data.xlsm", "Other transport pkm", "R107C2")<<km>>	
Other total travel time		yr		Other global average travel time*Other global trips	total travel time

Name	Dimensions	Unit	Type	Definition	Documentation
Other transport average distance				Bass Model Other transport.Overall average distance	
Other transport average distance historical		km/trip	Real	0	The share of TGV and operational speed based on it is not really based on literature and the relation with average distance seems a bit high.
Other transport commercial effectiveness			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R27C3")	
Other transport distance distribution	Dist_class		Real	0.1	Fraction of adopters per distance class, set to follow a power law with -2.3 coefficient and delivering the average trip distance. Fine tuned by setting lowest class to 0, adjusting second class to between 0 and 1.0 and leaving classes with more than 24 hours our of the equation (zero trips, though there of course were some).
Other transport historical CSR_HSR speeds	Rail kinds	km/hr	Real	100<<km/hr>>	
Other transport historical speeds				(1-Other HSR rail share)*Other transport historical CSR_HSR speeds[ConvSpRail] +Other HSR rail share*Other transport historical CSR_HSR speeds[HighSpRail]	
Other transport historical X-factor			Real	1	This variable controls all other factors (X) like the effective anti-car use campaign in the USA during the WW-II, that caused people to stop driving (see (Gilbert & Perl, 2008, pp. 27-29). Also eventual production capacity problems could be part of this variable.
Other transport max to average speed ratio ConvR			Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Global timeseries data.xlsm", "Other transport speed", "R3C26")	

Name	Dimensions	Unit	Type	Definition	Documentation
Other transport max to average speed ratio HST			Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Global timeseries data.xlsm", "Other transport speed", "R3C27")	
Other transport speed-dist constants	Rail kinds, Speed_dist_constants		Real	{{Other transport max to average speed ratio ConvR,7.138,0.428}, {Other transport max to average speed ratio HST,10.484,0.447}}	The first factor gives the operational versus maximum speed ratio (see Global time series data.xlsx, sheet 'other transport speed' T112 conversion factor to calculate the max speed), the two others are taken from the underlying data based on MONS (see (Peeters & Landré, 2012)).
Other transport X-factor			Real	Other transport historical X-factor+Other policy X-factor	
Other travel price corrected				IF(Scenario on,1+Global ticket tax Other,1)* (Other ticket price historical +Global carbon tax ticket cost[Car]) *Average return distance per class	
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	
Time constraint other		hr/trip	Real	42<<hr/trip>>	The assumption is based on data from CVO file ravel time return frequency 2010.spv and assumes that growth is reduced from the beginning of the last bin before the first zero bin linearly until 25% of the initial travel time. CVO for rail is 42 hr.
Total adopters fraction				Total adopters/Global Population	
Total trips per mode	Transport modes			{Air global trips,Car global trips,Other global trips}	
Trips per cap				Global travel inclination policy factor* Pop at max frac*Max glob trips p cap +IF(Pop at max frac<Share rich, alpha*(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap) *(Share rich*(beta/Share rich)^(1/alpha)-Pop at max frac*(beta/Pop at max frac)^(1/alpha)) /(alpha-1)	Based on the GINI procedure.

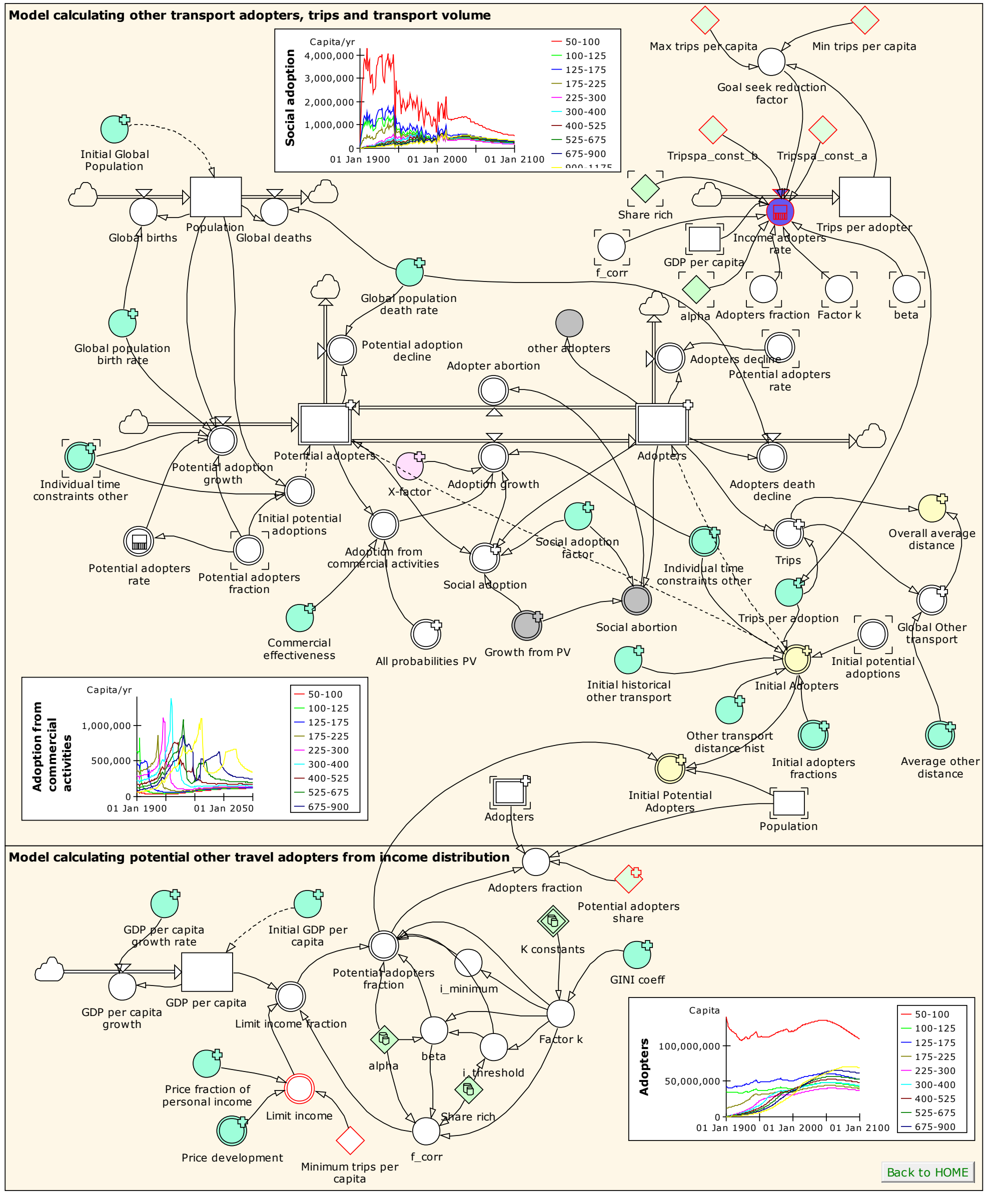
Name	Dimensions	Unit	Type	Definition	Documentation
				+(EXP(Factor k)*EXP(-Share rich*Factor k)-1) *(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap) /(EXP(Factor k)-1), (EXP(Factor k)*EXP(-Pop at max frac*Factor k)-1) *(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap)/(EXP(Factor k)-1))	

Bass Model Other transport

Description/task: Calculate the number of adopters per distance class

Main inputs: GDP, pop., GINI, ticket price, PV rates

Main outputs: Other trips, travel time/distance class


Model calculating other transport adopters, trips and transport volume
Social adoption
Capita/yr
01 Jan 1900
01 Jan 2000
01 Jan 2100
50-100
100-125
125-175
175-225
225-300
300-400
400-525
525-675
675-900
Max trips per capita
Min trips per capita
Goal seek reduction factor
Tripspa_const_b
Tripspa_const_a
Initial Global Population
Population
Global births
Global deaths
Share rich
Income adopters rate
Trips per adopter
f_corr
GDP per capita
alpha
Adopters fraction
Factor k
beta
Global population death rate
Global population birth rate
Potential adoption decline
other adopters
Adopter abortion
Adopters decline
Potential adopters rate
Potential adopters
Adopters
Individual time constraints other
Potential adoption growth
X-factor
Adoption growth
Adopters death decline
Initial potential adoptions
Adoption from commercial activities
Social adoption factor
Trips
Overall average distance
Potential adopters rate
Potential adopters fraction
Social adoption
Social abortion
Trips per adoption
Global Other transport
Commercial effectiveness
All probabilities PV
Growth from PV
Initial historical other transport
Initial Adopters
Other transport distance hist
Initial adopters fractions
Average other distance
Adoption from commercial activities
Initial Potential Adopters
Model calculating potential other travel adopters from income distribution
Adopters fraction
Potential adopters share
GDP per capita growth rate
Initial GDP per capita
K constants
GINI coeff
GDP per capita growth
Limit income fraction
i_minimum
Factor k
i_threshold
Price fraction of personal income
Limit income
Price development
Minimum trips per capita
Adopters
Capita
01 Jan 1900
01 Jan 2000
01 Jan 2100
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Bass Model Other transport.Adopter abortion				Social abortion	
Bass Model Other transport.Adopters		Capita		Initial Adopters	
Bass Model Other transport.Adopters death decline				//reduction from death rate// Global population death rate*Adopters	
Bass Model Other transport.Adopters decline				//quit rate from reduced potential share// FOR(i=DIM(Adopters,1)| MAX(-Potential adopters rate[i]*Adopters[i],0<<Capita/yr>>))	
Bass Model Other transport.Adopters fraction				Potential adopters share*ARRAVERAGE(Potential adopters fraction) +(1-Potential adopters share)*ARRSUM(Adopters)/Population	The adopters fraction is used to calculate the average income of the partly potential adopters population.
Bass Model Other transport.Adoption from commercial activities				Commercial effectiveness* Potential adopters* All probabilities PV[Other,*]/1<<yr>>	
Bass Model Other transport.Adoption growth				Individual time constraints other* ((Adoption from commercial activities +Social adoption) *X-factor)//reduces (or increases) growth in special times like global crises	
Bass Model Other transport.All probabilities PV				Parent~All probabilities of PV	
Bass Model Other transport.alpha			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R3C2")	The value of alpha is found to differ rather widely: • 2.0-2.3 for the UK wealth ((Drăgulescu & Yakovenko, 2001)) • 1.7 for the US wealth ((Drăgulescu & Yakovenko, 2001)) • Between 2.3 and 2.9 for the UK based on income ((Atkinson, 2005)) • Between 2.64 and 3.75 (which is an outlier above 3.14) for GDP/capita in Brazil ((Figueira et al., 2011)) • Rather variation of between 2.4 and 3.7 for Indian

Name	Dimensions	Unit	Type	Definition	Documentation
					household and personal income and or rural and urban communities ((Ghosh et al., 2011)). • 2.34 and 2.63 for income for the USA ((Banerjee & Yakovenko, 2010)).
Bass Model Other transport.Average other distance	Dist_class	km/trip	Real	Parent~Average return distance per class	
Bass Model Other transport.beta				(-(i_threshold^alpha))*(LN((i_threshold*(EXP(Factor k)-1))/Factor k)/Factor k-1)	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Other transport.Commercial effectiveness			Real	Parent~Other transport commercial effectiveness	
Bass Model Other transport.f_corr				(Share rich*alpha*EXP((LN(beta/Share rich)/alpha))/(alpha-1)+(EXP(Factor k)*EXP(-Share rich*Factor k)-1)/(EXP(Factor k)-1))	
Bass Model Other transport.Factor k				(K constants[a]+K constants[b]*GINI coeff+ K constants[c]*GINI coeff^2 +K constants[d]*GINI coeff^3)/ (K constants[e]+K constants[f]*GINI coeff+GINI coeff^2)	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Other transport.GDP per capita		USD/ Capita	Real	Initial GDP per capita	Because the GDP/capita is only available historically, we have constructed this model to use the growth figures from scenarios and reconstruct GDP/capita from that. Results equal during historical runs.
Bass Model Other transport.GDP per capita growth				GDP per capita*GDP per capita growth rate	
Bass Model Other transport.GDP per capita growth rate		1/yr		Parent~Global GDP growth rate	
Bass Model Other transport.GINI coeff				Parent~Global GINI coeff	The GINI coefficient has been scaled between 1900 and 1992 based on the value for 1992 given by (Korzeniewicz & Moran, 1996) and

Name	Dimensions	Unit	Type	Definition	Documentation
					including a trend of increase from 1900 (but taking 0.7 as the value for 1900, an arbitrary guestimate). After 1992 we used the decline as found using data from Worldbank (see global gini data.xls).
Bass Model Other transport.Global births				Global population birth rate*Population	
Bass Model Other transport.Global deaths				Global population death rate*Population	
Bass Model Other transport.Global Other transport				Average other distance*Trips	
Bass Model Other transport.Global population birth rate		1/yr	Real	Parent~Global Birthrate	
Bass Model Other transport.Global population death rate		1/yr		Parent~Global Deathrate	
Bass Model Other transport.Goal seek reduction factor			Real	(1-TANH(Trips per adopter/(Max trips per capita-Min trips per capita)*6- (Min trips per capita+Max trips per capita)*3/(Max trips per capita-Min trips per capita)))/2	X-min and x-max provide the range over x you want the S-shape reduction from 1 to 0. Replace the X-value variable with your real X. See also S-curve mechanism.xlsx.
Bass Model Other transport.Growth from PV				Parent~Other PV growth rates//+'test growth step'	
Bass Model Other transport.i_minimum				Factor k/(EXP(Factor k)-1)	See Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd
Bass Model Other transport.i_threshold				(Factor k*(EXP(-Factor k*(Share rich-1)))/(EXP(Factor k)-1))	Based on mathcad file Chotikapanig Lorenz solution_NEW_13.xmcd
Bass Model Other transport.Income adopters rate				Goal seek reduction factor* DERIVN(Tripspa_const_a*GDP per capita*f_corr* IF(Adopters fraction<Share rich,(beta/Adopters fraction)^(1/alpha), (Factor k*EXP(-Factor k*(Adopters fraction-1))/(EXP(Factor k)-1)))/1000	As the trip per capita depends on adopters it was necessary to insert a level by taking the first derivative and integrating again. The calculation is based on the equation 7 in sup. file 2 of (Peeters, 2013) by solving it for population share and average income.

Name	Dimensions	Unit	Type	Definition	Documentation
				+Tripspa_const_b,1)	
Bass Model Other transport.Individual time constraints other	Dist_class			Parent~Individual time constraints other	
Bass Model Other transport.Initial Adopters				Individual time constraints other* MIN(Initial historical other transport/Other transport distance hist *Initial adopters fractions/Trips per adoption,Initial potential adoptions)	This variable is required for the initialisation of adopters and potential adopters after factual introduction of air transport supply (in a somewhat substantial way). This is necessary due to the match of historical and calculated data. for a new transport mode like space tourism it should not be necessary. Also for car and rail it is not necessary as these existed already in 1900.
Bass Model Other transport.Initial adopters fractions	Dist_class		Real	Parent~Other transport distance distribution	
Bass Model Other transport.Initial GDP per capita		USD/ Capita	Real	Parent~Global GDP per capita initial	
Bass Model Other transport.Initial Global Population		Capita		Parent~Global Population	
Bass Model Other transport.Initial historical other transport		km	Real	Parent~Other historic global transport	
Bass Model Other transport.Initial Potential Adopters				Population*Potential adopters fraction-Initial Adopters	This auxiliary just helps to set the potential adopters after start of civil aviation year.
Bass Model Other transport.Initial potential adoptions				Individual time constraints other*Potential adopters fraction*Population	
Bass Model Other transport.K constants	k_constants		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model	See the fitted curve as given in Mathcad - Chotikapanig Lorenz solution_13.xmcd and Findgraph solution given there.

Name	Dimensions	Unit	Type	Definition	Documentation
				files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R4C3:R9C3")	
Bass Model Other transport.Limit income				(Price development)/Price fraction of personal income*Minimum trips per capita	
Bass Model Other transport.Limit income fraction				Limit income/GDP per capita*f_corr	
Bass Model Other transport.Max trips per capita		trips/ Capita	Real	3	As there is a maximum to global nr of trips and as most travellers are one-mode only we have taken a slightly lower max per mode.
Bass Model Other transport.Min trips per capita		trips/ Capita	Real	2.5	Bit arbitrary taken somewhat lower than max.
Bass Model Other transport.Minimum trips per capita		trip/ Capita	Real	1<<trips/Capita>>	
Bass Model Other transport.other adopters				ARRSUM(Adopters)	
Bass Model Other transport.Other transport distance hist		km/tri p	Real	Parent~Other transport average distance historical	
Bass Model Other transport.Overall average distance				IF(ARRSUM(Trips)<.0001<<trips>>,1<<km/t rip>>, ARRSUM(Global Other transport)/ARRSUM(Trips))	1-way distance (actually per flight)
Bass Model Other transport.Population		Capita		Initial Global Population	
Bass Model Other transport.Potential adopters		Capita		Initial potential adoptions-Initial Adopters	
Bass Model Other transport.Potential adopters fraction				IF(Limit income fraction<i_minimum,1, IF(Limit income fraction<i_threshold, 1-LN(Limit income fraction*(EXP(Factor k)-1)/Factor k)/Factor k, beta/(Limit income	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.

Name	Dimensions	Unit	Type	Definition	Documentation
				fraction^alpha)))	
Bass Model Other transport.Potential adopters rate				DERIVN(Potential adopters fraction)	
Bass Model Other transport.Potential adopters share			Real	Parent~Other Potential adopters share	This factor determines the share of real adopters in calculating the average income of the travelling population. The remainder is the average for all distance classes of potential adopters
Bass Model Other transport.Potential adoption decline				(Global population death rate*Potential adopters)	
Bass Model Other transport.Potential adoption growth				Individual time constraints other* (Global population birth rate*(Potential adopters fraction*Population)//follow population growth// +Potential adopters rate*Population)//follow potential fraction growth and decline//	
Bass Model Other transport.Price development				Parent~Other travel price corrected	Based on information given by (Grübler et al., 1999) for 1900-1980 and price indexes given by http://www.census.gov/compendia/statab/2010/tables/10s0721.xls for 1990-2010
Bass Model Other transport.Price fraction of personal income			Real	Parent~Other ticket price fraction of personal income	Based this on motorization rate, annual cost for the car, car lifetime; see (Schäfer, 1998)
Bass Model Other transport.Share rich			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R2C2")	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Bass Model Other transport.Social abortion				FOR(i=DIM(Growth from PV)| IF(Social adoption factor*Growth from PV[i]<0<<1/yr>>, -Growth from PV[i],0<<1/yr>>)*Adopters[i]*Social	

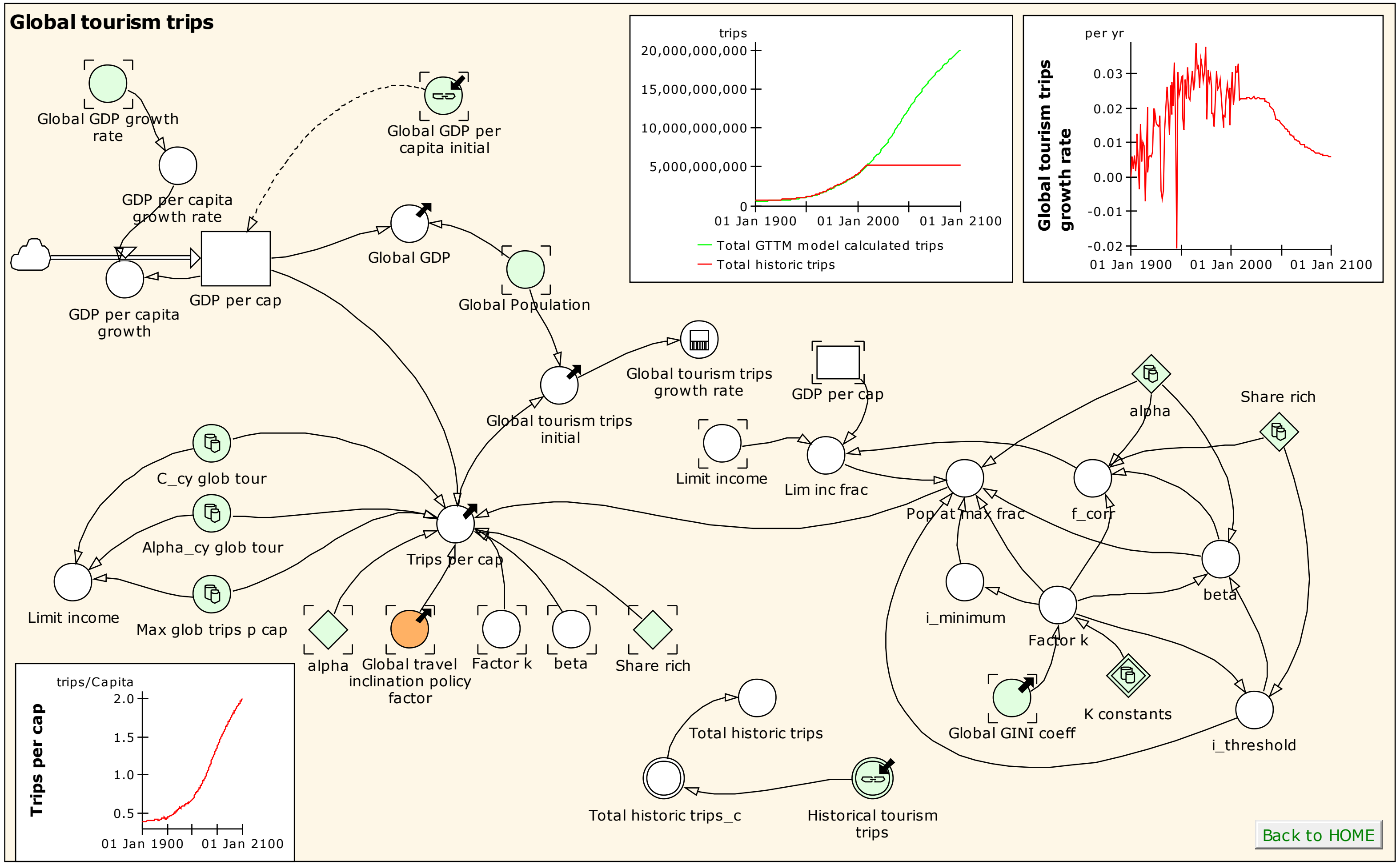
Name	Dimensions	Unit	Type	Definition	Documentation
				adoption factor)	
Bass Model Other transport.Social adoption				FOR(i=DIM(Growth from PV)| IF(Social adoption factor*Growth from PV[i]<0<<1/yr>>,0<<1/yr>>, Growth from PV[i])*Potential adopters[i]*Adopters[i]*Social adoption factor DIVZ0(Adopters[i]+Potential adopters[i]))	
Bass Model Other transport.Social adoption factor			Real	Parent~Other social adoption factor	
Bass Model Other transport.Trips				Adopters*Trips per adoption	
Bass Model Other transport.Trips per adopter		trips/ Capita	Real	2.75	
Bass Model Other transport.Trips per adoption		trips/ Capita	Real	Trips per adopter	
Bass Model Other transport.Tripspa_const_a		trips/USD	Real	0.2623	see CVO trips per capita per mode.xlsx
Bass Model Other transport.Tripspa_const_b		trips/ Capita	Real	-0.3	see CVO trips per capita per mode.xlsx
Bass Model Other transport.X-factor			Real	Parent~Other transport X-factor	

Global tourism trips

Description/task: Calculates the global number of tourist trips

Main inputs: GDP, population, GINI

Main outputs: Number of trips



Name	Dimensions	Unit	Type	Definition	Documentation
alpha			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM	

Name	Dimensions	Unit	Type	Definition	Documentation
				constants", "R3C2")	
Alpha_cy glob tour		trip/USD	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R13C2")// <<trips/USD>>	
beta				(-(i_threshold^alpha))*(LN((i_threshold*(EXP(Factor k)-1))/Factor k)/Factor k-1)	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
C_cy glob tour		trip/ Capita	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R12C2")// <<trip/Capita>>	
f_corr				(Share rich*alpha*EXP((LN(beta/Share rich)/alpha))/(alpha-1)+(EXP(Factor k)*EXP(-Share rich*Factor k)-1)/(EXP(Factor k)-1))	
Factor k				(K constants[a]+K constants[b]*Global GINI coeff+ K constants[c]*Global GINI coeff^2 +K constants[d]*Global GINI coeff^3)/ (K constants[e]+K constants[f]*Global GINI coeff+Global GINI coeff^2)	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
GDP per cap		USD/ Capita	Real	Global GDP per capita initial	taken from (Maddison, 2010).
GDP per capita growth				GDP per cap*GDP per capita growth rate	
GDP per capita growth rate		1/yr		Global GDP growth rate	
Global GDP				GDP per cap*Global Population	
Global GDP growth rate		1/yr		Global_GDP_growth_rates[INDEX(Global_economy_sc_switch)]	
Global GDP per capita initial		USD/ Capita	Real	0	
Global GINI coeff				IF(Global_economy_Gini_switch=0, GINI coeff scenarios[INDEX(Global_economy_sc_switch)], GINI coeff scenarios[INDEX(Global_economy_Gini_switch)])	

Name	Dimensions	Unit	Type	Definition	Documentation
Global Population				Global_Population_UN_Scen[INDEX(Global_pop_sc_switch)]	
Global tourism trips growth rate				DERIVN(Global tourism trips initial)/Global tourism trips initial	
Global tourism trips initial				Global Population*Trips per cap	
Global travel inclination policy factor				IF(Scenario on, GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global travel inclination), 1)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Historical tourism trips	Transport modes	trip	Real	0<<trips>>	
i_minimum				Factor k/(EXP(Factor k)-1)	see Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd
i_threshold				(Factor k*(EXP(-Factor k*(Share rich-1)))/ (EXP(Factor k)-1))	Based on mathcad file Chotikapanig Lorenz solution_NEW_13.xmcd
K constants	k_constants		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R4C3:R9C3")	
Lim inc frac				Limit income/GDP per cap*f_corr	
Limit income		USD/ Capita	Real	(Max glob trips p cap-C_cy glob tour)/Alpha_cy glob tour	
Max glob trips p cap		trip/ Capita	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R14C2")// <<trips/Capita>>	Value based on ((Mulder et al., 2007)) and (Peeters & Landré, 2012).
Pop at max frac				IF(Lim inc frac<i_minimum,1, IF(Lim inc frac<i_threshold, 1-LN(Lim inc frac*(EXP(Factor k)-1)/Factor k)/Factor k, beta/(Lim inc frac^alpha)))	See the mathcad GINI sheet in Chotikapanig Lorenz solution_NEW_13_globalPop.xmcd.
Share rich			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/GTTM constants.xlsx", "GTTM constants", "R2C2")	

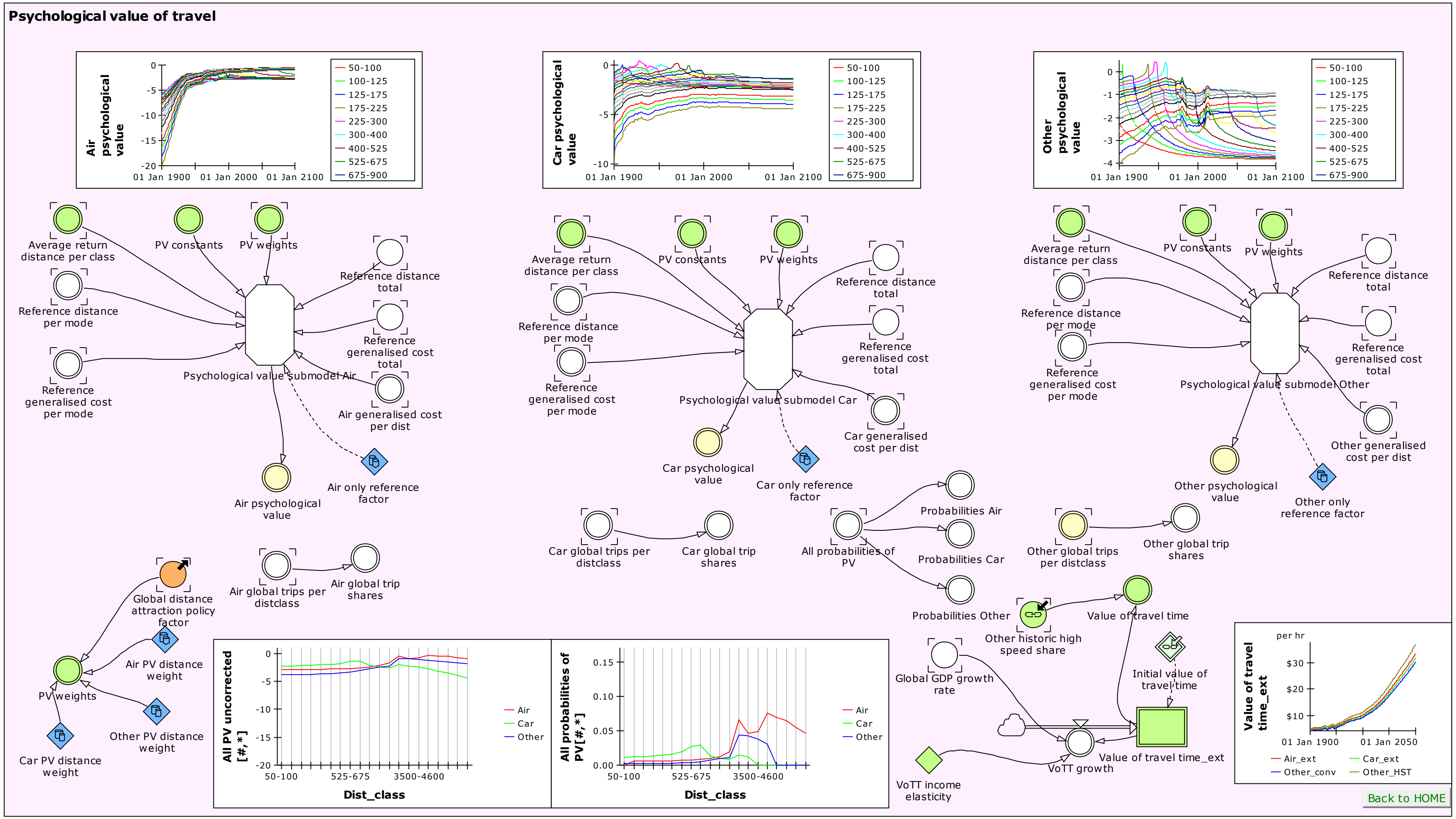
Name	Dimensions	Unit	Type	Definition	Documentation
Total historic trips		trip	Real	Total historic trips_c[Other]	
Total historic trips_c	Transport modes	trip	Real	{Historical tourism trips[Air], Historical tourism trips[Air]+Historical tourism trips[Car], Historical tourism trips[Air]+Historical tourism trips[Car]+Historical tourism trips[Other]}	
Trips per cap				Global travel inclination policy factor* Pop at max frac*Max glob trips p cap +IF(Pop at max frac<Share rich, alpha*(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap) *(Share rich*(beta/Share rich)^(1/alpha)-Pop at max frac*(beta/Pop at max frac)^(1/alpha)) /(alpha-1) +(EXP(Factor k)*EXP(-Share rich*Factor k)-1) *(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap) /(EXP(Factor k)-1), (EXP(Factor k)*EXP(-Pop at max frac*Factor k)-1) *(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap)/(EXP(Factor k)-1))	Based on the GINI procedure.

Psychological value of travel

Description/task: Link PV growth model to PV sub-models

Main inputs: Cost and time data

Main outputs: All PV values



Name	Dimensions	Unit	Type	Definition	Documentation
Air generalised cost per dist				Air travel price corrected+Value of travel time[Air]*Air average travel time	

Name	Dimensions	Unit	Type	Definition	Documentation
Air global trip shares				IF(ARRSUM(Air global trips per distclass)=0<<trips>>,0, Air global trips per distclass/ARRSUM(Air global trips per distclass))	
Air global trips per distclass				Bass Model Air transport.Adopters*Bass Model Air transport.Trips per adoption	
Air only reference factor			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R6C3")	This factor determines the share of the within a transport mode PV based on the individual attribute (dist, time, cost) weighted summed for share of the previous year. 1 = Only air average is reference value 0 = All modes average is reference value
Air psychological value				Psychological value submodel Air.Overall psychological value	The values need to be zero until air transport starts up as theyt impact all growth factors of all modes and distances.
Air PV distance weight			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R8C3")//	
All probabilities of PV				Individual time constraints all* EXP(All PV constrained) /ARRSUM(Individual time constraints all*EXP(All PV constrained))	
Average return distance per class	Dist_class	km/trip	Real	{75,112.5,150,200,262.5,350,462.5,600,787.5,1037.5,1362.5,1787.5,2337.5,3075,4050,5312.5,6975,9175,12062.5,15850}*2<<km/trip>>	These are now the metric averages, but this should be updated with GTTD measured averages for the whole database.
Car generalised cost per dist				Car travel price corrected+Value of travel time[Car]*Car average travel time	
Car global trip shares				Car global trips per distclass/ARRSUM(Car global trips per distclass)	
Car global trips per distclass				Bass Model Car transport.Adopters*Bass Model Car transport.Trips per adoption	
Car only reference factor			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R12C3")	This factor determines the share of the within a transport mode PV based on the individual attribute (dist, time, cost) weighted summed for share of the

Name	Dimensions	Unit	Type	Definition	Documentation
					previous year. 1 = Only car average is reference value 0 = All modes average is reference value
Car psychological value				Psychological value submodel Car.Overall psychological value	
Car PV distance weight			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R14C3")	
Global distance attraction policy factor				IF(Scenario on, GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy distance attraction), 1)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Global GDP growth rate		1/yr		Global_GDP_growth_rates[INDEX(Global_economy_sc_switch)]	
Initial value of travel time	Transport modes ext	USD/hr	Real	10<<USD/hr>>	
Other generalised cost per dist				Other travel price corrected+Value of travel time[Other]*Other average travel time	
Other global trip shares				Other global trips per distclass/ARRSUM(Other global trips per distclass)	
Other global trips per distclass				Bass Model Other transport.Adopters*Bass Model Other transport.Trips per adoption	
Other historic high speed share			Real	0	
Other only reference factor			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R22C3")	This factor determines the share of the within a transport mode PV based on the individual attribute (dist, time, cost) weighted summed for share of the previous year. 1 = Only other average is reference value 0 = All modes average is reference value

Name	Dimensions	Unit	Type	Definition	Documentation
Other psychological value	Dist_class			Psychological value submodel Other.Overall psychological value	
Other PV distance weight			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R24C3")	
Probabilities Air				All probabilities of PV[Air,*]	
Probabilities Car				All probabilities of PV[Car,*]	
Probabilities Other				All probabilities of PV[Other,*]	
Psychological value submodel Air					
Psychological value submodel Car					
Psychological value submodel Other					
PV constants	Psych Value kinds,PV_constants		Real	{{0.4,0.4,-2.5},{0.5,0.5,-2.0}}	based on the labda values given by (Kahneman, 2003, p. 1456). The alpha and beta are first fitted to the excel example (based on http://wiki.dickinson.edu/index.php/Basic_Concepts) assuming lambda to be -2.0. For distance we assume lambda to be a bit higher then for cost and time. However, (al-Nowaihi et al., 2008) have given formal proof that alpha and beta will be the same. Therefore we have chosen to change them all to 0.5, the original value for alpha.

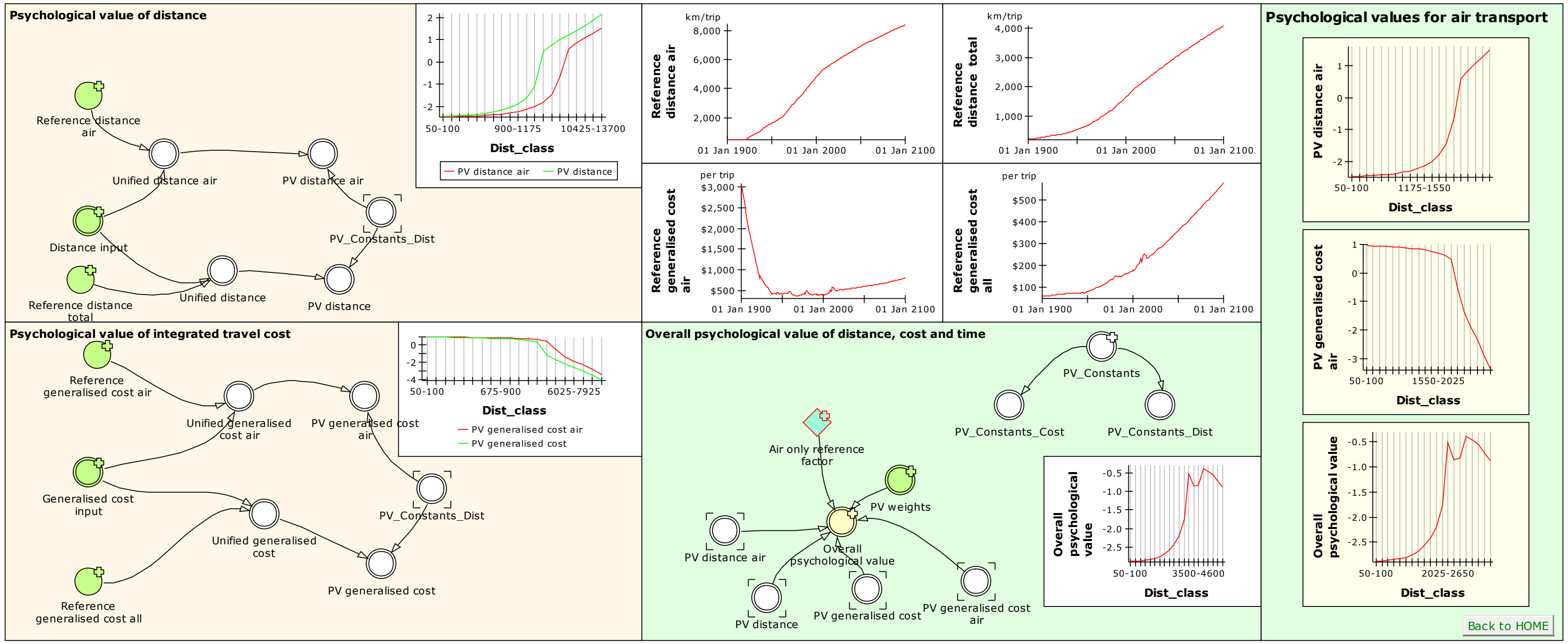
Name	Dimensions	Unit	Type	Definition	Documentation
PV weights	Transport modes, Psych Value kinds			Global distance attraction policy factor* {{Air PV distance weight,1},{Car PV distance weight,1},{Other PV distance weight,1}}	
Reference distance per mode	Transport modes			{Air total global transport,Car total global transport,Other total global transport} DIVZ0{Air global trips,Car global trips,Other global trips}	
Reference distance total				(Air total global transport+Car total global transport+Other total global transport)/ (Air global trips+Car global trips+Other global trips)	
Reference generalised cost per mode	Transport modes			{Air generalised cost,Car generalised cost,Other generalised cost} DIVZ0{Air global trips,Car global trips,Other global trips}	
Reference gerenalised cost total				(Air generalised cost+Car generalised cost+Other generalised cost)/ (Air global trips+Car global trips+Other global trips)	
Value of travel time	Transport modes	USD/ hr	Real	{Value of travel time_ext[Air_ext], Value of travel time_ext[Car_ext], (1-Other historic high speed share)*Value of travel time_ext[Other_conv] +Other historic high speed share*Value of travel time_ext[Other_HST]}	
Value of travel time_ext	Transport modes ext	USD/ hr	Real	Initial value of travel time	
VoTT growth				VoTT income elasticity*Global GDP growth rate*Value of travel time_ext	
VoTT income elasticity			Real	0.5	see (Gunn, 2008) for .5 elasticity value (page 513). (Roman et al., 2007) is also involved in this

Psychological value submodel Air

Description/task: Calculate PV per distance class Air

Main inputs: Air cost, time ref. cost/distance

Main outputs: Air PV per distance class



Name	Dimensions	Unit	Type	Definition	Documentation
Psychological value submodel Air.Air only reference factor			Real	Parent~Air only reference factor	1 = Only mode average is reference value 0 = All modes average is reference value
Psychological value submodel Air.Distance input	Dist_class	km/trip	Real	Parent~Average return distance per class	
Psychological value submodel Air.Generalised cost input	Dist_class			Parent~Air generalised cost per dist	
Psychological value submodel Air.Overall psychological value				Air only reference factor* (PV weights[Air,PV_Distance]*PV distance air+ PV weights[Air,PV_Cost]*PV generalised cost air)+	

Name	Dimensions	Unit	Type	Definition	Documentation
				(1-Air only reference factor)* (PV weights[Air,PV_Distance]*PV distance+ PV weights[Air,PV_Cost]*PV generalised cost)	
Psychological value submodel Air.PV distance				FOR(i=DIM(Unified distance,1)| IF(Unified distance[i]>0 ,Unified distance[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified distance[i])^PV_Constants_Dist[Beta]))	The constants have been created for a standardised psychological value as was based on example given on http://wiki.dickinson.edu/index.php/Basic_Concepts and fitted using FindGraph (see gain and loss files in documentation directory).
Psychological value submodel Air.PV distance air				FOR(i=DIM(Unified distance air,1)| IF(Unified distance air[i]>0 ,Unified distance air[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified distance air[i])^PV_Constants_Dist[Beta]))	Ibid.
Psychological value submodel Air.PV generalised cost				FOR(i=DIM(Unified generalised cost,1)| IF(Unified generalised cost[i]>0 ,Unified generalised cost[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified generalised cost[i])^PV_Constants_Dist[Beta]))	Ibid.
Psychological value submodel Air.PV generalised cost air				FOR(i=DIM(Unified generalised cost air,1)| IF(Unified generalised cost air[i]>0 ,Unified generalised cost air[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified generalised cost air[i])^PV_Constants_Dist[Beta]))	Ibid.
Psychological value submodel Air.PV weights				Parent~PV weights	
Psychological value submodel Air.PV_Constants	Psych Value kinds, PV_constants		Real	Parent~PV constants	
Psychological value submodel Air.PV_Constants_Cost	PV_constants		Real	PV_Constants[PV_Cost]	

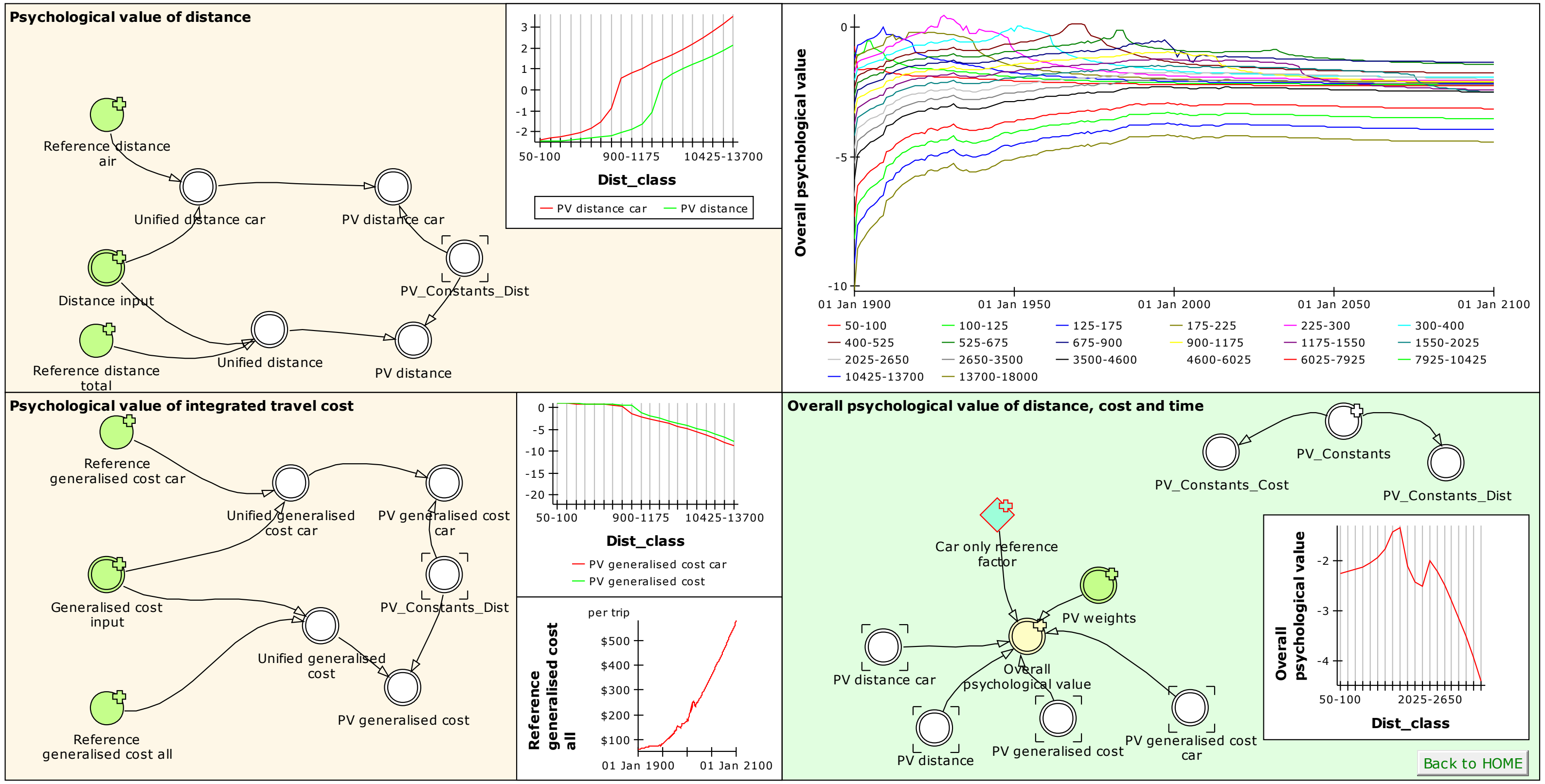
Name	Dimensions	Unit	Type	Definition	Documentation
Psychological value submodel Air.PV_Constants_Dist	PV_constants		Real	PV_Constants[PV_Distance]	
Psychological value submodel Air.Reference distance total		km/trip		Parent~Reference distance total	Here the average over all modes is initially assumed; this ignores that the reference may differ in the minds between different transport modes and thus distort the calculation; experiment may give a solution here; alternative is the average of the mode itself as reference value (e.g. people expect air transport to be used for longer trips at low cost)
Psychological value submodel Air.Reference distance air				Parent~Reference distance per mode[Air]	Ibid.
Psychological value submodel Air.Reference generalised cost air				Parent~Reference generalised cost per mode[Air]	Ibid.
Psychological value submodel Air.Reference generalised cost all				Parent~Reference gerenalised cost total	Ibid.
Psychological value submodel Air.Unified distance				(Distance input-Reference distance total)/Reference distance total	The 0-1 positive scale for distance above reference
Psychological value submodel Air.Unified distance air				(Distance input-Reference distance air)DIVZ0Reference distance air	Ibid.
Psychological value submodel Air.Unified generalised cost				(Reference generalised cost all-Generalised cost input)DIVZ0Reference generalised cost all	Ibid.
Psychological value submodel Air.Unified generalised cost air				(Reference generalised cost air-Generalised cost input)DIVZ0Reference generalised cost air	Ibid.

Psychological value submodel Car

Description/task: Calculate PV per distance class Car

Main inputs: Car cost, time ref. cost/distance

Main outputs: Car PV per distance class



Name	Dimensions	Unit	Type	Definition	Documentation
Psychological value submodel Car.Car			Real	Parent~Car only reference factor	1 = Only mode average is reference value 0 = All modes average is reference value

Name	Dimensions	Unit	Type	Definition	Documentation
only reference factor					
Psychological value submodel Car.Distance input	Dist_class	km/trip	Real	Parent~Average return distance per class	
Psychological value submodel Car.Generalised cost input	Dist_class			Parent~Car generalised cost per dist	
Psychological value submodel Car.Overall psychological value				Car only reference factor* (PV weights[Car,PV_Distance]*PV distance car+ PV weights[Car,PV_Cost]*PV generalised cost car)+ (1-Car only reference factor)* (PV weights[Car,PV_Distance]*PV distance+ PV weights[Car,PV_Cost]*PV generalised cost)	
Psychological value submodel Car.PV distance				FOR(i=DIM(Unified distance,1)| IF(Unified distance[i]>0 ,Unified distance[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified distance[i])^PV_Constants_Dist[Beta]))	The constants have been created for a standardised psychological value as was based on example given on http://wiki.dickinson.edu/index.php/Basic_Concepts and fitted using FindGraph (see gain and loss files in documentation directory).
Psychological value submodel Car.PV distance car				FOR(i=DIM(Unified distance car,1)| IF(Unified distance car[i]>0 ,Unified distance car[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified distance car[i])^PV_Constants_Dist[Beta]))	Ibid.
Psychological value submodel Car.PV generalised cost				FOR(i=DIM(Unified generalised cost,1)| IF(Unified generalised cost[i]>0 ,Unified generalised cost[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified generalised cost[i])^PV_Constants_Dist[Beta]))	Ibid.
Psychological value submodel Car.PV generalised cost car				FOR(i=DIM(Unified generalised cost car,1)| IF(Unified generalised cost car[i]>0 ,Unified generalised cost car[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified	Ibid.

Name	Dimensions	Unit	Type	Definition	Documentation
				generalised cost car[i])^PV_Constants_Dist[Beta]))	
Psychological value submodel Car.PV weights				Parent~PV weights	
Psychological value submodel Car.PV_Constants	Psych Value kinds, PV_constants		Real	Parent~PV constants	
Psychological value submodel Car.PV_Constants_Cost	PV_constants		Real	PV_Constants[PV_Cost]	
Psychological value submodel Car.PV_Constants_Dist	PV_constants		Real	PV_Constants[PV_Distance]	
Psychological value submodel Car.Reference distance total		km/trip		Parent~Reference distance total	Here the average over all modes is initially assumed; this ignores that the reference may differ in the minds between different transport modes and thus distort the calculation; experiment may give a solution here; alternative is the average of the mode itself as reference value (e.g. people expect air transport to be used for longer trips at low cost)
Psychological value submodel Car.Reference distance air				Parent~Reference distance per mode[Car]	Ibid.
Psychological value submodel Car.Reference generalised cost all				Parent~Reference gerenalised cost total	Ibid.
Psychological value submodel Car.Reference generalised cost car				Parent~Reference generalised cost per mode[Car]	Ibid.

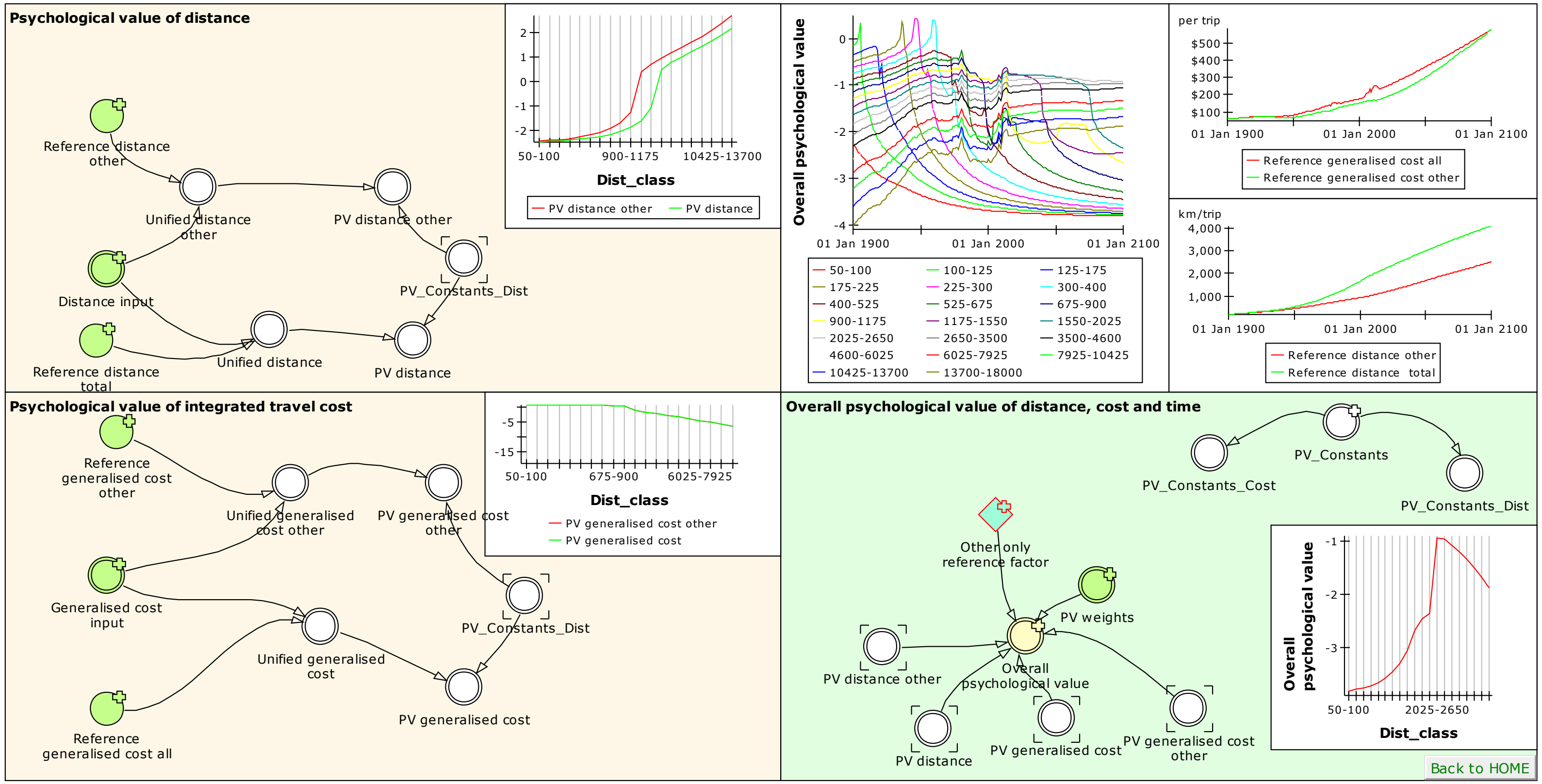
Name	Dimensions	Unit	Type	Definition	Documentation
Psychological value submodel Car.Unified distance				(Distance input-Reference distance total)/Reference distance total	The 0-1 positive scale for distance above reference
Psychological value submodel Car.Unified distance car				(Distance input-Reference distance air)/Reference distance air	Ibid.
Psychological value submodel Car.Unified generalised cost				(Reference generalised cost all-Generalised cost input)/Reference generalised cost all	Ibid.
Psychological value submodel Car.Unified generalised cost car				(Reference generalised cost car-Generalised cost input)/Reference generalised cost car	Ibid.

Psychological value submodel Other

Description/task: Calculate PV per distance class Other

Main inputs: Other cost, time ref. cost/distance

Main outputs: Other PV per distance class



Name	Dimensions	Unit	Type	Definition	Documentation
Psychological value submodel Other.Distance input	Dist_class	km/trip	Real	Parent~Average return distance per class	
Psychological value submodel Other.Generalised cost input	Dist_class			Parent~Other generalised cost per dist	
Psychological value submodel Other.Other only reference factor			Real	Parent~Other only reference factor	1 = Only mode average is reference value 0 = All modes average is reference value

Name	Dimensions	Unit	Type	Definition	Documentation
Psychological value submodel Other.Overall psychological value				Other only reference factor* (PV weights[Other,PV_Distance]*PV distance other+ PV weights[Other,PV_Cost]*PV generalised cost other)+ (1-Other only reference factor)* (PV weights[Other,PV_Distance]*PV distance+ PV weights[Other,PV_Cost]*PV generalised cost)	
Psychological value submodel Other.PV distance				FOR(i=DIM(Unified distance,1)| IF(Unified distance[i]>0 ,Unified distance[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified distance[i])^PV_Constants_Dist[Beta]))	The constants have been created for a standardised psychological value as was based on example given on http://wiki.dickinson.edu/index.php/ Basic_Concepts and fitted using FindGraph (see gain and loss files in documentation directory).
Psychological value submodel Other.PV distance other				FOR(i=DIM(Unified distance other,1)| IF(Unified distance other[i]>0 ,Unified distance other[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified distance other[i])^PV_Constants_Dist[Beta]))	Ibid.
Psychological value submodel Other.PV generalised cost				FOR(i=DIM(Unified generalised cost,1)| IF(Unified generalised cost[i]>0 ,Unified generalised cost[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified generalised cost[i])^PV_Constants_Dist[Beta]))	Ibid.
Psychological value submodel Other.PV generalised cost other				FOR(i=DIM(Unified generalised cost other,1)| IF(Unified generalised cost other[i]>0 ,Unified generalised cost other[i]^PV_Constants_Dist[Alpha] ,PV_Constants_Dist[Labda]*ABS(Unified generalised cost other[i])^PV_Constants_Dist[Beta]))	Ibid.
Psychological value submodel Other.PV weights				Parent~PV weights	
Psychological value submodel Other.PV_Constants	Psych Value kinds, PV_constants		Real	Parent~PV constants	
Psychological value submodel	PV_constants		Real	PV_Constants[PV_Cost]	

Name	Dimensions	Unit	Type	Definition	Documentation
Other.PV_Constants_Cost					
Psychological value submodel Other.PV_Constants_Dist	PV_constants		Real	PV_Constants[PV_Distance]	
Psychological value submodel Other.Reference distance total		km/trip		Parent~Reference distance total	Here the average over all modes is initially assumed; this ignores that the reference may differ in the minds between different transport modes and thus distort the calculation; experiment may give a solution here; alternative is the average of the mode itself as reference value (e.g. people expect air transport to be used for longer trips at low cost)
Psychological value submodel Other.Reference distance other				Parent~Reference distance per mode[Other]	Ibid.
Psychological value submodel Other.Reference generalised cost all				Parent~Reference gerenalised cost total	Ibid.
Psychological value submodel Other.Reference generalised cost other				Parent~Reference generalised cost per mode[Other]	Ibid.
Psychological value submodel Other.Unified distance				(Distance input-Reference distance total)/Reference distance total	The 0-1 positive scale for distance above reference
Psychological value submodel Other.Unified distance other				(Distance input-Reference distance other)/Reference distance other	Ibid.
Psychological value submodel Other.Unified generalised cost				(Reference generalised cost all-Generalised cost input)/Reference generalised cost all	Ibid.

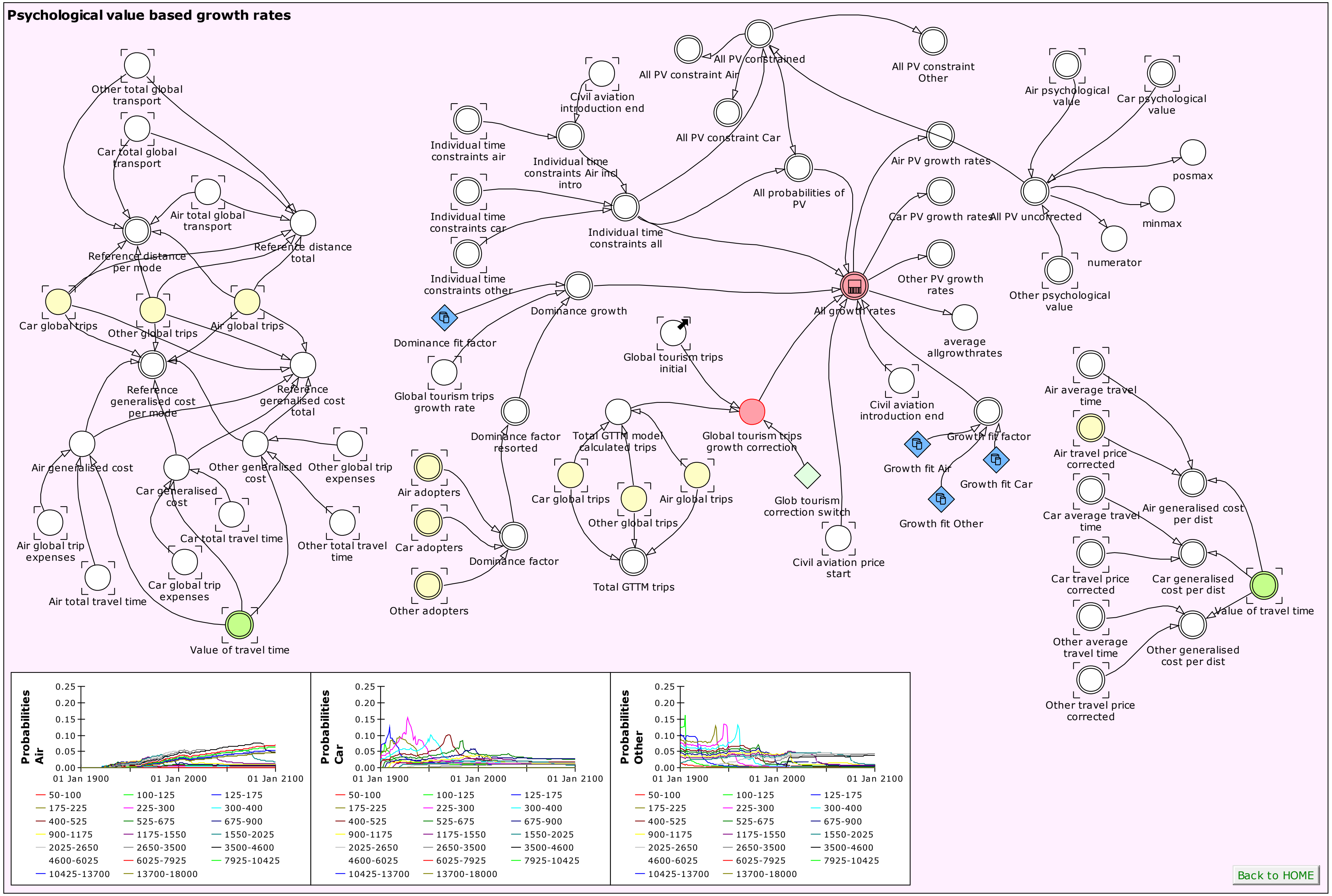
Name	Dimensions	Unit	Type	Definition	Documentation
Psychological value submodel Other.Unified generalised cost other				(Reference generalised cost other-Generalised cost input)/Reference generalised cost other	Ibid.

Psychological value based growth rate

Description/task: Prepare data for the Psychological value sub-models and collect results

Main inputs: Trips per distance class and mode

Main outputs: All PV growth rates



Psychological value based growth rates
Other total global transport
Car total global transport
Air total global transport
Reference distance per mode
Reference distance total
Car global trips
Other global trips
Air global trips
Reference generalised cost per mode
Reference generalised cost total
Air generalised cost
Car generalised cost
Other generalised cost
Other global trip expenses
Air global trip expenses
Car total travel time
Other total travel time
Air total travel time
Car global trip expenses
Value of travel time
Individual time constraints air
Civil aviation introduction end
Individual time constraints Air incl intro
Individual time constraints car
Individual time constraints all
Individual time constraints other
All PV constraint Air
All PV constrained
All PV constraint Car
All PV constraint Other
All probabilities of PV
Air PV growth rates
Car PV growth rates
Other PV growth rates
All PV uncorrected
Air psychological value
Car psychological value
Other psychological value
posmax
minmax
numerator
Dominance fit factor
Dominance growth
All growth rates
average allgrowthrates
Global tourism trips growth rate
Global tourism trips initial
Dominance factor resorted
Total GTTM model calculated trips
Global tourism trips growth correction
Civil aviation introduction end
Growth fit factor
Growth fit Air
Growth fit Car
Growth fit Other
Glob tourism correction switch
Civil aviation price start
Air adopters
Car adopters
Other adopters
Dominance factor
Car global trips
Other global trips
Air global trips
Total GTTM trips
Air average travel time
Air travel price corrected
Air generalised cost per dist
Car average travel time
Car travel price corrected
Car generalised cost per dist
Value of travel time
Other average travel time
Other generalised cost per dist
Other travel price corrected
Probabilities Air
Probabilities Car
Probabilities Other
0.25
0.20
0.15
0.10
0.05
0.00
01 Jan 1900
01 Jan 2000
01 Jan 2100
50-100
100-125
125-175
175-225
225-300
300-400
400-525
525-675
675-900
900-1175
1175-1550
1550-2025
2025-2650
2650-3500
3500-4600
4600-6025
6025-7925
7925-10425
10425-13700
13700-18000
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Air adopters				Bass Model Air transport.Adopters	
Air average travel time				IF(Air average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Air average trip speed)	Return time in hours
Air generalised cost				Air global trip expenses+Value of travel time[Air]*Air total travel time	
Air generalised cost per dist				Air travel price corrected+Value of travel time[Air]*Air average travel time	
Air global trip expenses				ARRSUM(Air global trips per distclass*Air travel price corrected)	
Air global trips				ARRSUM(Bass Model Air transport.Trips)	
Air psychological value				Psychological value submodel Air.Overall psychological value	The values need to be zero until air transport starts up as they impact all growth factors of all modes and distances.
Air PV growth rates				All growth rates[Air]	
Air total global transport				ARRSUM(Air global transport)	
Air total travel time		yr		Air global average travel time*Air global trips	
Air travel price corrected				Bass Model Air transport.Air travel price corrected	
All growth rates				IF((Civil aviation price startAND NOTCivil aviation introduction end),0,1)* Individual time constraints all* Growth fit factor*DERIVN(All probabilities of PV)+ (Global tourism trips growth correction/1<<yr>>)+Dominance growth	
All probabilities of PV				Individual time constraints all* EXP(All PV constrained) /ARRSUM(Individual time constraints all*EXP(All PV constrained))	
All PV				FOR(i=DIM(All PV uncorrected,1),j=DIM(All PV	

Name	Dimensions	Unit	Type	Definition	Documentation
constrained				uncorrected,2)| IF(Individual time constraints all[i,j]=0,ARRMIN(All PV uncorrected),All PV uncorrected[i,j]))	
All PV constraint Air				All PV constrained[Air,*]	
All PV constraint Car				All PV constrained[Car,*]	
All PV constraint Other				All PV constrained[Other,*]	
All PV uncorrected	Transport modes, Dist_class			{Air psychological value,Car psychological value,Other psychological value}	
average allgrowthrates				ARRAVERAGE(All growth rates)	
Car adopters				Bass Model Car transport.Adopters	
Car average travel time				IF(Car average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Car average trip speed)	return travel time
Car generalised cost				Car global trip expenses+Value of travel time[Car]*Car total travel time	
Car generalised cost per dist				Car travel price corrected+Value of travel time[Car]*Car average travel time	
Car global trip expenses				ARRSUM(Car global trips per distclass*Car travel price corrected)	
Car global trips				ARRSUM(Bass Model Car transport.Trips)	
Car psychological value				Psychological value submodel Car.Overall psychological value	
Car PV growth rates				All growth rates[Car]	
Car total global transport				ARRSUM(Car global transport)	

Name	Dimensions	Unit	Type	Definition	Documentation
Car total travel time		yr		Car global average travel time*Car global trips	Multiply with 2 as all times are one-way.
Car travel price corrected				Car variable price*Average return distance per class	
Civil aviation introduction end				IF(YEAR(TIME)>Civil aviation introduction year+1,TRUE,FALSE)	This variable triggers the introduction of civil air transport at the year set in the linked constant. This is necessary because of the fact that before a certain year civil air transport has not been on offer.
Civil aviation price start				IF(YEAR(TIME)>Civil aviation introduction year-1,TRUE,FALSE)	This year triggers the cost of air transport calculation, 1 year ahead of the start of air transport in the model, because otherwise the triggering itself would strongly affect the transport volume in the wrong way.
Dominance factor	Dist_class, Transport modes			FOR(i=DIM(Air adopters)| {IF(Air adopters[i]=MAX(Air adopters[i],Car adopters[i],Other adopters[i]), Air adopters[i]DIVZ0(Air adopters[i]+Car adopters[i]+Other adopters[i]), IF(Air adopters[i]=MIN(Air adopters[i],Car adopters[i],Other adopters[i]), -Air adopters[i]DIVZ0(Air adopters[i]+Car adopters[i]+Other adopters[i]),0)), IF(Car adopters[i]=MAX(Air adopters[i],Car adopters[i],Other adopters[i]), Car adopters[i]DIVZ0((Air adopters[i]+Car adopters[i]+Other adopters[i])), IF(Car adopters[i]=MIN(Air adopters[i],Car adopters[i],Other adopters[i]), -Car adopters[i]DIVZ0(Air adopters[i]+Car adopters[i]+Other adopters[i]),0)), IF(Other adopters[i]=MAX(Air adopters[i],Car adopters[i],Other adopters[i]), Other adopters[i]DIVZ0((Air adopters[i]+Car adopters[i]+Other adopters[i])), IF(Other adopters[i]=MIN(Air adopters[i],Car adopters[i],Other adopters[i]), -Other adopters[i]DIVZ0(Air adopters[i]+Car adopters[i]+Other adopters[i]),0))})	The attraction of certain markets is not only a function of its direct attributes, but might also be a function of its position within choices and the size of the market (Simonson, 1989). The first effect is coined the 'compromise' effect, in which a product with 'middle' attributes has more attraction at the cost of product with more extreme attributes. The latter effect is known as the 'market dominance attraction'. Part of this effect is caused by a reduction of abandon rates, because that entails "extremely large switching costs that deter consumers from adopting new alternatives even if they are superior" (Lee & O'Connor, 2003). But dominant products also have a higher attraction as a choice for such a dominant product is more easily justified towards

Name	Dimensions	Unit	Type	Definition	Documentation
					one's peers (Simonson, 1989).
Dominance factor resorted				FOR(i=DIM(Dominance factor,2),j=DIM(Dominance factor,1)| Dominance factor[j,i])	Ibid.
Dominance fit factor			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R18C3")	Ibid.
Dominance growth				Dominance fit factor* FOR(i=DIM(Dominance factor resorted,1),j=DIM(Dominance factor resorted,2)| IF(Dominance factor resorted[i,j]=0,0<<1/yr>>, Global tourism trips growth rate*(Dominance factor resorted[i,j])))	
Glob tourism correction switch			Real	0.2	1 = correction 0 = no correction
Global tourism trips growth correction				Glob tourism correction switch*(Global tourism trips initial-Total GTTM model calculated trips)/Global tourism trips initial	
Global tourism trips growth rate				DERIVN(Global tourism trips initial)/Global tourism trips initial	
Global tourism trips initial				Global Population*Trips per cap	
Growth fit Air			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R19C3")	
Growth fit Car			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R20C3")	
Growth fit factor	Transport modes,		Real	{{Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit	

Name	Dimensions	Unit	Type	Definition	Documentation
	Dist_class			Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air,Growth fit Air}, {Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car,Growth fit Car}, {Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other,Growth fit Other}}	
Growth fit Other			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v50/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R21C3")	
Individual time constraints air	Dist_class			FOR(i=DIM(Air average travel time)| Supress shortest air distance[i]* MAX(0,MIN(1,1.25*Time constraint air/(1.25*Time constraint air-Time constraint air) +Air average travel time[i]/(Time constraint air-1.25*Time constraint air))))	
Individual time constraints Air incl intro				FOR(i=DIM(Individual time constraints air)| IF(Civil aviation introduction end,Individual time constraints air[i],0))	
Individual time constraints all	Transport modes, Dist_class			{Individual time constraints Air incl intro,Individual time constraints car,Individual time constraints other}	
Individual time constraints car	Dist_class			FOR(i=DIM(Car average travel time)| Car lower class attraction limit[i]* MAX(0,MIN(1,1.25*Time constraint car/(1.25*Time constraint car-Time constraint car) +Car average travel time[i]/(Time constraint car-1.25*Time constraint car))))	

Name	Dimensions	Unit	Type	Definition	Documentation
Individual time constraints other	Dist_class			FOR(i=DIM(Other average travel time)| MAX(0,MIN(1,1.25*Time constraint other/(1.25*Time constraint other-Time constraint other) +Other average travel time[i]/(Time constraint other-1.25*Time constraint other))))	
minmax				ARRMIN(All PV uncorrected)	
numerator				MAX(ARRMAX(All PV uncorrected),ABS(ARRMIN(All PV uncorrected)))	
Other adopters				Bass Model Other transport.Adopters	
Other average travel time				IF(Other average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Other average trip speed)	return travel times
Other generalised cost				Other global trip expenses+Value of travel time[Other]*Other total travel time	
Other generalised cost per dist				Other travel price corrected+Value of travel time[Other]*Other average travel time	
Other global trip expenses				ARRSUM(Other global trips per distclass*Other travel price corrected)	
Other global trips				ARRSUM(Bass Model Other transport.Trips)	
Other psychological value	Dist_class			Psychological value submodel Other.Overall psychological value	
Other PV growth rates				All growth rates[Other]	
Other total global transport				ARRSUM(Other global transport)	
Other total travel time		yr		Other global average travel time*Other global trips	total travel time
Other travel price corrected				IF(Scenario on,1+Global ticket tax Other,1)* (Other ticket price historical +Global carbon tax ticket cost[Car]) *Average return distance per class	
posmax				ARRMAX(All PV uncorrected)	

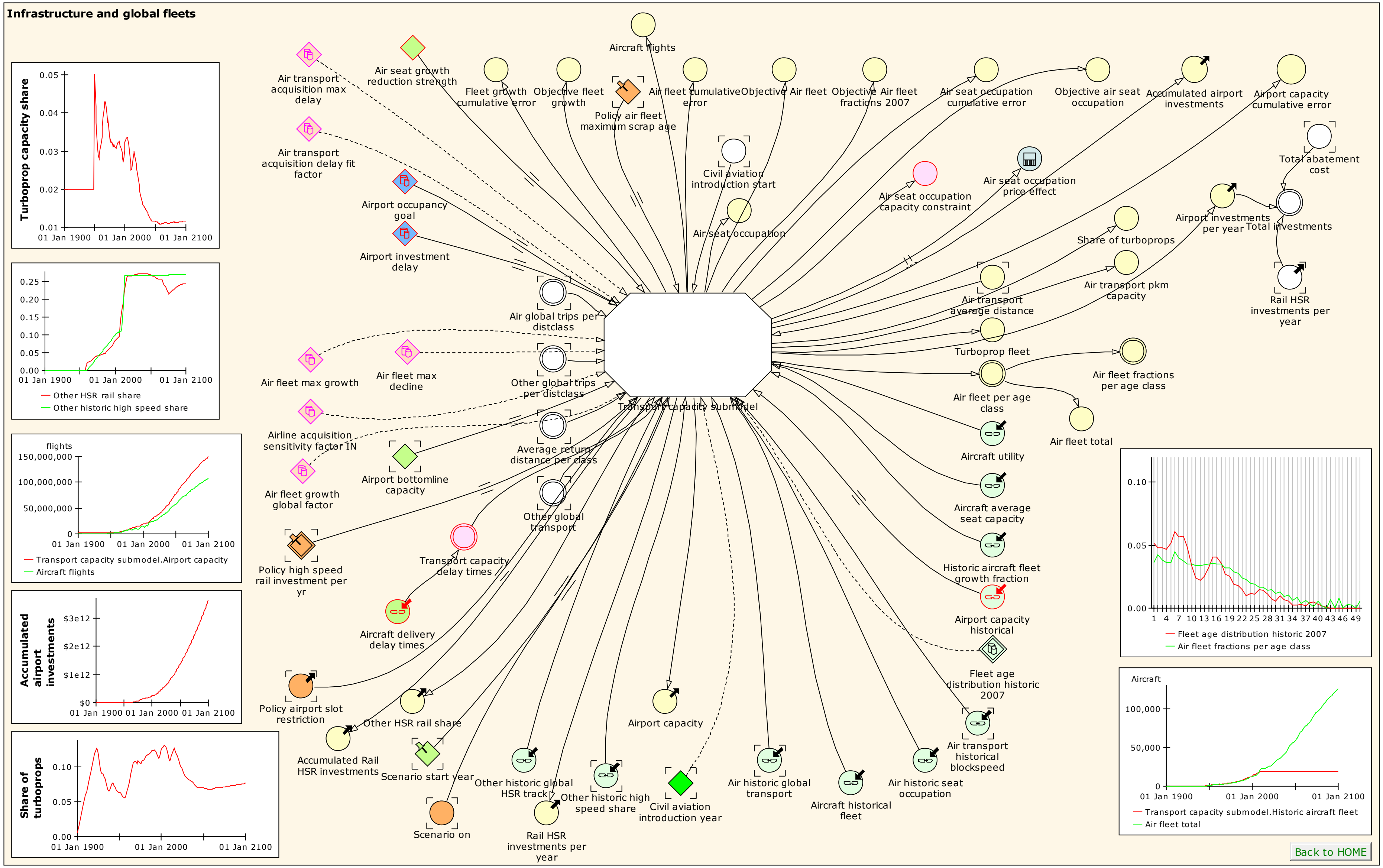
Name	Dimensions	Unit	Type	Definition	Documentation
Reference distance per mode	Transport modes			{Air total global transport,Car total global transport,Other total global transport} DIVZ0{Air global trips,Car global trips,Other global trips}	
Reference distance total				(Air total global transport+Car total global transport+Other total global transport)/ (Air global trips+Car global trips+Other global trips)	
Reference generalised cost per mode	Transport modes			{Air generalised cost,Car generalised cost,Other generalised cost} DIVZ0{Air global trips,Car global trips,Other global trips}	
Reference gerenalised cost total				(Air generalised cost+Car generalised cost+Other generalised cost)/ (Air global trips+Car global trips+Other global trips)	
Total GTTM model calculated trips				Air global trips+Car global trips+Other global trips	
Total GTTM trips	Transport modes			{Air global trips, Air global trips+Car global trips, Air global trips+Car global trips+Other global trips}	
Value of travel time	Transport modes			{Value of travel time_ext[Air_ext], Value of travel time_ext[Car_ext], (1-Other historic high speed share)*Value of travel time_ext[Other_conv] +Other historic high speed share*Value of travel time_ext[Other_HST]}	

Infrastructure and global fleets

Description/task: Organise inputs sub-model

Main inputs: Air and 'other' transport volumes

Main outputs: Air seat occupation, airport capacity, investments


Infrastructure and global fleets
Turbopropo capacity share
Other HSR rail share
Other historic high speed share
flights
Transport capacity submodel.Airport capacity
Aircraft flights
Accumulated airport investments
Share of turboprops
Air transport acquisition max delay
Air seat growth reduction strength
Fleet growth cumulative error
Objective fleet growth
Aircraft flights
Policy air fleet maximum scrap age
Air fleet cumulative error
Objective Air fleet
Objective Air fleet fractions 2007
Air seat occupation cumulative error
Objective air seat occupation
Accumulated airport investments
Airport capacity cumulative error
Total abatement cost
Air transport acquisition delay fit factor
Civil aviation introduction start
Air seat occupation capacity constraint
Air seat occupation price effect
Airport occupancy goal
Air seat occupation
Airport investments per year
Total investments
Share of turboprops
Airport investment delay
Air global trips per distclass
Air transport average distance
Air transport pkm capacity
Rail HSR investments per year
Air fleet max growth
Air fleet max decline
Other global trips per distclass
Turboprop fleet
Air fleet fractions per age class
Air fleet per age class
Transport capacity submodel
Air fleet total
Airline acquisition sensitivity factor IN
Average return distance per class
Aircraft utility
Air fleet growth global factor
Airport bottomline capacity
Other global transport
Aircraft average seat capacity
Historic aircraft fleet growth fraction
Policy high speed rail investment per yr
Transport capacity delay times
Airport capacity historical
Aircraft delivery delay times
Fleet age distribution historic 2007
Fleet age distribution historic 2007
Air fleet fractions per age class
Policy airport slot restriction
Other HSR rail share
Airport capacity
Accumulated Rail HSR investments
Scenario start year
Other historic global HSR track
Other historic high speed share
Civil aviation introduction year
Air historic global transport
Aircraft historical fleet
Air historic seat occupation
Air transport historical blockspeed
Scenario on
Rail HSR investments per year
Aircraft
Transport capacity submodel.Historic aircraft fleet
Air fleet total
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Accumulated airport investments		USD	Real	Transport capacity submodel.Accumulated airport investments	
Accumulated Rail HSR investments		USD	Real	Transport capacity submodel.Accumulated Rail HSR investments	
Air fleet cumulative error			Real	Transport capacity submodel.Air fleet cumulative error	
Air fleet fractions per age class	Vehicle Age		Real	Air fleet per age class/ ARRSUM(Air fleet per age class)	
Air fleet growth global factor			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R56C3")	
Air fleet max decline			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R57C3")	This maximum has been installed to avoid over reaction of the system. Bit of a risk in large change situations!
Air fleet max growth			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R58C3")	Ibid.
Air fleet per age class	Vehicle Age	Aircraft	Real	Transport capacity submodel.Aircraft fleet	
Air fleet total		Aircraft	Real	ARRSUM(Air fleet per age class)	
Air global trips per distclass				Bass Model Air transport.Adopters*Bass Model Air transport.Trips per adoption	
Air historic global transport		km	Real	0	
Air historic seat occupation			Real	0.5	
Air seat growth reduction strength			Real	0.25	This factor determines the minimum cost effect of scarcity of air transport capacity. When at 1 it will go to zero meaning it will increase price by a maxed factor of 200. A

Name	Dimensions	Unit	Type	Definition	Documentation
					better setting is for instance 0.35 meaning it limits the cost factor by 1/(1-0.35)=1.67. A low value avoids too much instability in the market when restricting for instance airport capacity. Therefore we chose 0.25.
Air seat occupation				Transport capacity submodel.Air seat occupation	
Air seat occupation capacity constraint				Transport capacity submodel.Air seat occupation capacity constraint	
Air seat occupation cumulative error			Real	Transport capacity submodel.Air seat occupation cumulative error	
Air seat occupation price effect				SLIDINGAVERAGE(Transport capacity submodel.Air seat occupation growth price effect ,9<<yr>>)	Keep the sliding average as is to avoid the oscillations when reducing airport capacity.
Air transport acquisition delay fit factor			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R60C3")	This maximum has been installed to avoid over reaction of the system. Bit of a risk in large change situations!
Air transport acquisition max delay		yr	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R61C3")<<yr>>	Ibid.
Air transport average distance				Bass Model Air transport.Overall average distance	
Air transport historical blockspeed		km/hr	Real	0	
Air transport pkm capacity		km	Real	Transport capacity submodel.Air transport skm capacity	Fleet times hours per aircraft gives total hours... times speed gives total km 'Total aircraft' (AC)*'Air average seat capacity' (seat/AC) gives total seats *'Aircraft Utility'

Name	Dimensions	Unit	Type	Definition	Documentation
					(hr/AC)*'Aircraft historical block speed' (km/hr) gives seatkm/AC. We need km, therefore a 'Aircraft seat unit conversion' (aircraft/seat) is required to multiply with. Actually the Aircraft utility should have been in hr/seat to solve this problem directly.
Aircraft average seat capacity		seat/Aircraft	Real	0<<seats/Aircraft>>	
Aircraft delivery delay times		yr	Real	1<<yr>>	
Aircraft flights				Transport capacity submodel.Aircraft flights	
Aircraft historical fleet		Aircraft	Real	0<<Aircraft>>	
Aircraft utility		hr/Aircraft	Real	1<<hr/Aircraft>>	This series is based upon fleet data from AERO ((Pulles et al., 2002)) for jets and ATA data ((ATA, 1950)) for the pistons, assuming a linear transition between 1950 and 1980.
Airline acquisition sensitivity factor IN			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R62C3")	This constant factors the strength of the airline reaction. At below 0.7 it cause a restriction on traffic growth in 1925-1927 and one instant around 1950s. High values cause large excursions from the historical fleet development, though on average OK. Therefore have chosen the lowest value with no limitation in traffic growth after 1930.
Airport bottomline capacity		flight	Real	10000000<<flights>> //Always set also the infrastrucure policy input graph to a minum of the value above!	To avoid zero or negative airport capacity we've set this at 1 million flights worldwide.
Airport capacity		flight	Real	Transport capacity submodel.Airport capacity	
Airport capacity cumulative error			Real	Transport capacity submodel.Airport capacity cumulative error	

Name	Dimensions	Unit	Type	Definition	Documentation
Airport capacity historical		flight	Real	1<<flight>>	
Airport investment delay		yr	Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R67C3")<<yr>>	
Airport investments per year				Transport capacity submodel.Airport investments per year	
Airport occupancy goal			Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Analyses variables input.xlsx", "Decision_values", "R69C3")	
Average return distance per class	Dist_class	km/trip	Real	{75,112.5,150,200,262.5,350,462.5,600,787.5,1037.5,1362.5,1787.5,2337.5,3075,4050,5312.5,6975,9175,12062.5,15850}*2<<km/trip>>	These are now the metric averages, but this should be updated with GTTD measured averages for the whole database.
Civil aviation introduction start			Logical	IF(YEAR(TIME)>Civil aviation introduction year-1,TRUE,FALSE) //For fleet reproduction set at -1 year.	This variable triggers the introduction of civil air transport at the year set in the linked constant. This is necessary because of the fact that before a certain year civil air transport has not been on offer.
Civil aviation introduction year			Real	1920	This year defines the moment that serious supply of air transport is introduced into the market; before this date the model keeps air transport and adopters at zero. It is connected to two events: 'Civil aviation start' triggering civil aviation supply and 'Civil aviation cost start', which runs one year ahead and avoids the cost trigger to heavily and inadvertently affect air transport volume.
Fleet age distribution historic 2007	Vehicle Age		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v51/./Datafiles/Excel_input/Infr	

Name	Dimensions	Unit	Type	Definition	Documentation
				astructure data.xlsm", "Air historic fleet age fraction", "R3C3:R52C3")	
Fleet growth cumulative error			Real	Transport capacity submodel.Fleet growth cumulative error	
Historic aircraft fleet growth fraction		yr^-1	Real	0<<1/yr>>	
Objective Air fleet			Real	Transport capacity submodel.Objective Air fleet	
Objective Air fleet fractions 2007			Real	Transport capacity submodel.Objective Air fleet fractions 2007	
Objective air seat occupation				Transport capacity submodel.Objective air seat occupation	
Objective fleet growth			Real	Transport capacity submodel.Objective fleet growth	
Other global transport				Average return distance per class*Other global trips per distclass	
Other global trips per distclass				Bass Model Other transport.Adopters*Bass Model Other transport.Trips per adoption	
Other historic global HSR track		km	Real	0<<km>>	
Other historic high speed share			Real	0	
Other HSR rail share			Real	Transport capacity submodel.Other HSR transport share	
Policy air fleet maximum scrap age			Real	50	This value sets scrap rates at 1as a proxy for a policy to remove old aircraft from the fleet.
Policy airport slot restriction				IF(Scenario on, MAX(Airport bottomline capacity, GRAPH(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy maximum airport slots)), Airport maximum historic capacity)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Policy high speed rail investment	Policy_Years	USD/yr	Real	{10285338005.29 ,16141947447.40 ,14851500121.30 ,29791303930.28 ,26421905147.43} <<USD/yr>>	The default gives more or less constant HSR share for the default background scenario.

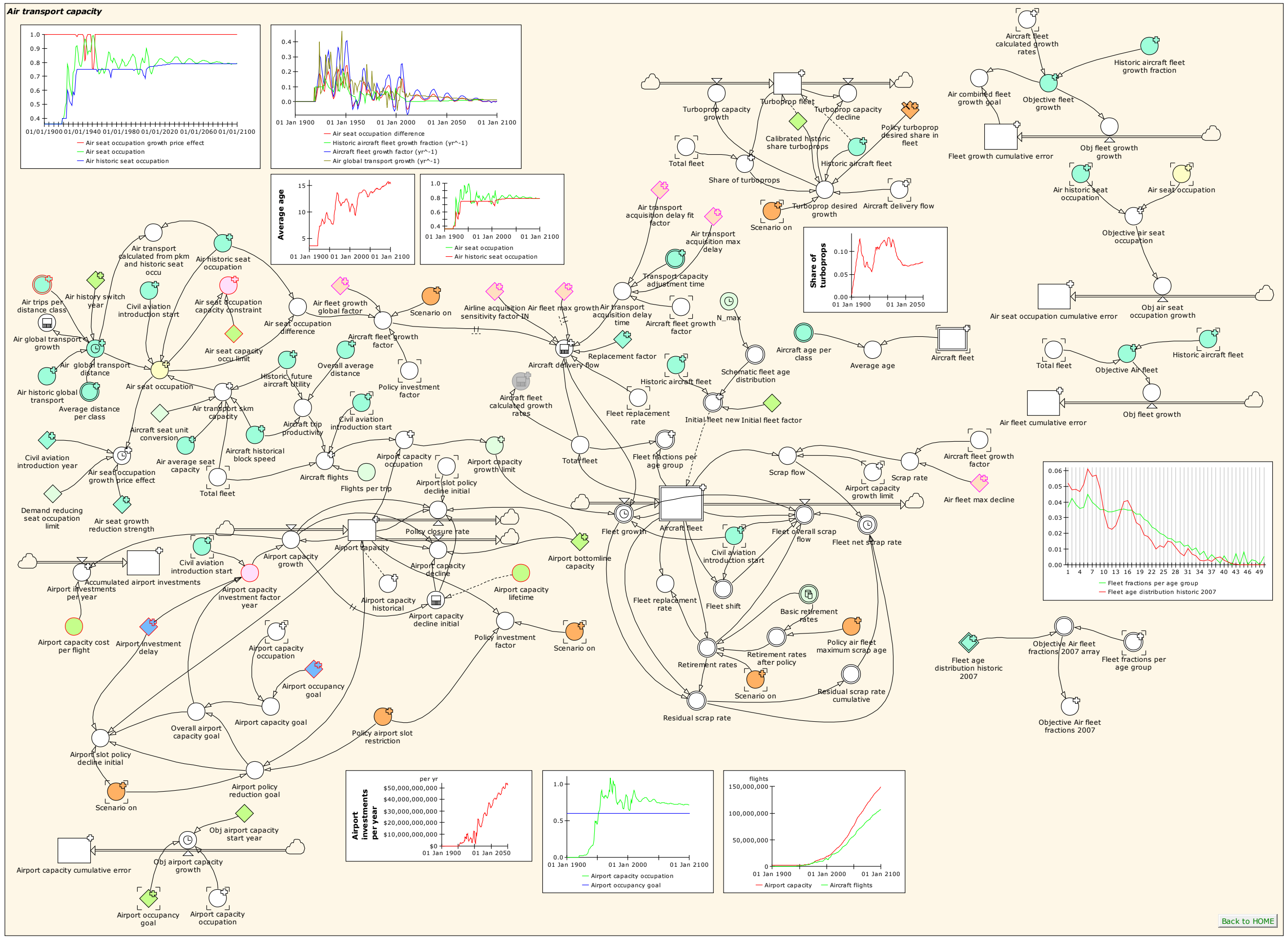
Name	Dimensions	Unit	Type	Definition	Documentation
per yr					
Rail HSR investments per year		USD/yr	Real	Transport capacity submodel.Rail HSR investments per year	
Scenario on			Logical	IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	
Scenario start year			Integer	2015	
Share of turboprops			Real	Transport capacity submodel.Share of turboprops	
Total abatement cost				ARRSUM(DUMP_abatement cost)	
Total investments	Investments			{Airport investments per year+Rail HSR investments per year+Total abatement cost*1<<1/yr>>, Rail HSR investments per year+Total abatement cost*1<<1/yr>>, Total abatement cost*1<<1/yr>>}	
Transport capacity delay times	Transport modes	yr	Real	{Aircraft delivery delay times,1<<yr>>,6<<yr>>}	
Transport capacity submodel					
Turboprop fleet		Aircraft	Real	Transport capacity submodel.Turboprop fleet	

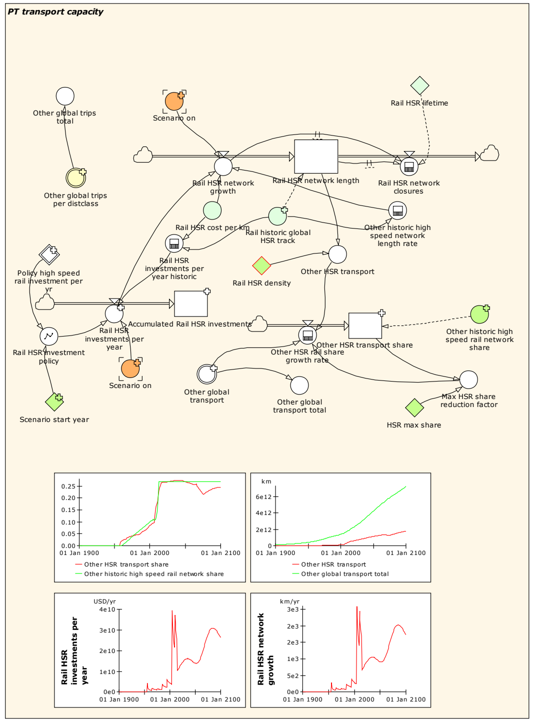
Transport capacity

Description/task: Calculate air fleet age distribution, airport capacity and investments, share of turboprop, air seat occupancy rate

Main inputs: Air and 'other' transport volumes

Main outputs: Air seat occupation, airport capacity, investments





Name	Dimensions	Unit	Type	Definition	Documentation
Transport capacity submodel.Accumulated airport investments		USD	Real	0<<USD>>	
Transport capacity submodel.Accumulated Rail		USD	Real	0<<USD>>	

Name	Dimensions	Unit	Type	Definition	Documentation
HSR investments					
Transport capacity submodel.Air global transport distance				IF(YEAR()<Air history switch year,Air historic global transport, ARRSUM(Air trips per distance class*Average distance per class))	
Transport capacity submodel.Air average seat capacity		seat/Aircraft	Real	Parent~Aircraft average seat capacity	
Transport capacity submodel.Air combined fleet growth goal			Real	Fleet growth cumulative error*Objective fleet growth	
Transport capacity submodel.Air fleet cumulative error			Real	0	
Transport capacity submodel.Air fleet growth global factor			Real	Parent~Air fleet growth global factor	
Transport capacity submodel.Air fleet max decline			Real	Parent~Air fleet max decline	This maximum has been installed to avoid over reaction of the system. Bit of a risk in large change situations!
Transport capacity submodel.Air fleet max growth			Real	Parent~Air fleet max growth	Ibid.
Transport capacity submodel.Air global transport growth				DERIVN(Air global transport distance)DIVZ0Air global transport distance	
Transport capacity submodel.Air historic global transport		km	Real	Parent~Air historic global transport	
Transport capacity submodel.Air historic seat occupation			Real	Parent~Air historic seat occupation	
Transport capacity submodel.Air history switch year			Integer	2005	The switch determines if a model run (0) or a test run (1) with historical transport [1] and/or fleet data [2] is made.
Transport capacity			Real	0.99	Be careful not to set at 1.0 as that causes

Name	Dimensions	Unit	Type	Definition	Documentation
submodel.Air seat capacity occu limit					crashes when having very strong airport capacity changes. Lower value cause more string noise in many cases.
Transport capacity submodel.Air seat growth reduction strength			Real	REF(Parent~Air seat growth reduction strength)	
Transport capacity submodel.Air seat occupation				IF(Civil aviation introduction start, Air global transport distance/Air transport skm capacity ,Air historic seat occupation)	
Transport capacity submodel.Air seat occupation capacity constraint				IF(Air seat occupation>Air seat capacity occu limit, MIN(Air seat occupation-Air seat capacity occu limit,Air seat capacity occu limit),0) /1<<yr>>	
Transport capacity submodel.Air seat occupation cumulative error			Real	0	
Transport capacity submodel.Air seat occupation difference				(Air seat occupation-Air historic seat occupation)	
Transport capacity submodel.Air seat occupation growth price effect				MAX(0.01, IF(YEAR()<Civil aviation introduction year,1, (1+(1-Air seat growth reduction strength)+Air seat growth reduction strength*COS(PI*IF(Air seat occupation<Demand reducing seat occupation limit, 0,(MIN(1,Air seat occupation)-Demand reducing seat occupation limit)/ (1-Demand reducing seat occupation limit))))/2))	This standard function creates a multiplier that reduces sigmoidal from 1 to zero (and is to be used to multiply growth with) for any ratio of a value/goal between a 'reduced growth limit ratio' (giving 1.0) and ratio 1 (giving 0.0). This function is inspired by section 8.5 in (Sterman, 2000). The workout for this purpose is in files Goal seeking growth form.xls and Goal seeking growth function.fgr. The latter function was for a reduction between 0.75 and 1.0, but has been simplified to give a reduction function for the whole 0-1 range and than using a condition to scale the x between the 'reduced growth limit ratio' and the ratio 1.0.
Transport capacity			Real	Parent~Air transport acquisition delay fit	This maximum has been installed to avoid

Name	Dimensions	Unit	Type	Definition	Documentation
submodel.Air transport acquisition delay fit factor				factor	over reaction of the system. Bit of a risk in large change situations!
Transport capacity submodel.Air transport acquisition delay time				MIN((Transport capacity adjustment time[Air]*1<<1/yr>>+ MAX(Aircraft fleet growth factor,0<<1/yr>>)*1<<yr>>)^Air transport acquisition delay fit factor* 1<<yr>>, Air transport acquisition max delay)	
Transport capacity submodel.Air transport acquisition max delay		yr	Real	Parent~Air transport acquisition max delay	This maximum has been installed to avoid over reaction of the system. Bit of a risk in large change situations!
Transport capacity submodel.Air transport calculated from pkm and historic seat occu				Air global transport distance/Air historic seat occupation	
Transport capacity submodel.Air transport skm capacity		km	Real	MAX(Total fleet*Air average seat capacity* Historic_future aircraft Utility* Aircraft historical block speed *Aircraft seat unit conversion, (10^6)*1<<km>>)	Fleet times hours per aircraft gives total hours... times speed gives total km 'Total aircraft' (AC)*'Air average seat capacity' (seat/AC) gives total seats *'Aircraft Utility' (hr/AC)*'Aircraft historical block speed' (km/hr) gives seatkm/AC. We need km, therefore a 'Aircraft seat unit conversion' (aircraft/seat) is required to multiply with. Actually the Aircraft utility should have been in hr/seat to solve this problem directly.
Transport capacity submodel.Air trips per distance class	Dist_class			Parent~Air global trips per distclass	
Transport capacity submodel.Aircraft age per class	Vehicle Age		Real	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19 ,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34, 35,36,37,38,39,40,41,42,43,44,45,46,47,48,49, 50}	
Transport capacity submodel.Aircraft delivery flow				(Airline acquisition sensitivity factor IN* DELAYINF(IF(Aircraft fleet growth factor<0<<1/yr>>, 0<<Aircraft/yr>>, Total fleet* MIN(Air fleet max growth*1<<1/yr>>,Aircraft fleet growth	

Name	Dimensions	Unit	Type	Definition	Documentation
				factor)) ,Air transport acquisition delay time,1) +Replacement factor*Fleet replacement rate*Total fleet)	
Transport capacity submodel.Aircraft fleet	Vehicle Age	Aircraft	Real	Initial fleet new	
Transport capacity submodel.Aircraft fleet calculated growth rates		yr^-1	Real	DERIVN(Total fleet)/Total fleet	
Transport capacity submodel.Aircraft fleet growth factor				IF(Scenario on, MAX(0,1+Policy investment factor), 1)* Air fleet growth global factor* Air seat occupation difference* 1<<1/yr>>	Straightforward growth factor function
Transport capacity submodel.Aircraft flights				IF(Civil aviation introduction start,1,0)* Aircraft trip productivity*Flights per trip*Total fleet	
Transport capacity submodel.Aircraft historical block speed		km/hr	Real	Parent~Air transport historical blockspeed	
Transport capacity submodel.Aircraft seat unit conversion		Aircraft/seat	Real	1<<Aircraft/seat>>	This factor is always 1 and has a unit of Aircraft/seat to get the total capacity right
Transport capacity submodel.Aircraft trip productivity				Historic_future aircraft Utility *Aircraft historical block speed /Overall average distance	
Transport capacity submodel.Airline acquisition sensitivity factor IN			Real	Parent~Airline acquisition sensitivity factor IN	This constant factors the strength of the airline reaction. At below 0.7 it cause a restriction on traffic growth in 1925-1927 and one instant around 1950s. High values cause large excursions from the historical fleet development, though on average OK. Therefore have chosen the lowest value with no limitation in traffic growth after 1930.
Transport capacity submodel.Airport bottomline capacity		flight	Real	REF(Parent~Airport bottomline capacity)	To avoid zero or negative airport capacity we've set this at 1 million flights worldwide.
Transport capacity submodel.Airport capacity		flight	Real	Airport capacity historical	

Name	Dimensions	Unit	Type	Definition	Documentation
Transport capacity submodel.Airport capacity cost per flight		USD/flight	Real	15268<<USD/flight>>	Based on file Airport investments data.xlsx. For the next 20 year a total of 1 trillion $ is required according to (IATA, 2012) Total investment 1E+12 (IATA, 2012) Current flights 2011 23,225,746 Based on GTTM_Dyn_v1.02_v32_PS9.sip Increase factor of global fleet 2012-2031 2 (Boeing, 2012) Cost per additional flight capacity 43056 calculated average airport occupancy 0.6 Guestimate Cost per additional theoretical capacity 25833 2011 dollar Conversion 2011 to 1990 dollar 0.591 (Sahr, 2011) In 1990$ 15268
Transport capacity submodel.Airport capacity cumulative error			Real	0	
Transport capacity submodel.Airport capacity decline				IF(Airport capacity+(Airport capacity growth-Airport capacity decline initial)*1<<yr>>>Airport bottomline capacity, Airport capacity decline initial, 0<<flights/yr>>)	
Transport capacity submodel.Airport capacity decline initial		flight/yr	Real	DELAYPPL(Airport capacity growth,Airport capacity lifetime,0<<flight/yr>>)// ,//	
Transport capacity submodel.Airport capacity goal				Airport capacity occupation-Airport occupancy goal	
Transport capacity submodel.Airport capacity growth				Airport capacity investment factor year*Airport capacity	
Transport capacity submodel.Airport capacity growth limit				MIN(1, IF(Airport capacity occupation>1, (Airport capacity occupation-1), 0))*1<<1/yr>>	This standard function creates a multiplier that reduces sigmoidal from 1 to zero (and is to be used to multiply growth with) for any ratio of a value/goal between a 'reduced growth limit ratio' (giving 1.0) and ratio 1 (giving 0.0). This function is inspired by

Name	Dimensions	Unit	Type	Definition	Documentation
					section 8.5 in (Sterman, 2000). The workout for this purpose is in files Goal seeking growth form.xls and Goal seeking growth function.fgr. The latter function was for a reduction between 0.75 and 1.0, but has been simplified to give a reduction function for the whole 0-1 range and than using a condition to scale the x between the 'reduced growth limit ratio' and the ratio 1.0.
Transport capacity submodel.Airport capacity historical		flight	Real	REF(Parent~Airport capacity historical)	
Transport capacity submodel.Airport capacity investment factor year				IF(Civil aviation introduction start,1,0)* IF(Overall airport capacity goal>0, Overall airport capacity goal/Airport investment delay, 0<<1/yr>>)	Fitted the variable to to get a restraint free development. Calibration for the whole 2010 period. Some interesting literature about US investments in (Dillingham, 2015).
Transport capacity submodel.Airport capacity lifetime		yr	Real	50<<yr>>	
Transport capacity submodel.Airport capacity occupation				Aircraft flights/Airport capacity	
Transport capacity submodel.Airport investment delay		yr	Real	REF(Parent~Airport investment delay)	calibration between 5 and 15 years. expect something near 10 years. The delay of investment is put into the investment factor; when it was at the investment itself, it appeared to become very spiky, while now it is more a smooth factor.
Transport capacity submodel.Airport investments per year				Airport capacity growth*Airport capacity cost per flight	
Transport capacity submodel.Airport occupancy goal			Real	REF(Parent~Airport occupancy goal)	Taken this over a range of 0.5-0.75. Not too high because peak hours will determine the capacity investments and these will be something like two times average. See example of Frankfurt in (Gelhausen et al.,

Name	Dimensions	Unit	Type	Definition	Documentation
					2013) and in excel 'Airport investments data.xlsx'. This reveals 0.63. For highest most busy airports the factor is found to be up to 0.7 (CUI, capacity utilisation factor). A world average will certainly be lower even though most air traffic goes through highly used airports. So we have chosen a value between 0.5 and 0.75.
Transport capacity submodel.Airport policy reduction goal				IF(Scenario on, MIN((Policy airport slot restriction-Airport capacity)/Airport capacity,0), 0)	
Transport capacity submodel.Airport slot policy decline initial				IF(Scenario on,1,0)* Airport capacity* IF(Airport policy reduction goal<0,-Overall airport capacity goal,0) /Airport investment delay	
Transport capacity submodel.Average age			Real	ARRSUM(Aircraft age per class*Aircraft fleet)/ARRSUM(Aircraft fleet)	
Transport capacity submodel.Average distance per class	Dist_class	km/trip	Real	Parent~Average return distance per class	
Transport capacity submodel.Basic retirement rates	Vehicle Age		Real	XLDATA("//psf/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/./Datafiles/Excel_input/Infrastructure data.xlsm", "Aircraft fleet constants", "R6C5:R55C5")	
Transport capacity submodel.Calibrated historic share turboprops		%	Real	0.54%	This number has been defined based on the 2014 turboprop fleet assuming continuous development until 2050. see excel Turboprop data 01.xlsx sheet Market share.
Transport capacity submodel.Civil aviation introduction start			Logical	Parent~Civil aviation introduction start	
Transport capacity submodel.Civil aviation introduction year			Real	Parent~Civil aviation introduction year	This year defines the moment that serious supply of air transport is introduced into the market; before this date the model keeps air

<table>
<tr><th>Name</th><th>Dimensions</th><th>Unit</th><th>Type</th><th>Definition</th><th>Documentation</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>transport and adopters at zero. It is connected to two events: 'Civil aviation start' triggering civil aviation supply and 'Civil aviation cost start', which runs one year ahead and avoids the cost trigger to heavily and inadvertently affect air transport volume.</td></tr>
<tr><td>Transport capacity submodel.Demand reducing seat occupation limit</td><td></td><td></td><td>Real</td><td>0.9</td><td></td></tr>
<tr><td>Transport capacity submodel.Fleet age distribution historic 2007</td><td>Vehicle Age</td><td></td><td>Real</td><td>Parent~Fleet age distribution historic 2007</td><td></td></tr>
<tr><td>Transport capacity submodel.Fleet fractions per age group</td><td>Vehicle Age</td><td></td><td>Real</td><td>Aircraft fleet/Total fleet</td><td></td></tr>
<tr><td>Transport capacity submodel.Fleet growth</td><td>Vehicle Age</td><td></td><td></td><td>IF(Civil aviation introduction start,1,0)* IF(TIMECYCLE(STARTTIME,1<<yr>>,TIMESTEP), CONCAT(IF(Airport capacity growth limit>0<<1/yr>>, MAX(0,1-Airport capacity growth limit*1<<yr>>),1)*{Aircraft delivery flow}, FOR(i=FIRST(Vehicle Age)+1..LAST(Vehicle Age)|Aircraft fleet[i-1]*1<<1/yr>>)), 0<<Aircraft/yr>>) /(TIMESTEP/1<<yr>>)</td><td></td></tr>
<tr><td>Transport capacity submodel.Fleet growth cumulative error</td><td></td><td></td><td>Real</td><td>0</td><td></td></tr>
<tr><td>Transport capacity submodel.Fleet net scrap rate</td><td>Vehicle Age</td><td></td><td></td><td>IF(Scrap flow=0<<Aircraft/yr>>,0<<Aircraft/yr>>, IF(TIMECYCLE(STARTTIME,TIMESTEP//1<<yr>>//,TIMESTEP), CONCAT(FOR(i=FIRST(Vehicle Age)..LAST(Vehicle Age)-1| IF(Residual scrap rate cumulative[i]/Scrap flow<=1,Residual scrap rate[i], IF((Residual scrap rate cumulative[i+1]/Scrap flow)<1, (1-</td><td></td></tr>
</table>

Name	Dimensions	Unit	Type	Definition	Documentation
				Residual scrap rate cumulative[i+1]/Scrap flow)*Scrap flow,0<<Aircraft/yr>>)]),{Residual scrap rate[LAST(Vehicle Age)]}) ,0<<Aircraft/yr>>)) /(TIMESTEP/1<<yr>>)	
Transport capacity submodel.Fleet overall scrap flow				IF(Civil aviation introduction start,1,0)* IF(Rate_2+Retirement rates+Fleet net scrap rate>=Aircraft fleet/TIMESTEP+Fleet growth, 1.00*Aircraft fleet/TIMESTEP+Fleet growth, Rate_2+Retirement rates+Fleet net scrap rate)	
Transport capacity submodel.Fleet replacement rate		yr^-1	Real	MAX(ARRSUM(Retirement rates) DIVZ0 ARRSUM(Aircraft fleet),0<<1/yr>>)	
Transport capacity submodel.Flights per trip		flight/trip	Real	2.514<<flights/trip>>	See Global time series data.xlsx: Corrections air for trips with more flights Air calculated 2 trips per return (too high!) Air according to UNWTO, 2008) 1030746520 820000000 Return flights/trip: 1.257007951 Single flights per trip 2.514015901
Transport capacity submodel.Historic aircraft fleet		Aircraft	Real	Parent~Aircraft historical fleet	
Transport capacity submodel.Historic aircraft fleet growth fraction		yr^-1	Real	Parent~Historic aircraft fleet growth fraction	
Transport capacity submodel.Historic_future aircraft Utility		hr/Aircraft	Real	Parent~Aircraft utility	This series is based upon fleet data from AERO ((Pulles et al., 2002)) for jets and ATA data ((ATA, 1950)) for the pistons, assuming a linear transition between 1950 and 1980.
Transport capacity submodel.HSR max share			Real	0.7	source: (UIC, 2015) High speed traffic 2014 pass-km (billions) Total (billion) share HSR JR 2013 89.2 260 34.3% SNCF 50.7 84 60.4% CR 2012 144.6 807 17.9% DB AG 24.2 79 30.5% KORAIL 2013 14.5 23 64.1% FS SpA 2012 12.8 39 33.2% RENFE 12.8 24 53.9% Max share 64.1%

Name	Dimensions	Unit	Type	Definition	Documentation
Transport capacity submodel.Initial fleet factor			Real	1	This factor helps to fit the initial situation of the fleet developments as that was too low without this.
Transport capacity submodel.Initial fleet new	Vehicle Age	Aircraft	Real	Initial fleet factor/ARRSUM(Schematic fleet age distribution)* Historic aircraft fleet*Schematic fleet age distribution	
Transport capacity submodel.Max HSR share reduction factor			Real	MIN(1,MAX(HSR max share/(HSR max share-0.6) +Other HSR transport share/(0.6-HSR max share),0))	
Transport capacity submodel.N_max			Real	MAX(10,MIN(50,YEAR(TIME)-1910))	This value gives now input for a schematic development of the fleet age distribution and assumes that airliners started in 2010 to be used in passenger transport fleets.
Transport capacity submodel.Obj air seat occupation growth				Objective air seat occupation*1<<1/yr>>	
Transport capacity submodel.Obj airport capacity growth				IF(YEAR(TIME)>Obj airport capacity start year, (Airport capacity occupation-Airport occupancy goal)^2*1<<1/yr>>, 0<<1/yr>>)	
Transport capacity submodel.Obj airport capacity start year			Real	1970	
Transport capacity submodel.Obj fleet growth		yr^-1	Real	Objective Air fleet*1<<1/yr>>	
Transport capacity submodel.Obj fleet growth growth		yr^-1	Real	Objective fleet growth*1<<1/yr>>	
Transport capacity submodel.Objective Air fleet			Real	SQRT(IF(Total fleet=0<<Aircraft>>, 0, ((Total fleet-Historic aircraft fleet)/Total fleet)^2))	The error is relative to the final 2005 figure as to give emphasis tot the latest years of the cumulative error (the first years errors are much smaller as total mobility is then much smaller). This helps to find data that are close to the 2005 known situation and avoids an emphasis on fit to early data that are not too reliable anyway.

Name	Dimensions	Unit	Type	Definition	Documentation
Transport capacity submodel.Objective Air fleet fractions 2007			Real	ARRSUM(Objective Air fleet fractions 2007 array)	
Transport capacity submodel.Objective Air fleet fractions 2007 array	Vehicle Age		Real	(100*Fleet age distribution historic 2007-100*Fleet fractions per age group)^2	
Transport capacity submodel.Objective air seat occupation				IF(Air historic seat occupation=0, 0, IF(Air seat occupation<=.95,.1,100)* SQRT(((Air seat occupation-Air historic seat occupation)/ Air historic seat occupation)^2))	
Transport capacity submodel.Objective fleet growth			Real	IF(Historic aircraft fleet growth fraction=0<<1/yr>>, 0, SQRT(((Aircraft fleet calculated growth rates-Historic aircraft fleet growth fraction)/ Historic aircraft fleet growth fraction)^2))	The error is relative to the final 2005 figure as to give emphasis tot the latest years of the cumulative error (the first years errors are much smaller as total mobility is then much smaller). This helps to find data that are close to the 2005 known situation and avoids an emphasis on fit to early data that are not too reliable anyway.
Transport capacity submodel.Other global transport	Dist_class	km		Parent~Other global transport	
Transport capacity submodel.Other global transport total				ARRSUM(Other global transport)	
Transport capacity submodel.Other global trips per distclass	Dist_class			Parent~Other global trips per distclass	
Transport capacity submodel.Other global trips total				ARRSUM(Other global trips per distclass)	
Transport capacity submodel.Other historic high speed network length rate		km/yr	Real	DERIVN(Rail historic global HSR track)	
Transport capacity submodel.Other historic			Real	Parent~Other historic high speed share	

Name	Dimensions	Unit	Type	Definition	Documentation
high speed rail network share					
Transport capacity submodel.Other HSR rail share growth rate				Max HSR share reduction factor* DERIVN(Other HSR transport/ARRSUM(Other global transport)) //'Other historic high speed share rate'	
Transport capacity submodel.Other HSR transport		km	Real	Rail HSR density*Rail HSR network length	
Transport capacity submodel.Other HSR transport share			Real	Other historic high speed rail network share	
Transport capacity submodel.Other rail HSR policy start year			Integ er	2015	This year defines the moment that the HSR infrastructure model switches from following historic HSR investments to investment induced growth. this to allow for policies. Historic data run until 2102 so there is a default setting.
Transport capacity submodel.Overall airport capacity goal				IF(Airport policy reduction goal<0,Airport policy reduction goal,Airport capacity goal)	
Transport capacity submodel.Overall average distance				Parent~Air transport average distance	1-way distance (actually per flight....)
Transport capacity submodel.Policy air fleet maximum scrap age			Real	REF(Parent~Policy air fleet maximum scrap age)	This value sets scrap rates at 1as a proxy for a policy to remove old aircraft from the fleet.
Transport capacity submodel.Policy airport slot restriction				REF(Parent~Policy airport slot restriction)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
Transport capacity submodel.Policy closure rate				MAX(0<<flights/yr>>, IF(Airport capacity-(Airport capacity decline initial+Airport capacity growth)*TIMESTEP>Airport bottomline capacity, Airport slot policy decline initial, 0<<flights/yr>>))	

Name	Dimensions	Unit	Type	Definition	Documentation
Transport capacity submodel.Policy high speed rail investment per yr	Policy_Years	USD/yr	Real	REF(Parent~Policy high speed rail investment per yr)	last value in historic run for 2015 used
Transport capacity submodel.Policy investment factor				IF(Scenario on, IF(Airport capacity<=Policy airport slot restriction,0, (Policy airport slot restriction-Airport capacity)/Airport capacity), 0)	This restriction actually allows the airport capacity to stay 1/'airport occupancy goal' higher then the policy set, but the idea works relatively stable.
Transport capacity submodel.Policy turboprop desired share in fleet		%	Real	10%	
Transport capacity submodel.Rail historic global HSR track		km	Real	Parent~Other historic global HSR track	
Transport capacity submodel.Rail HSR cost per km		USD/km	Real	15304647	18 million EUR in 2005 according to (Campos & de Rus, 2009) and corrected for 1990 and converted to $.
Transport capacity submodel.Rail HSR density			Real	20000000<<km/km>>	Source: (UIC, 2012, p. 19) and excel file 'Infrastructure data.xlsm', sheet 'Other infrastructure'
Transport capacity submodel.Rail HSR investment policy		USD/yr	Real	GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy high speed rail investment per yr)	
Transport capacity submodel.Rail HSR investments per year		USD/yr	Real	IF(Scenario on, Rail HSR investment policy, Rail HSR investments per year historic)	
Transport capacity submodel.Rail HSR investments per year historic		USD/yr	Real	Rail HSR cost per km* DERIVN(Rail historic global HSR track)	
Transport capacity submodel.Rail HSR lifetime		yr	Real	60<<yr>>	
Transport capacity submodel.Rail HSR network closures		km/yr	Real	DELAYPPL(MIN(Rail HSR network length*1<<1/yr>>, Rail HSR network growth), Rail HSR lifetime)	

Name	Dimensions	Unit	Type	Definition	Documentation
Transport capacity submodel.Rail HSR network growth		km/yr	Real	IF(Scenario on, Rail HSR investments per year/Rail HSR cost per km, Other historic high speed network length rate)	
Transport capacity submodel.Rail HSR network length		km	Real	Rail historic global HSR track	
Transport capacity submodel.Replacement factor			Real	1	
Transport capacity submodel.Residual scrap rate				(Aircraft fleet*1<<1/yr>>+Fleet growth-Retirement rates)	
Transport capacity submodel.Residual scrap rate cumulative	1..50			CUMULATIVESUM(Residual scrap rate,TRUE)	
Transport capacity submodel.Retirement rates	Vehicle Age	Aircraft/yr	Real	IF(Scenario on, Retirement rates after policy*Aircraft fleet, Basic retirement rates*Aircraft fleet*1<<1/yr>>)	
Transport capacity submodel.Retirement rates after policy	Vehicle Age	yr^-1	Real	FOR(i=DIM(Basic retirement rates)| IF(i<Policy air fleet maximum scrap age,Basic retirement rates[i]*1<<1/yr>>,1<<1/yr>>))	
Transport capacity submodel.Scenario on			Logical	REF(Parent~Scenario on)	
Transport capacity submodel.Scenario start year			Integer	REF(Parent~Scenario start year)	
Transport capacity submodel.Schematic fleet age distribution	Vehicle Age		Real	FOR(i=FIRST(Vehicle Age)..LAST(Vehicle Age)| IF(i<=N_max,2/N_max+2/N_max^2-2*i/N_max^2-2*i/N_max^3,0))	This age distribution is linear and used as initialising the fleet age distribution at introduction time of civil aviation (in the model) or the start time, whichever is later.
Transport capacity submodel.Scrap flow				ARRSUM(Aircraft fleet)* (Scrap rate+Airport capacity growth limit)	
Transport capacity submodel.Scrap rate				IF(Aircraft fleet growth factor<0<<1/yr>> ,MIN(Air fleet max decline*1<<1/yr>>,-Aircraft fleet growth factor) ,0.0<<1/yr>>)	

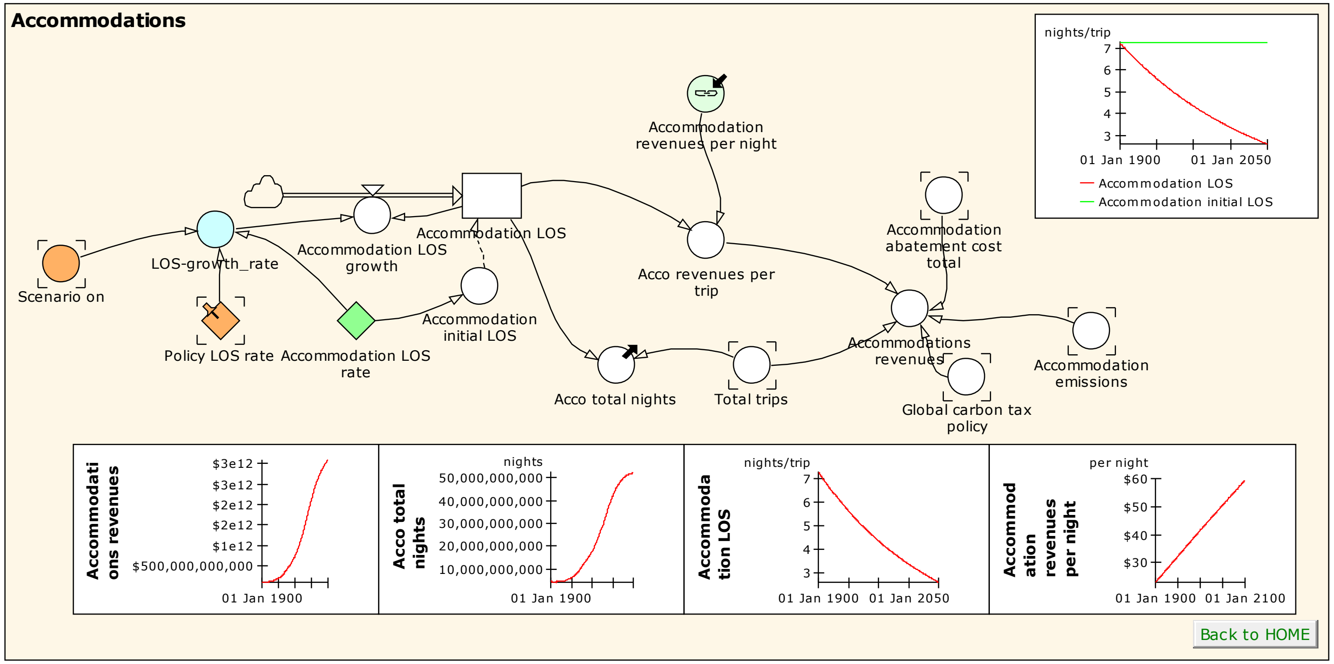
Name	Dimensions	Unit	Type	Definition	Documentation
Transport capacity submodel.Share of turboprops			Real	IF(Total fleet=0<<Aircraft>>,0,Turboprop fleet/Total fleet)	
Transport capacity submodel.Total fleet		Aircraft	Real	ARRSUM(Aircraft fleet)	
Transport capacity submodel.Transport capacity adjustment time	Transport modes	yr	Real	Parent~Transport capacity delay times	These numbers are taken from the SUSNORD model.
Transport capacity submodel.Turboprop capacity decline				IF(Turboprop desired growth<0<<Aircraft/yr>>, MIN(-Turboprop desired growth,Turboprop fleet*1<<1/yr>>), 0<<Aircraft/yr>>)	
Transport capacity submodel.Turboprop capacity growth				IF(Turboprop desired growth>=0<<Aircraft/yr>>, Turboprop desired growth,0<<Aircraft/yr>>)	
Transport capacity submodel.Turboprop desired growth				IF(Scenario on, Aircraft delivery flow* (Policy turboprop desired share in fleet-Share of turboprops), Calibrated historic share turboprops*Historic aircraft fleet*1<<1/yr>>)	
Transport capacity submodel.Turboprop fleet		Aircraft	Real	Calibrated historic share turboprops*Historic aircraft fleet	The assumptions here are: Turboprop share at calibrated level as to create the 2880 fleet in 2014 according to ATR, 2014 report. After 2015 the policy setting determines the share of turboprops in the fleet (share of aircraft).

Accommodations

Description/task: Calculate the length of stay (LOS), nights and revenues

Main inputs: LOS rate (fraction per year)

Main outputs: Number of nights, accommodation revenues



Name	Dimensions	Unit	Type	Definition	Documentation
Acco revenues per trip		USD/trip	Real	Accommodation revenues per night*Accommodation LOS	
Acco total nights				Accommodation LOS*Total trips	
Accommodation abatement cost total				Accommodatie abatement average cost*Accommodation emissions*MU_Acc*(1/(1-MU_Acc)-1)	
Accommodation emissions				Accommodation emission factor*Accommodation LOS*Total trips	
Accommodation initial LOS		night/trip	Real	(7.251+(YEAR(STARTTIME)-1900)*(Accommodation LOS rate*1<<yr>>))*1<<night/trip>>	LOS in simulation start year based on the GTTM_adv linear LOS development from 2005 to 2050: LOS in 2005: 4.15 LOS in 2010: 4.06 LOS in 2050: 3.55 LOS in 1900: 4.06+110/40*0.49=5.406. HOWEVER: in (Gössling & Peeters, 2015) we have used a different method with a more dynamic LOS

Name	Dimensions	Unit	Type	Definition	Documentation
					development: The grand tour LOS Year Days Remarks Source calculated 1900 7.268162625 7.251 1975 5 Dom+Int (WTO, 1977, 1979) 4.935 2005 4.212765957 Dom+Int (UNWTO-UNEP-WMO, 2008) 4.231 2035 3.624597234 Dom+Int (UNWTO-UNEP-WMO, 2008) 3.627 2100 2.616736566 Dom+Int 2.598 Source: (Vasilyev, 2004) y = exp(a-b*x); a=11.733396, b=0.0051309019 LOS_a 11.73 Std. Error = 0.02740995959457895 LOS_b 0.005131 Exponential 2-3 function. We have differentiated with mathcad (see LOS equation differentiation. xmcd): y' = -b*exp(a-b*x)
Accommodation LOS		night/trip	Real	Accommodation initial LOS	
Accommodation LOS growth				LOS-growth_rate*Accommodation LOS	
Accommodation LOS rate		1/yr	Real	-0.0051	This default has been fitted such that the values generated with a linear model are reproduced for 1900 and 2100 in accordance with the more complex exponential function in (Gössling & Peeters, 2015).
Accommodation revenues per night		USD/night	Real	75<<USD/night>>	
Accommodations revenues				Total trips*Acco revenues per trip+ Accommodation abatement cost total+ Global carbon tax policy*Accommodation emissions	
Global carbon tax policy				IF(Scenario on,1,0)* (Global tourism carbon tax+Global shadow cost mitigation)	A 5 year delay has been added to avoid a too strong impulse at the beginning of the measure.
LOS-growth_rate		1/yr		IF(Scenario on, Policy LOS rate, Accommodation LOS rate)	
Policy LOS rate		yr^-1	Real	-0.0051<<1/yr>>	This default has been fitted such that the values generated with a linear model are reproduced for 1900 and 2100 in accordance with the more complex exponential function in (Gössling &

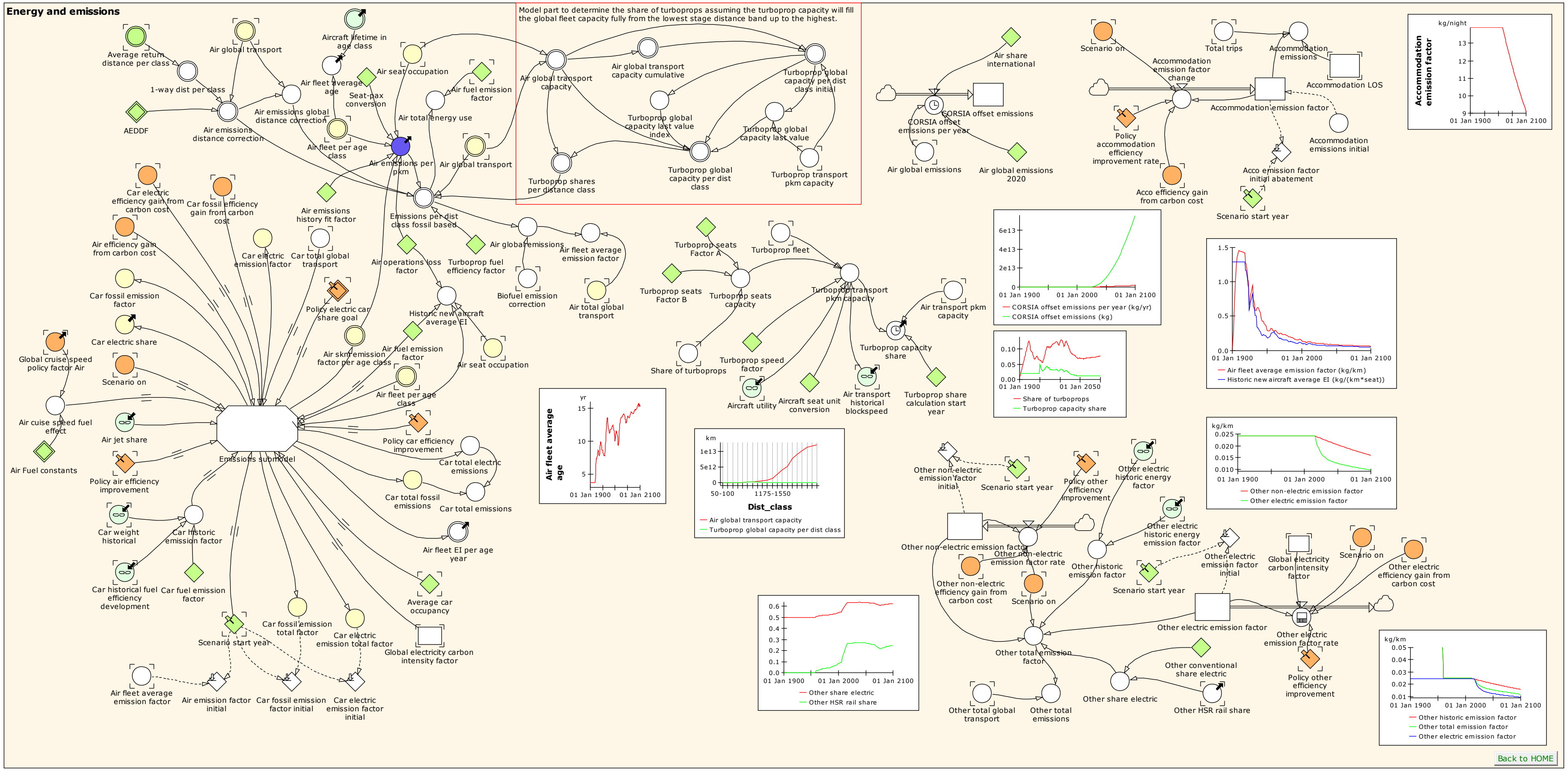
Name	Dimensions	Unit	Type	Definition	Documentation
					Peeters, 2015).
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	
Total trips				ARRSUM(Total trips per mode)	

Energy and emissions

Description/task: Calculate accommodation emission factor; share turboprop; organise input/output transport emissions

Main inputs: Historic/policy assumptions

Main outputs: Emission factors accommodation and other transport



Name	Dimensions	Unit	Type	Definition	Documentation
1-way dist per class	Dist_class		Real	Average return distance per class/2<<km/trip>>	
Acco efficiency gain from carbon cost				Carbon tax sector switch[Acco]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg> >,Global carbon tax policy-Acco abatement	The assumption is that a certain carbon cost gives an incentive to reduce emissions by the MU belonging to the same abatement cost but times

Name	Dimensions	Unit	Type	Definition	Documentation
				cost)DIVZ0Global carbon tax policy *Acco max effiency improvement-Policy accommodation efficiency improvement rate), Acco efficiency delay time,6)	the sensitivity factor. Furthermore this annual rate will be less than the maximum annual rate defined for this technology (air, car electric, acco, etc.).
Acco emission factor initial abatement		kg/night	Real	INITIF(YEAR(TIME)=Scenario start year,Accommodation emission factor)	
Accommodation emission factor		kg/night	Real	Accommodation emissions initial	
Accommodation emission factor change				IF(Scenario on, (Policy accommodation efficiency improvement rate+Acco efficiency gain from carbon cost) *Accommodation emission factor, 0<<kg/(yr*night)>>)	Carefull: all policy efficiency rates are negative when improving efficiency!
Accommodation emissions				Accommodation emission factor*Accommodation LOS*Total trips	
Accommodation emissions initial		kg/night	Real	13.9	Based on GTTM_adv for 2005 which was 19 kg/night for western domestic and international and 4 for non-western domestic, equating to 13.9 on average.
Accommodation LOS				Accommodation initial LOS	
AEDDF	Air emissions decay factors		Real	{1.1201,1.5568,336.23,14.559,2850.8,-14.277,2971.2}	Based on data from (UNWTO-UNEP-WMO, 2008) it is found that air transport CO2 emissions are a function of distance. We found the following function describing a decay factor using Findgraph (Vasilyev, 2004), which found the best fit for an exponential function (see files Aviation dstance decay form 2005.fgr and Aviation dstance decay form 2005.xls: y = a + b*exp(-x/c) + d*exp(-x/g) + h*exp(-x/k); a=1.1200873, b=1.5568404, c=336.22858, d=14.558499, g=2850.7959, h=-14.276807, k=2971.1826 a 1.1201 b 1.5568 c 336.23 d 14.559 g 2850.8 h -14.277 k 2971.2
Air cuise speed fuel effect				Air Fuel constants[1]+ Air Fuel constants[2]*(1+Global cruise speed policy factor Air)+ Air Fuel constants[3]*(1+Global cruise speed policy factor Air)^2	The relationship between fuel consumption and the optimum DOC speed or the whole fleet is based on B737-400, B747-400, B767-200 and B767-300ER data as shown in file Overview speed

Name	Dimensions	Unit	Type	Definition	Documentation
					restrictions.xlsx based on (Peeters, 2000).
Air efficiency gain from carbon cost				Carbon tax sector switch[Air]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Air abatement cost)DIVZ0Global carbon tax policy *Air max effiency improvement-Policy air efficiency improvement), Air efficiency delay time,6)	The assumption is that a certain carbon cost gives an incentive to reduce emissions by the MU belonging to the same abatement copst but times the sensitivity factor. Furthermore this annual rate will be less than the maximum annual rate defined for this technology (air, car electric, acco, etc.).
Air emission factor initial				INITIF(YEAR(TIME)=Scenario start year,Air fleet average emission factor)	
Air emissions distance correction				FOR(i=DIM(Air global transport)| Air global transport[i]* (AEDDF[a]+ AEDDF[b]*1/EXP(1-way dist per class[i]/AEDDF[c])+ AEDDF[d]*1/EXP(1-way dist per class[i]/AEDDF[g])+ AEDDF[h]*1/EXP(1-way dist per class[i]/AEDDF[k])))	Based on data from (UNWTO-UNEP-WMO, 2008) it is found that air transport CO2 emissions are a function of distance. We found the following function describing a decay factor using Findgraph (Vasilyev, 2004), which found the best fit for an exponential function (see files Aviation dstance decay form 2005.fgr and Aviation dstance decay form 2005.xls: y = a + b*exp(-x/c) + d*exp(-x/g) + h*exp(-x/k); a=1.1200873, b=1.5568404, c=336.22858, d=14.558499, g=2850.7959, h=-14.276807, k=2971.1826 a 1.1201 b 1.5568 c 336.23 d 14.559 g 2850.8 h -14.277 k 2971.2 0.5*'Average return distance per class' (0.1672*0.5*'Average return distance per class'/(-129.5+0.5*'Average return distance per class')-0.08361*0.5*'Average return distance per class'/(498.9+0.5*'Average return distance per class')+0.00002837*0.5*'Average return distance per class')
Air emissions global distance correction				ARRSUM(Air global transport)/ ARRSUM(Air emissions distance correction)	
Air emissions history fit factor			Real	1.15	Fitted to average misfit for (Lee et al., 2009) (2005) and (Sausen & Schumann, 2000) (1995). Now with the 1.15 factor for wind/ATC.
Air emissions per pkm				Air emissions history fit factor* Air operations loss factor* ARRSUM(Air fleet per age class*Air skm emission factor per age class)*Seat-pax	

Name	Dimensions	Unit	Type	Definition	Documentation
				conversion /MAX(0.1,Air seat occupation)/ARRSUM(Air fleet per age class) //the max 0.1 seat occu to prevent emission calculation problems when no air transport left.	
Air fleet average age				ARRSUM(Air fleet per age class*Aircraft lifetime in age class)/ ARRSUM(Air fleet per age class)	
Air fleet average emission factor				Air global emissions/Air total global transport	
Air fleet EI per age year	Vehicle Age	MJ/(seat*km)	Real	Emissions submodel.Air fleet EI per age year	This variable is required to calculate the land use limits of biofuels.
Air fleet per age class	Vehicle Age			Transport capacity submodel.Aircraft fleet	
Air Fuel constants	1..3		Real	{13.128, -25.644, 13.516}	The relationship between fuel consumption and the deviation of the optimum DOC speed for the whole fleet is based on B737-400, B747-400, B767-200 and B767-300ER data as shown in file Overview speed restrictions.xlsx based on (Peeters, 2000).
Air fuel emission factor		kg/MJ	Real	0.06723	This constant calculates the carbon emissions in kg from the energy intensity of MJ/seatkm. We use the kerosene factor for both kerosine and the short historic period with gasoline for pistons because the two factors do not differ much. From www.jl-group.eu/doc/Jet-Fuel.pdf: 42.8 MJ/kg minimum heat of combustion. from (EPA, 2004) we find 19.33 kg C/Mbtu which translates to 3.66667*19.33/1054.2 = 0,06723 kg CO2/MJ
Air global emissions				Biofuel emission correction*ARRSUM(Emissions per dist class fossil based)	
Air global emissions 2020		kg	Real	949192156673.27 <<kg>>	Based on Ref Scenario 2100 from GTTMdyn.
Air global transport				Average return distance per class*Air global trips per distclass	
Air global transport capacity				Air global transport/Air seat occupation	

Name	Dimensions	Unit	Type	Definition	Documentation
Air global transport capacity cumulative				CUMULATIVESUM(Air global transport capacity)	
Air jet share			Real	0	
Air operations loss factor			Real	1.05*1.1	Added inefficiency factor for Air emissions for wind (1.05) and ATC/detours(1.10) of 1.05*1.1 based on (Peeters & Williams, 2009).
Air seat occupation				Transport capacity submodel.Air seat occupation	
Air share international		%	Real	62<<%>>	Based on division of emisisons for international (62%) in 2015 from (OECD & ITF, 2017).
Air skm emission factor per age class				Emissions submodel.Air skm emission factor per age class NEW	
Air total energy use				ARRSUM(Emissions per dist class fossil based)/Air fuel emission factor	
Air total global transport				ARRSUM(Air global transport)	
Air transport historical blockspeed		km/hr	Real	0	
Air transport pkm capacity				Transport capacity submodel.Air transport skm capacity	Fleet times hours per aircraft gives total hours... times speed gives total km 'Total aircraft' (AC)*'Air average seat capacity' (seat/AC) gives total seats *'Aircraft Utility' (hr/AC)*'Aircraft historical block speed' (km/hr) gives seatkm/AC. We need km, therefore a 'Aircraft seat unit conversion' (aircraft/seat) is required to multiply with. Actually the Aircraft utility should have been in hr/seat to solve this problem directly.
Aircraft lifetime in age class	Vehicle Age	yr	Real	FOR(i=Vehicle Age| i)*1<<yr>>	
Aircraft seat unit conversion		Aircraft/seat	Real	1<<Aircraft/seat>>	Thisn factor is alway 1 and has a unit of Aircraft/seat to get the total capacity right
Aircraft utility		hr/Aircraft	Real	1<<hr/Aircraft>>	This series is based upon fleet data from AERO ((Pulles et al., 2002)) for jets and ATA data ((ATA, 1950)) for the pistons, assuming a linear

Name	Dimensions	Unit	Type	Definition	Documentation
					transition between 1950 and 1980.
Average car occupancy		Capita/Car	Real	2.208	See average from global tourism as used in (UNWTO-UNEP-WMO, 2008) and calculated in WTOUNEPWMO2008_figures_02_Final.xls sheet 'Transport World' cell L22.
Average return distance per class	Dist_class	km/trip	Real	{75,112.5,150,200,262.5,350,462.5,600,787.5,1037.5,1362.5,1787.5,2337.5,3075,4050,5312.5,6975,9175,12062.5,15850}*2<<km/trip>>	These are now the metriuc averages, but this should be updated with GTTD measured averages for the whole database.
Biofuel emission correction				ARRSUM(Biofuel LUC fraction fossil Plus*Biofuel shares Plus)	This factor corrects kerosene based emissions downward based on biofuel shares and individual emission reductions.
Car electric efficiency gain from carbon cost				Carbon tax sector switch[Car]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Car electric abatement cost)DIVZ0Global carbon tax policy *Car max effiency improvement-Policy car efficiency improvement), Car efficiency delay time,6)	The assumption is that a certain carbon cost gives an incentive to reduce emissions by the MU belonging to the same abatement copst but times the sensitivity factor. Furthermore this annual rate will be less than the maximum annual rate defined for this technology (air, car electric, acco, etc.).
Car electric emission factor		kg/(km*Car)	Real	Emissions submodel.Car electric emission factor	This figure is based on (Jochem et al., 2015) for the marginal emission factor (as added because of the additional electric cars. This s a cinservative assumption but still way below the global average.
Car electric emission factor initial		kg/(km*Car)	Real	INITIF(YEAR(TIME)=Scenario start year,Car electric emission total factor)	
Car electric emission total factor		kg/(km*Car)	Real	Emissions submodel.Car electric emission factor	
Car electric share			Real	Emissions submodel.Car electric share	
Car fossil efficiency gain from carbon cost				Carbon tax sector switch[Car]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Car fossil abatement cost)DIVZ0Global carbon tax policy *Car max effiency improvement-Policy car efficiency improvement), Car efficiency delay time,6)	The assumption is that a certain carbon cost gives an incentive to reduce emissions by the MU belonging to the same abatement copst but times the sensitivity factor. Furthermore this annual rate will be less than the maximum annual rate defined for this technology (air, car electric, acco, etc.).

Name	Dimensions	Unit	Type	Definition	Documentation
Car fossil emission factor		kg/(km*Car)	Real	Emissions submodel.Car fossil emission factor	
Car fossil emission factor initial		kg/(km*Car)	Real	INITIF(YEAR(TIME)=Scenario start year,Car fossil emission total factor)	
Car fossil emission total factor		kg/(km*Car)	Real	Emissions submodel.Car fossil emission factor	
Car fuel emission factor		Car^-1	Real	3.150<<kg/kg/Car>>	This is based on CBS data for netherlands showing a very consistent emission factor from kg fuel to kg CO2 for teh whole car fleet. See file Car Feitelijke_emissies__040116160203.xlsx.
Car historic emission factor		kg/(km*Car)	Real	Car historical fuel efficiency development*Car weight historical*Car fuel emission factor	
Car historical fuel efficiency development		kg/km/kg	Real	0	data from file Global timeseries data.xlsm
Car total electric emissions				Emissions submodel.Car total electric emissions	
Car total emissions				Car total electric emissions+Car total fossil emissions	
Car total fossil emissions				Emissions submodel.Car total fossil emissions	
Car total global transport				ARRSUM(Car global transport)	
Car weight historical		kg	Real	0<<kg>>	Input from file Global timeseries data.xlsm
CORSIA offset emissions		kg	Real	0<<kg>>	
CORSIA offset emissions per year				IF(YEAR(TIME)>2020, (Air global emissions-Air global emissions 2020)*Air share international, 0<<kg>>) *1<<1/yr>>	
Emissions per dist class fossil based				FOR(i=DIM(Air global transport)| (1+(Turboprop fuel efficiency factor-1)*Turboprop shares per distance class[i])* Air	Based on data from (UNWTO-UNEP-WMO, 2008) it is found that air transport CO2 emissions are a function of distance. We found the following

Name	Dimensions	Unit	Type	Definition	Documentation
				emissions global distance correction* Air emissions per pkm* Air emissions distance correction[i])	function describing a decay factor using Findgraph (Vasilyev, 2004), which found the best fit for a Double Hyperbola: y = a*x/(b + x) + c*x/(d + x) + g*x; with a=0.16717229, b=-129.49736, c=-0.083611835, d=498.87337, g=2.8367594e-006 a 0.1672 b -129.5 c -0.08361 d 498.9 g 0.000002837 0.5*'Average return distance per class' (0.1672*0.5*'Average return distance per class'/(-129.5+0.5*'Average return distance per class')-0.08361*0.5*'Average return distance per class'/(498.9+0.5*'Average return distance per class')+0.00002837*0.5*'Average return distance per class')
Emissions submodel					
Global cruise speed policy factor Air				IF(Scenario on,1,0)* GRAPHCURVE(YEAR(TIME),Scenario start year,(YEAR(STOPTIME)-Scenario start year)/4, Policy cruise speed factor Air)	A 5 year delay has been added to avoid a too strong impus at the beginning of the measure.
Global electricity carbon intensity factor			Real	1	
Historic new aircraft average EI				Emissions submodel.Historic new aircraft average EI* Air fuel emission factorDIVZ0 Air seat occupation* Air operations loss factor	
Other conventional share electric			Real	0.5	First estimate assuming that busses, etc take about 50% of total conventional rail plus road PT share (Peeters & Dubois, 2010). See also poserwsim studio model 'Global Tourism model_21_Brussels_new_optimisation_07_tbv thesis.sip'. All high speed is assumed to be above that and 100% electric.
Other electric efficiency gain from carbon cost				Carbon tax sector switch[Other]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Other electric abatement cost)DIVZ0Global carbon tax policy *Other max effiency improvement-Policy other efficiency improvement), Other efficiency delay	The assumption is that a certain carbon cost gives an incentive to reduce emissions by the MU belonging to the same abatement copst but times the sensitivity factor. Furthermore this annual rate will be less than the maximum annual rate defined for this technology (air, car electric, acco, etc.).

Name	Dimensions	Unit	Type	Definition	Documentation
				time,6)	
Other electric emission factor		kg/km	Real	0.024381219<<kg/km>>	This figure is based on (Jochem et al., 2015) for the marginal emission factor (as added because of the additional electric cars). This s a conservative assumption but still way below the global average.
Other electric emission factor initial		kg/km	Real	INITIF(YEAR(TIME)=Scenario start year,Other electric emission factor)	
Other electric emission factor rate				MIN(Other electric emission factor*1<<1/yr>>, -1*Other electric emission factor* (Policy other efficiency improvement+Other electric efficiency gain from carbon cost +DERIVN(Global electricity carbon intensity factor))* IF(Scenario on,1,0))	
Other electric historic energy emission factor		kg/MJ	Real	0	
Other electric historic energy factor		MJ/km	Real	0	
Other historic emission factor		kg/km	Real	Other electric historic energy factor*Other electric historic energy emission factor	
Other HSR rail share				Transport capacity submodel.Other HSR transport share	
Other non-electric efficiency gain from carbon cost				Carbon tax sector switch[Other]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Other non-electric abatement cost)DIVZ0Global carbon tax policy *Other max effiency improvement-Policy other efficiency improvement), Other efficiency delay time,6)	The assumption is that a certain carbon cost gives an incentive to reduce emissions by the MU belonging to the same abatement copst but times the sensitivity factor. Furthermore this annual rate will be less than the maximum annual rate defined for this technology (air, car electric, acco, etc.).
Other non-electric emission factor		kg/km	Real	0.024381219<<kg/km>>	
Other non-electric emission factor initial		kg/km	Real	INITIF(YEAR(TIME)=Scenario start year,Other non-electric emission factor)	
Other non-electric emission factor rate				Other non-electric emission factor* (Policy other efficiency improvement+Other non-electric efficiency gain from carbon cost)* IF(Scenario	

Name	Dimensions	Unit	Type	Definition	Documentation
				on,1,0)	
Other share electric				Other conventional share electric*(1-Other HSR rail share)+Other HSR rail share	The assumption is that of all conventional speed other transport a constant amount is electric rail and that high speed is 100 electric.
Other total emission factor				IF(Scenario on, Other share electric*Other electric emission factor+ (1-Other share electric)*Other non-electric emission factor, Other historic emission factor)	
Other total emissions				Other total emission factor*Other total global transport	
Other total global transport				ARRSUM(Other global transport)	
Policy accommodation efficiency improvement rate		%/yr	Real	-0.5	
Policy air efficiency improvement		%/yr	Real	0	
Policy car efficiency improvement		%/yr	Real	-0.55	Default chosen as the result of the future trends assumed in the global timeseries excel for fuel efficiency and car weight.
Policy electric car share goal	Policy_ecar_share_transition		Real	{.1,.15}	We guess that the electric car will in a trend scenario take up 10% of the market at a rate of change factor of 0.15.
Policy other efficiency improvement		%/yr	Real	-0.5	Default based on assumption from (Gössling & Peeters, 2015): 0.5% improvement overall, taken to be in efficiency without accounting for difference between electric and non-electric.
Scenario on			Logical	IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	
Scenario start year			Integer	2015	
Seat-pax conversion		seat	Real	1<<seat>>	
Share of turboprops				Transport capacity submodel.Share of turboprops	

Name	Dimensions	Unit	Type	Definition	Documentation
Total trips				ARRSUM(Total trips per mode)	
Turboprop capacity share				IF(YEAR(TIME)<Turboprop share calculation start year,0.02, Turboprop transport pkm capacity/Air transport pkm capacity)	
Turboprop fleet		Aircraft		Transport capacity submodel.Turboprop fleet	
Turboprop fuel efficiency factor			Real	0.9	See calculations with MVdb (CAEP10_GRdb_Ver4-1a_2014-01-28_CO2ma_ZUERICH_ICSA_NEW_TPout.xlsx) Plus also (Peeters, 2010) en (Megan S. Ryerson & Ge, 2014; Megan Smirti Ryerson & Hansen, 2010)
Turboprop global capacity last value				Turboprop transport pkm capacity-ARRSUM(Turboprop global capacity per dist class initial)	
Turboprop global capacity last value index			Integer	ELEMCOUNT(Turboprop global capacity per dist class initial)- COUNTSAME(Turboprop global capacity per dist class initial,0<<km>>)+1	Here the index last non-zero alue index in the turboprop array is generated. This value is needed to calculate the last share, which is less then 1.0 (100%) for this last share, assuming turboprops are usedfor the shortests distances flowbn filling up until all turboprop capacity is allocated.
Turboprop global capacity per dist class				FOR(i=DIM(Air global transport capacity)| IF(NUMERICAL(i)=Turboprop global capacity last value index+1, Turboprop global capacity last value, Turboprop global capacity per dist class initial[i]))	
Turboprop global capacity per dist class initial				FOR(i=DIM(Air global transport capacity)| IF(Air global transport capacity cumulative[i]<=Turboprop transport pkm capacity, Air global transport capacity[i], 0<<km>>))	
Turboprop seats capacity				Turboprop seats Factor A *Share of turboprops+ Turboprop seats Factor B	
Turboprop seats Factor A		seat/Aircraft	Real	193.5<<seats/Aircraft>>	The seat capacity has been taken as being a function of share up to the seat capacity of jets in case there is 100% turboprops and coming from a

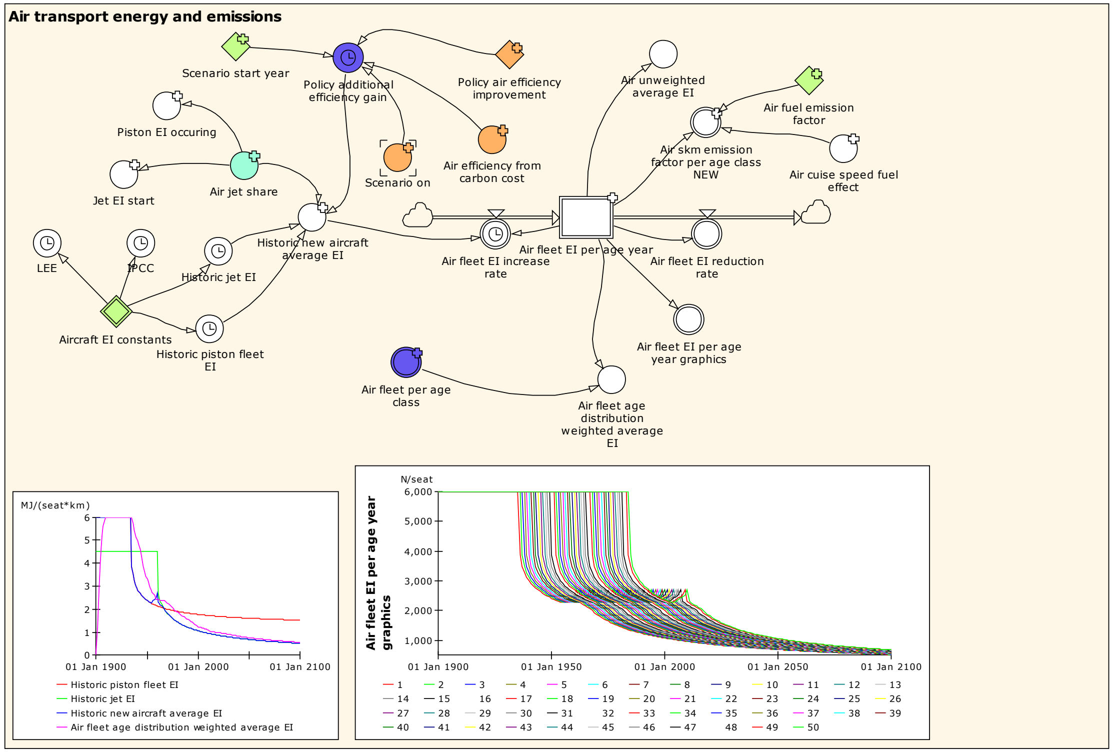
Name	Dimensions	Unit	Type	Definition	Documentation
					vlaue in 2015 of 55 seats. This latter has been based on the G&R CAEP database in file CAEP10_GRdb_Ver4-1a_2014-01-28_CO2ma_ZUERICH_ICSA_NEW_TPout.xlsx; see sheet SO trend and weighted for deliveries 2020-2040 (unweighted it is 53, weighted it is 57 so took 55...). SEE Turboprop data 01.xlsx!
Turboprop seats Factor B		seat/ Aircr aft	Real	26.54<<seats/Aircraft>>	The seat capacity has been taken as being a function of share up to the seat capacity of jets in case there is 100% turboprops and coming from a vlaue in 2015 of 55 seats. This latter has been based on the G&R CAEP database in file CAEP10_GRdb_Ver4-1a_2014-01-28_CO2ma_ZUERICH_ICSA_NEW_TPout.xlsx; see sheet SO trend and weighted for deliveries 2020-2040 (unweighted it is 53, weighted it is 57 so took 55). SEE Turboprop data 01.xlsx.
Turboprop share calculation start year			Real	1950	
Turboprop shares per distance class				Turboprop global capacity per dist classDIVZ0 Air global transport capacity	
Turboprop speed factor			Real	1-0.5*(1-300/500)	Based on the cruise speed difference of 300 mph for turboprops and 500 for regional jets given in (ATR, 2014). Then taken half of the disadvantage because LTO, taxying, etc. is the same.
Turboprop transport pkm capacity				Turboprop fleet*Turboprop seats capacity* Aircraft utility* Air transport historical blockspeed*Turboprop speed factor *Aircraft seat unit conversion	

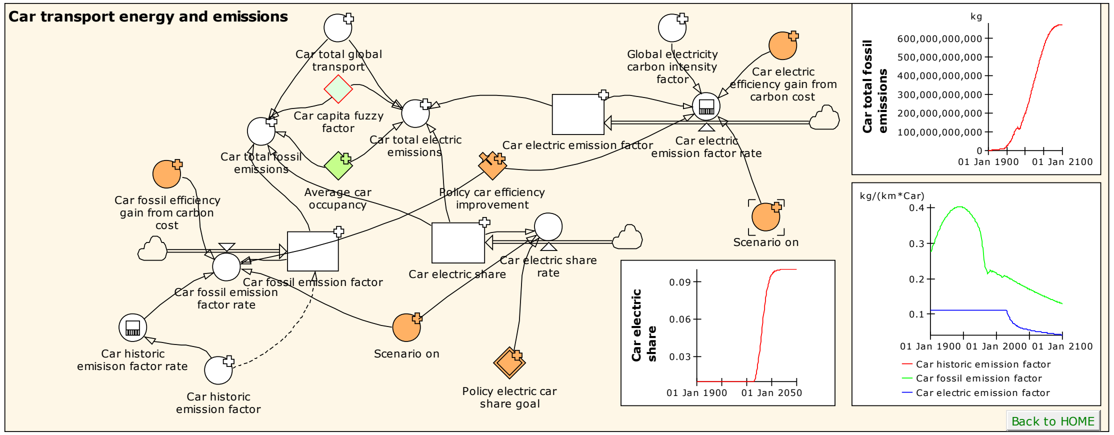
Emissions submodel

Description/task: Calculate air and car emission factors per mode and energy source

Main inputs: Historic/policy assumptions

Main outputs: Emission factors air and car


Air transport energy and emissions
Scenario start year
Policy additional efficiency gain
Policy air efficiency improvement
Air unweighted average EI
Air fuel emission factor
Piston EI occuring
Scenario on
Air efficiency from carbon cost
Air skm emission factor per age class NEW
Air cuise speed fuel effect
Jet EI start
Air jet share
Historic new aircraft average EI
Air fleet EI increase rate
Air fleet EI per age year
Air fleet EI reduction rate
LEE
IPCC
Historic jet EI
Aircraft EI constants
Historic piston fleet EI
Air fleet EI per age year graphics
Air fleet per age class
Air fleet age distribution weighted average EI
MJ/(seat*km)
01 Jan 1900
01 Jan 2000
01 Jan 2100
Historic piston fleet EI
Historic jet EI
Historic new aircraft average EI
Air fleet age distribution weighted average EI
N/seat
Air fleet EI per age year graphics
01 Jan 1900
01 Jan 1950
01 Jan 2000
01 Jan 2050
01 Jan 2100


Car transport energy and emissions
Car total global transport
Global electricity carbon intensity factor
Car electric efficiency gain from carbon cost
Car capita fuzzy factor
Car total electric emissions
Car electric emission factor
Car electric emission factor rate
Car total fossil emissions
Average car occupancy
Policy car efficiency improvement
Car fossil efficiency gain from carbon cost
Scenario on
Car fossil emission factor
Car electric share
Car electric share rate
Car fossil emission factor rate
Car historic emisson factor rate
Car historic emission factor
Policy electric car share goal
Car electric share
01 Jan 1900
01 Jan 2050
kg
Car total fossil emissions
01 Jan 1900
01 Jan 2100
kg/(km*Car)
01 Jan 1900
01 Jan 2000
01 Jan 2100
Car historic emission factor
Car fossil emission factor
Car electric emission factor
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Emissions submodel.Air cuise speed fuel effect				REF(Parent~Air cuise speed fuel effect)	
Emissions submodel.Air efficiency from carbon cost				REF(Parent~Air efficiency gain from carbon cost)	
Emissions submodel.Air fleet age distribution weighted average EI				ARRSUM(Air fleet EI per age year*Air fleet per age class)/ ARRSUM(Air fleet per age class)	
Emissions submodel.Air fleet EI increase rate	Vehicle Age	MJ/(seat *km)/yr		IF(TIMECYCLE(STARTTIME,1<<yr>>,TIMESTEP), CONCAT({Historic new aircraft average EI}*1<<1/yr>>,FOR(i=FIRST(Vehicle Age)+1..LAST(Vehicle Age)| Air fleet EI per age year[i-1]*1<<1/yr>>)),0<<MJ/(seat*km)/yr>>) /(TIMESTEP/1<<yr>>)	
Emissions submodel.Air fleet EI per age year	Vehicle Age	MJ/(seat *km)	Real	0	
Emissions submodel.Air fleet EI per age year graphics	Vehicle Age	N/seat	Real	FOR(i=DIM(Air fleet EI per age year,1)| IF(Air fleet EI per age year[i]=0<<MJ/(seat*km)>>,6<<MJ/(seat*km)>>,Air fleet EI per age year[i]))	
Emissions submodel.Air fleet EI reduction rate	Vehicle Age	MJ/(seat *km)/yr	Real	Air fleet EI per age year*1<<1/yr>>	
Emissions submodel.Air fleet per age class	Vehicle Age			REF(Parent~Air fleet per age class)	
Emissions submodel.Air fuel emission factor		kg/MJ	Real	REF(Parent~Air fuel emission factor)	This constant calculates the carbon emissions in kg from the energy intensity of MJ/seatkm. We use the kerosene factor for both kerosine and the short historic period with gasoline for pistons because the two

Name	Dimensions	Unit	Type	Definition	Documentation
					factors do not differ much. From www.jl-group.eu/doc/Jet-Fuel.pdf: 42.8 MJ/kg minimum heat of combustion. from (EPA, 2004) we find 19.33 kg C/Mbtu which translates to 3.66667*19.33/1054.2 = 0,06723 kg CO2/MJ
Emissions submodel.Air jet share			Real	Parent~Air jet share	
Emissions submodel.Air skm emission factor per age class NEW				Air cuise speed fuel effect* Air fuel emission factor*Air fleet EI per age year	
Emissions submodel.Air unweighted average EI		N/seat	Real	ARRAVERAGE(Air fleet EI per age year)* ELEMCOUNT(Air fleet EI per age year)/ COUNTNEQ(Air fleet EI per age year,0<<MJ/(seat*km)>>)	
Emissions submodel.Aircraft EI constants	Aircraft_EI_curve,Aircraft_EI_constants		Real	{{-0.2010,3.207,2.214,19.69,0.7183,1958}, {0.0446,2.855,2.213,19.69,0.7183,1958}, {1.195,2.746,3.916,10.22,0.7186,1931}}	See (Peeters & Middel, 2007, p. Table 1)
Emissions submodel.Average car occupancy		Capita/Car	Real	REF(Parent~Average car occupancy)	
Emissions submodel.Car capita fuzzy factor		Capita	Real	1<<Capita>>	To get rit of the capita unit in the car occupancy rate. Changing the Car BASS model to accommodate the unit better appeared to be too cumbersome. 4-1-2016.
Emissions submodel.Car electric efficiency gain from carbon cost				REF(Parent~Car electric efficiency gain from carbon cost)	The assumption is that a certain carbon cost gives an incentive to reduce emissions by the MU belonging to the same abatement cost but times the sensitivity factor. Furthermore this annual rate will be less than the maximum annual rate

Name	Dimensions	Unit	Type	Definition	Documentation
					defined for this technology (air, car electric, acco, etc.).
Emissions submodel.Car electric emission factor		kg/(km* Car)	Real	.11<<kg/(Car*km)>>	This figure is based on (Jochem et al., 2015) for the marginal emission factor (as added because of the additional electric cars. This is a conservative assumption but still way below the global average.
Emissions submodel.Car electric emission factor rate				Car electric emission factor* (Policy car efficiency improvement+Car electric efficiency gain from carbon cost+DERIVN(Global electricity carbon intensity factor))* IF(Scenario on,1,0)	
Emissions submodel.Car electric share			Real	0.01	
Emissions submodel.Car electric share rate		yr^-1	Real	IF(Scenario on, Car electric share*(Policy electric car share goal[Policy goal]-Car electric share)/ Policy electric car share goal[Policy goal], 0)*Policy electric car share goal[Policy change factor] *1<<1/yr>>	The following equation makes it possible to set electric cars also to 0%, but then all values (ver slightly) change... IF('Scenario on', 'Car electric share'*('Policy electric car share goal'['Policy goal']-'Car electric share')*/// 'Policy electric car share goal'['Policy change factor'], 0)//*'Policy electric car share goal'['Policy change factor'] *1<<1/yr>>
Emissions submodel.Car fossil efficiency gain from carbon cost				REF(Parent~Car fossil efficiency gain from carbon cost)	The assumption is that a certain carbon cost gives an incentive to reduce emissions by the MU belonging to the same abatement copst but times the sensitivity factor. Furthermore this annual rate will be less than the maximum annual rate defined for this technology (air, car electric, acco, etc.).
Emissions		kg/(km*	Real	Car historic emission factor	

Name	Dimensions	Unit	Type	Definition	Documentation
submodel.Car fossil emission factor		Car)			
Emissions submodel.Car fossil emission factor rate				IF(Scenario on, (Policy car efficiency improvement+Car fossil efficiency gain from carbon cost)*Car fossil emission factor, Car historic emisison factor rate)	
Emissions submodel.Car historic emisison factor rate		kg/(yr*km*Car)	Real	DERIVN(Car historic emission factor)	
Emissions submodel.Car historic emission factor		kg/(km*Car)	Real	REF(Parent~Car historic emission factor)	
Emissions submodel.Car total electric emissions				Car electric share* Car capita fuzzy factor* Car electric emission factor* Car total global transport/ Average car occupancy	
Emissions submodel.Car total fossil emissions				(1-Car electric share)* Car capita fuzzy factor* Car fossil emission factor* Car total global transport/ Average car occupancy	
Emissions submodel.Car total global transport				REF(Parent~Car total global transport)	
Emissions submodel.Global electricity carbon intensity factor			Real	REF(Parent~Global electricity carbon intensity factor)	
Emissions submodel.Historic jet EI		N/seat	Real	(IF(YEAR()<1961,4.5, Aircraft EI constants[IPCC,EI_0]+Aircraft EI constants[IPCC,CE_I]/(1+(((YEAR()-Aircraft EI constants[IPCC,Y_ref]) -Aircraft EI constants[IPCC,C_1])/Aircraft EI constants[IPCC,C_2])^Aircraft EI constants[IPCC,Gamma])) *1<<MJ/(seat*km)>> + IF(YEAR()<1961,4.5, Aircraft EI constants[Lee,EI_0]+Aircraft EI constants[Lee,CE_I]/(1+(((YEAR()-Aircraft EI constants[Lee,Y_ref]) -Aircraft EI constants[Lee,C_1])/Aircraft EI constants[Lee,C_2])^Aircraft EI constants[Lee,Gamma])) *1<<MJ/(seat*km)>>)/2	The emissions are based on (Peeters & Middel, 2007) IPCC jets and calculate up to 2100 for all scenarios. This is assumed to be the endogenous trend.

Name	Dimensions	Unit	Type	Definition	Documentation
Emissions submodel.Historic new aircraft average EI		MJ/(seat *km)		((1-Air jet share)*Historic piston fleet EI+Air jet share*Historic jet EI) *(1+Policy additional efficiency gain)	
Emissions submodel.Historic piston fleet EI		MJ/(seat *km)	Real	IF(YEAR()<1935,6, Aircraft EI constants[Piston fleet,EI_0]+Aircraft EI constants[Piston fleet,CE_I]/ (1+(((YEAR()-Aircraft EI constants[Piston fleet,Y_ref]) - Aircraft EI constants[Piston fleet,C_1])/Aircraft EI constants[Piston fleet,C_2]) ^Aircraft EI constants[Piston fleet,Gamma])) *1<<MJ/(seat*km)>>	
Emissions submodel.IPCC		N/seat	Real	IF(YEAR()<1961,4.5, Aircraft EI constants[IPCC,EI_0]+Aircraft EI constants[IPCC,CE_I]/ (1+(((YEAR()-Aircraft EI constants[IPCC,Y_ref]) -Aircraft EI constants[IPCC,C_1])/Aircraft EI constants[IPCC,C_2]) ^Aircraft EI constants[IPCC,Gamma])) *1<<MJ/(seat*km)>>	
Emissions submodel.Jet EI start			Logical	IF(Air jet share>0,TRUE,FALSE)	
Emissions submodel.LEE		N/seat	Real	IF(YEAR()<1961,4.5, Aircraft EI constants[Lee,EI_0]+Aircraft EI constants[Lee,CE_I]/ (1+(((YEAR()-Aircraft EI constants[Lee,Y_ref]) -Aircraft EI constants[Lee,C_1])/Aircraft EI constants[Lee,C_2]) ^Aircraft EI constants[Lee,Gamma])) *1<<MJ/(seat*km)>>	
Emissions submodel.Piston EI occuring			Logical	IF(Air jet share=0,TRUE,FALSE)	
Emissions submodel.Policy additional efficiency gain				IF(Scenario on, (1+(Policy air efficiency improvement+Air efficiency from carbon cost)*1<<yr>>) ^(YEAR(TIME)-Scenario start year)-1, 0)	
Emissions submodel.Policy air efficiency improvement		%/yr	Real	REF(Parent~Policy air efficiency improvement)	Default based on assumption from (Gössling & Peeters, 2015): 0.5% improvement overall, taken to be in efficiency without accounting for difference between electric and non-

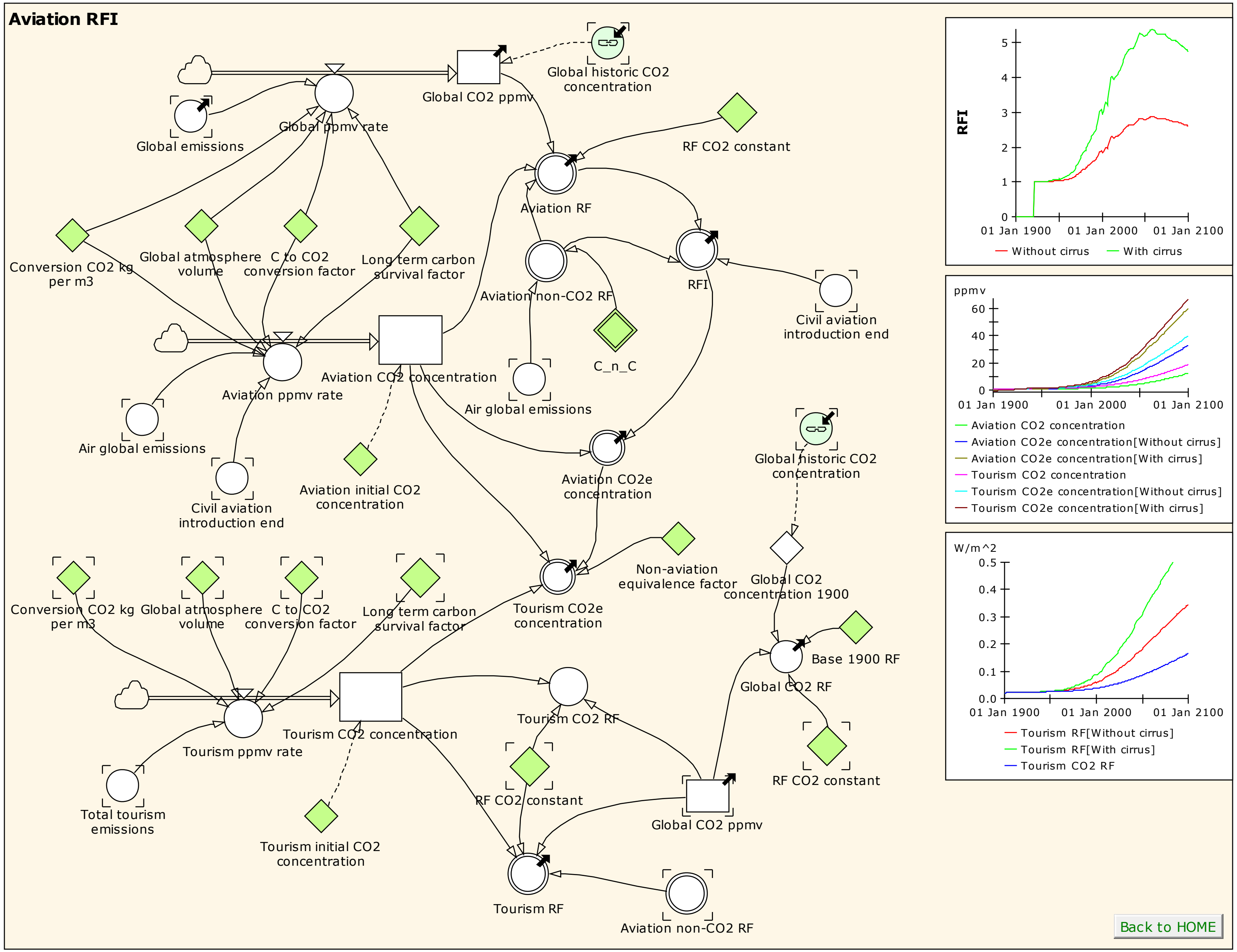
Name	Dimensions	Unit	Type	Definition	Documentation
					electric.
Emissions submodel.Policy car efficiency improvement		1/yr	Real	REF(Parent~Policy car efficiency improvement)	
Emissions submodel.Policy electric car share goal	Policy_ecar_share_transition		Real	REF(Parent~Policy electric car share goal)	take electric cars impact from (Jochem et al., 2015)
Emissions submodel.Scenario on			Logical	REF(Parent~Scenario on)	
Emissions submodel.Scenario start year			Integer	REF(Parent~Scenario start year)	

Aviation RFI

Description/task: Calculate aviation radiative forcing and radiative forcing index (RF respectively RFI)

Main inputs: Global (tourism) emissions

Main outputs: RF, RFI


Aviation RFI
Global historic CO2 concentration
Global CO2 ppmv
Global emissions
Global ppmv rate
RF CO2 constant
Aviation RF
Conversion CO2 kg per m3
Global atmosphere volume
C to CO2 conversion factor
Long term carbon survival factor
Aviation non-CO2 RF
RFI
Civil aviation introduction end
C_n_C
Aviation CO2 concentration
Aviation ppmv rate
Air global emissions
Aviation initial CO2 concentration
Aviation CO2e concentration
Tourism CO2e concentration
Non-aviation equivalence factor
Global CO2 concentration 1900
Base 1900 RF
Global CO2 RF
Tourism ppmv rate
Tourism CO2 concentration
Tourism CO2 RF
Total tourism emissions
Tourism initial CO2 concentration
Tourism RF
Back to HOME
RFI
01 Jan 1900
01 Jan 2000
01 Jan 2100
Without cirrus
With cirrus
ppmv
Aviation CO2 concentration
Aviation CO2e concentration[Without cirrus]
Aviation CO2e concentration[With cirrus]
Tourism CO2 concentration
Tourism CO2e concentration[Without cirrus]
Tourism CO2e concentration[With cirrus]
W/m^2
Tourism RF[Without cirrus]
Tourism RF[With cirrus]
Tourism CO2 RF

Name	Dimensions	Unit	Type	Definition	Documentation
Air global emissions				Biofuel emission correction*ARRSUM(Emissions per dist class fossil based)	
Aviation CO2 concentration		ppmv	Real	Aviation initial CO2 concentration	See Table 5 in (Peeters et al., 2007); The value has been calibrated to produce the Sausen et al. (2005) update IPCC paper value of 25.3 RF in 2000.
Aviation CO2e concentration				Aviation CO2 concentration*RFI	
Aviation initial CO2 concentration		ppmv	Real	1.277<<ppmv>>	See Table 5 in (Peeters et al., 2007); The value has been calibrated to produce the Sausen et al. (2005) update IPCC paper value of 25.3 RF in 2000.
Aviation non-CO2 RF		W/m^2		Air global emissions*C_n_C	
Aviation ppmv rate				IF(Civil aviation introduction end,1,0)* 1/C to CO2 conversion factor* Air global emissions*Conversion CO2 kg per m3/Global atmosphere volume*1<<1/yr>> *Long term carbon survival factor	
Aviation RF		W/m^2		Aviation non-CO2 RF+ RF CO2 constant*LN((Global CO2 ppmv+Aviation CO2 concentration)/Global CO2 ppmv)	
Base 1900 RF		kg/s^3	Real	0.2268<<W/m^2>>	Fitted to get the 1.66 W/m^2 from (IPCC, 2013).
C to CO2 conversion factor			Real	12/44<<GtCO2/GtC>>	
C_n_C	RFI	W/m^2/GtCO2	Real	{0.0458,0.10687}	Fixed ratio between 1992 non-carbon RF as updated from Sausen et al. 2005 and the total aviation 1992 CO2 emissions given by Prather et al. 1999 (Peeters et al., 2007, p. 41). Again updated to represent the inclduing average cirrus of 30 mW/m2 from Sausen et al. 2005. The total non-CO2 then would be 47.8+30.0-25.3=52.5.
Civil aviation introduction				IF(YEAR(TIME)>Civil aviation introduction year+1,TRUE,FALSE)	This variable triggers the introduction of civil air transport at the year set in the linked constant. This is

Name	Dimensions	Unit	Type	Definition	Documentation
end					necessary because of the fact that before a certain year civil air transport has not been on offer.
Conversion CO2 kg per m3		m^3*ppmv/GtCO2	Real	1.94*10^+18*1<<ppmv/(GtCO2/m^3)>>	The conversion from 1 ppmv to kg is: 1.94 mg/m^3 Source: http://www.lenntech.com/calculators/ppm/converter-parts-per-million.htm
Global atmosphere volume		m^3	Real	48600227828<<km^3>>	
Global CO2 concentration 1900		ppmv	Real	Global historic CO2 concentration	
Global CO2 ppmv		ppmv	Real	Global historic CO2 concentration	Global CO2 concentration in 1900 (IS92a scenario)
Global CO2 RF		kg/s^3	Real	Base 1900 RF+RF CO2 constant*LN(Global CO2 ppmv/Global CO2 concentration 1900)	
Global emissions				CO2 emission correction factor for population* Global scenario dependent emissions[INDEX(Global_economy_sc_switch), INDEX(Global mitigation scenario switch)]	
Global historic CO2 concentration		ppmv	Real	1<<ppmv>>	
Global ppmv rate				1/C to CO2 conversion factor* Global emissions*Conversion CO2 kg per m3/Global atmosphere volume*1<<1/yr>> *Long term carbon survival factor	
Long term carbon survival factor			Real	0.3522	long term ratio between CO2 remaining in atmosphere and CO2 emitted; see (Peeters et al., 2007, p. 41) Adjusted to get the observed 369.2 (IIASA) in 2000.

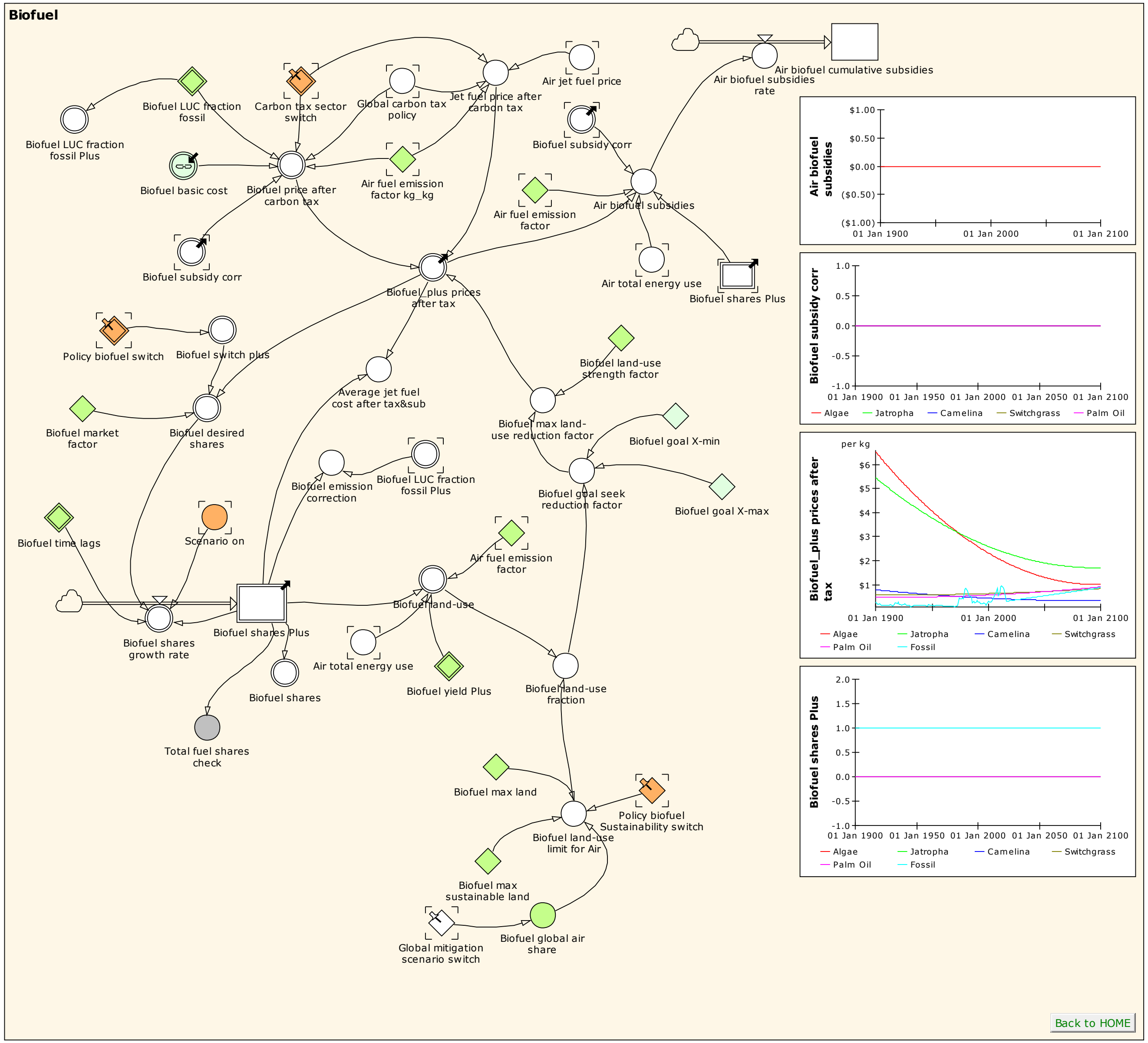
Name	Dimensions	Unit	Type	Definition	Documentation
Non-aviation equivalence factor			Real	1.1	Own estimate
RF CO2 constant		W/m^2	Real	5.34	Constant from eq. 10 in (Peeters et al., 2007).
RFI				IF(Civil aviation introduction end,1,0)* Aviation RF/(Aviation RF-Aviation non-CO2 RF)	
Total tourism emissions		GtCO2		Accommodation emissions+ Air global emissions+ Car total emissions+ Other total emissions	
Tourism CO2 concentration		ppmv	Real	Tourism initial CO2 concentration	See Table 5 in (Peeters et al., 2007); The value has been calibrated to produce the Sausen et al. (2005) update IPCC paper value of 25.3 RF in 2000.
Tourism CO2 RF		W/m^2	Real	RF CO2 constant*LN((Global CO2 ppmv+Tourism CO2 concentration)/Global CO2 ppmv)	
Tourism CO2e concentration				Non-aviation equivalence factor*(Tourism CO2 concentration-Aviation CO2 concentration) +Aviation CO2e concentration	
Tourism initial CO2 concentration		ppmv	Real	1.227<<ppmv>>	Rather rough guestimate
Tourism ppmv rate				1/C to CO2 conversion factor* Total tourism emissions*Conversion CO2 kg per m3/Global atmosphere volume*1<<1/yr>> *Long term carbon survival factor	
Tourism RF		W/m^2		Aviation non-CO2 RF+ RF CO2 constant*LN((Global CO2 ppmv+Tourism CO2 concentration)/Global CO2 ppmv)	

Biofuel

Description/task: Calculate the markets for 5 biofuel feedstock's

Main inputs: Cost and subsidies for biofuels; global land-use restriction

Main outputs: Shares of kerosene and biofuels


Biofuel
Biofuel LUC fraction fossil Plus
Biofuel LUC fraction fossil
Carbon tax sector switch
Global carbon tax policy
Jet fuel price after carbon tax
Air jet fuel price
Air biofuel subsidies rate
Air biofuel cumulative subsidies
Biofuel basic cost
Biofuel price after carbon tax
Air fuel emission factor kg_kg
Biofuel subsidy corr
Air fuel emission factor
Air biofuel subsidies
Air total energy use
Biofuel shares Plus
Biofuel subsidy corr
Biofuel_plus prices after tax
Policy biofuel switch
Biofuel switch plus
Biofuel land-use strength factor
Average jet fuel cost after tax&sub
Biofuel market factor
Biofuel desired shares
Biofuel max land-use reduction factor
Biofuel goal X-min
Biofuel emission correction
Biofuel LUC fraction fossil Plus
Biofuel goal seek reduction factor
Biofuel goal X-max
Biofuel time lags
Scenario on
Air fuel emission factor
Biofuel land-use
Biofuel shares growth rate
Biofuel shares Plus
Air total energy use
Biofuel yield Plus
Biofuel shares
Biofuel land-use fraction
Total fuel shares check
Biofuel max land
Policy biofuel Sustainability switch
Biofuel land-use limit for Air
Biofuel max sustainable land
Global mitigation scenario switch
Biofuel global air share
Air biofuel subsidies
$1.00
$0.50
$0.00
($0.50)
($1.00)
01 Jan 1900
01 Jan 2000
01 Jan 2100
Biofuel subsidy corr
1.0
0.5
0.0
-0.5
-1.0
01 Jan 1900
01 Jan 1950
01 Jan 2000
01 Jan 2050
01 Jan 2100
Algae
Jatropha
Camelina
Switchgrass
Palm Oil
Biofuel_plus prices after tax
per kg
$6
$5
$4
$3
$2
$1
01 Jan 1900
01 Jan 2000
01 Jan 2100
Algae
Jatropha
Camelina
Switchgrass
Palm Oil
Fossil
Biofuel shares Plus
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
01 Jan 1900
01 Jan 1950
01 Jan 2000
01 Jan 2050
01 Jan 2100
Algae
Jatropha
Camelina
Switchgrass
Palm Oil
Fossil
Back to HOME

Name	Dimensions	Unit	Type	Definition	Documentation
Air biofuel cumulative subsidies		USD	Real	0	
Air biofuel subsidies				ARRSUM(Air total energy use*Air fuel emission factor* Biofuel shares Plus*Biofuel_plus prices after tax* CONCAT({Biofuel subsidy corr[Algae]}, {Biofuel subsidy corr[Jatropha]}, {Biofuel subsidy corr[Camelina]}, {Biofuel subsidy corr[Switchgrass]}, {Biofuel subsidy corr[Palm Oil]}, (European Tourism Forum 2002))) //It is a subsidy and therefore a negative number or zero.	As it is a subsidy the result is a negative in terms of taxes.
Air biofuel subsidies rate				Air biofuel subsidies*1<<1/yr>>	
Air fuel emission factor		kg/MJ	Real	0.06723	This constant calculates the carbon emissions in kg from the energy intensity of MJ/seatkm. We use the kerosene factor for both kerosine and the short historic period with gasoline for pistons because the two factors do not differ much. From www.jl-group.eu/doc/Jet-Fuel.pdf: 42.8 MJ/kg minimum heat of combustion. from (EPA, 2004) we find 19.33 kg C/Mbtu which translates to 3.66667*19.33/1054.2 = 0,06723 kg CO2/MJ
Air fuel emission factor kg_kg			Real	3.157<<kg/kg>>	Based on ICAO calculator (ICAO, 2014)
Air jet fuel price				Air transport jet fuel price[INDEX(Global mitigation scenario switch)]	
Air total energy use				ARRSUM(Emissions per dist class fossil based)/Air fuel emission factor	
Average jet fuel cost after tax&sub				ARRSUM(Biofuel shares Plus*Biofuel_plus prices after tax)	
Biofuel basic cost	Biofuels	USD/kg	Real	0<<USD/kg>>	

Name	Dimensions	Unit	Type	Definition	Documentation
Biofuel desired shares				Biofuel switch plus*(Biofuel_plus prices after tax/1<<USD/kg>>)^-Biofuel market factor/ (Biofuel switch plus[Algae]*(Biofuel_plus prices after tax[Algae]/1<<USD/kg>>)^-Biofuel market factor+ Biofuel switch plus[Jatropha]*(Biofuel_plus prices after tax[Jatropha]/1<<USD/kg>>)^-Biofuel market factor+ Biofuel switch plus[Camelina]*(Biofuel_plus prices after tax[Camelina]/1<<USD/kg>>)^-Biofuel market factor+ Biofuel switch plus[Switchgrass]*(Biofuel_plus prices after tax[Switchgrass]/1<<USD/kg>>)^-Biofuel market factor+ Biofuel switch plus[Palm Oil]*(Biofuel_plus prices after tax[Palm Oil]/1<<USD/kg>>)^-Biofuel market factor+ Biofuel switch plus[Fossil]*(Biofuel_plus prices after tax[Fossil]/1<<USD/kg>>)^-Biofuel market factor)	
Biofuel emission correction		%	Real	ARRSUM(Biofuel LUC fraction fossil Plus*Biofuel shares Plus)	This factor corrects kerosene based emissions downward based on biofuel shares and individual emission reductions.
Biofuel global air share			Real	{0.4,0.3,0.2,0.1}[INDEX(Global mitigation scenario switch)]	Clearly the global share of airtransport biofuel land-use will depend on the global mitigation scenario as a strong mitigation will cause demands from other transport and non-transport sectors.
Biofuel goal seek reduction factor				(1-TANH(Biofuel land-use fraction/(Biofuel goal X-max-Biofuel goal X-min)*6- (Biofuel goal X-min+Biofuel goal X-max)*3/(Biofuel goal X-max-Biofuel goal X-min)))/2	X-min and x-max prionvide the range over x you want the S-shape reduction from 1 to 0. Replace the X-value variable with your real X.
Biofuel goal X-max			Real	1.2	

Name	Dimensions	Unit	Type	Definition	Documentation
Biofuel goal X-min			Real	0.5	
Biofuel land-use				Air total energy use*Biofuel shares Plus/ Biofuel yield Plus*Air fuel emission factor	
Biofuel land-use fraction				(ARRSUM(Biofuel land-use))/Biofuel land-use limit for Air	
Biofuel land-use limit for Air		ha	Real	Biofuel global air share* {Biofuel max land,Biofuel max sustainable land}[INDEX(Policy biofuel Sustainability switch)]	
Biofuel land-use strength factor			Real	0.01	
Biofuel LUC fraction fossil	Biofuels	%	Real	{78,42,63,66,61}<<%>>	See excel Biofuel measure model literature study.xlsx.
Biofuel LUC fraction fossil Plus	Biofuels_Plus	%	Real	{Biofuel LUC fraction fossil[Algae], Biofuel LUC fraction fossil[Jatropha], Biofuel LUC fraction fossil[Camelina], Biofuel LUC fraction fossil[Switchgrass], Biofuel LUC fraction fossil[Palm Oil], 1}	
Biofuel market factor			Real	6	Market share model: see supplementary file with (Agusdinata, Zhao, Ileleji, & DeLaurentis, 2011, p. 8)
Biofuel max land		ha	Real	13333000000<<ha>>	Based on (World Bank Group, 2010); See excel Biofuel measure model literature study.xlsx.
Biofuel max land-use reduction factor				MAX(Biofuel land-use strength factor,Biofuel goal seek reduction factor)	The power 4 helps to get the available land area closely used by biofuels though it will still lag a couple of per cents (which seems a good representation of what in reality may happen). The factor strongly increases the prices of biofuels in case land becomes scarce. That mechanism reduces the shares to within the land use requirement. The sometimes strong oscilations do not affect the share of biofuels itself or the effect on emissions.
Biofuel max sustainable land		ha	Real	446000000<<ha>>	Based on (World Bank Group, 2010), See excel Biofuel measure model literature study.xlsx.

Name	Dimensions	Unit	Type	Definition	Documentation
Biofuel price after carbon tax				(1-Biofuel subsidy corr)* (Biofuel basic cost+ IF(Carbon tax sector switch[Air]=1, Biofuel LUC fraction fossil*Global carbon tax policy*Air fuel emission factor kg_kg,0<<USD/kg>>))	
Biofuel shares	Biofuels		Real	{Biofuel shares Plus[Algae], Biofuel shares Plus[Jatropha], Biofuel shares Plus[Camelina], Biofuel shares Plus[Switchgrass], Biofuel shares Plus[Palm Oil]}	
Biofuel shares growth rate	Biofuels_Plus			IF(Scenario on,1,0)* (Biofuel desired shares-Biofuel shares Plus)/Biofuel time lags	
Biofuel shares Plus	Biofuels_Plus		Real	{0,0,0,0,0,1}	
Biofuel subsidy corr				MIN(Biofuel max subsidy,MAX({0,0,0,0,0},Biofuel subsidy))	
Biofuel switch plus	Biofuels_Plus		Real	{Policy biofuel switch[Algae], Policy biofuel switch[Jatropha], Policy biofuel switch[Camelina], Policy biofuel switch[Switchgrass], Policy biofuel switch[Palm Oil], 1}	Add kerosene to the fuel lists
Biofuel time lags	Biofuels_Plus	yr	Real	20 <<yr>>	It is clear that a biofuel and feedstock system requires time to adjust to market demands. But actually this is also a strength of response constant.
Biofuel yield Plus	Biofuels_Plus	kg/ha	Real	{16435,779,2727,4869,3486,10^15}*1<<kg/ha>>	See excel Biofuel measure model literature study.xlsx. The fossil yield has been set at a prohibitive small amount so it marginally affects total land use. In reality there is of course some land use from fossil fuels as well but far less then for biofuels, thus we ignore this.
Biofuel_plus prices after tax	Biofuels_Plus			{Biofuel price after carbon tax[Algae], Biofuel price after carbon tax[Jatropha], Biofuel price after carbon tax[Camelina],	

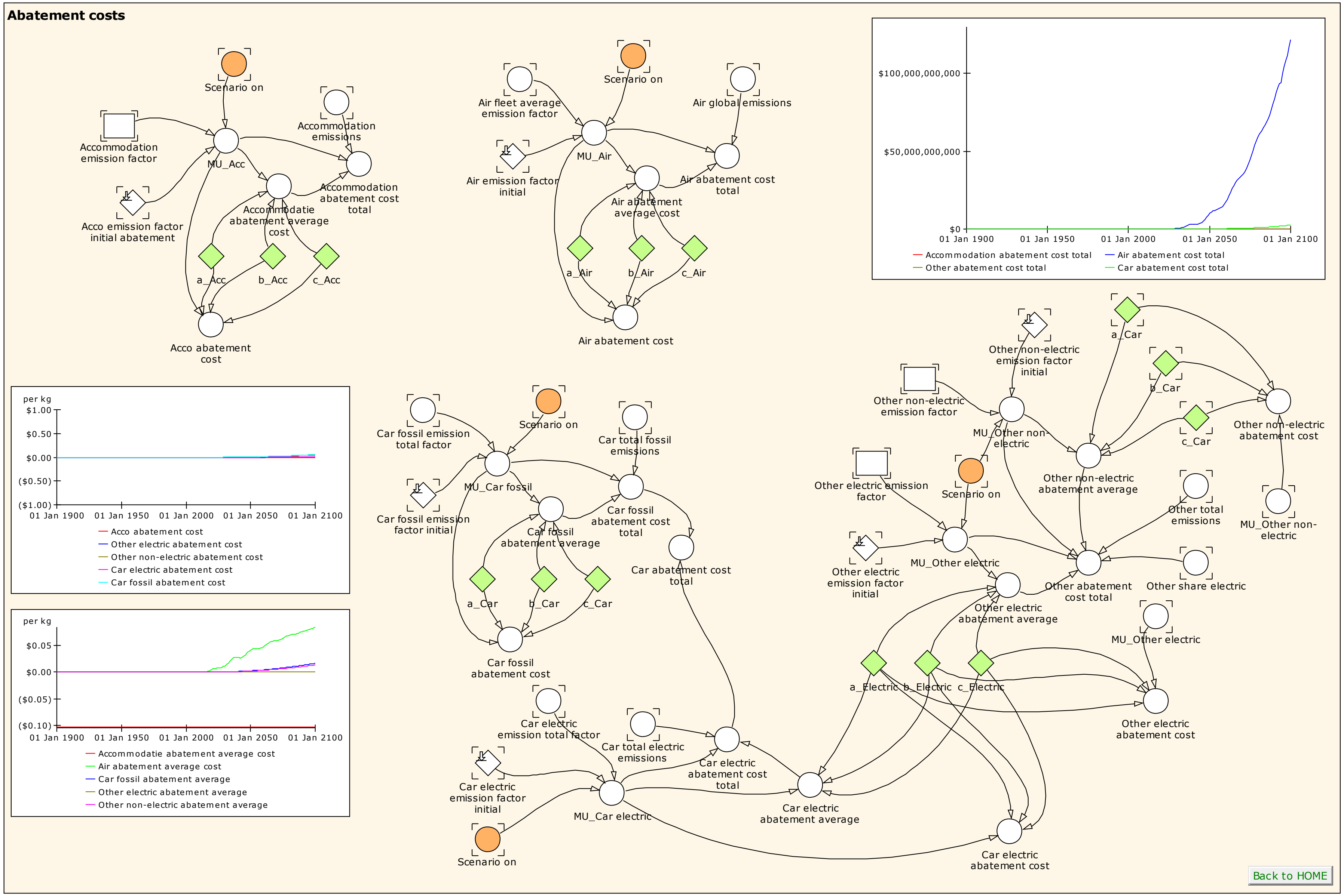
Name	Dimensions	Unit	Type	Definition	Documentation
				Biofuel price after carbon tax[Switchgrass], Biofuel price after carbon tax[Palm Oil], Jet fuel price after carbon tax*Biofuel max land-use reduction factor}/Biofuel max land-use reduction factor	
Carbon tax sector switch	Emission_cats		Integer	1	Carbon tax applied to each mode with 1.
Global carbon tax policy				IF(Scenario on,1,0)* (Global tourism carbon tax+Global shadow cost mitigation)	A 5 year delay has been added to avoid a too strong impus at the beginning of the measure.
Global mitigation scenario switch			Integer	1	Global mitigation scenario switch: 1 unlimited 2 moderate (3.5) 3 Paris Goal (2.0) 4 Paris Ambition (1.5)
Jet fuel price after carbon tax				Air jet fuel price+ Carbon tax sector switch[Air]*Global carbon tax policy*Air fuel emission factor kg_kg	
Policy biofuel Sustainability switch			Integer	1	0: Max landuse limit 1: sustainable land use limit
Policy biofuel switch	Biofuels		Integer	0	Carbon tax applied to each mode with 1.
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	
Total fuel shares check			Real	ARRSUM(Biofuel shares Plus)	

Abatement cost

Description/task: Calculate the abatement cost for CO2 emission reductions

Main inputs: Relative change in CO2 emission factors

Main outputs: Abatement cost for accommodations and transport modes


Abatement costs
Scenario on
Accommodation emission factor
Accommodation emissions
MU_Acc
Accommodation abatement cost total
Accommodatie abatement average cost
Acco emission factor initial abatement
a_Acc
b_Acc
c_Acc
Acco abatement cost
Air fleet average emission factor
Air global emissions
MU_Air
Air emission factor initial
Air abatement cost total
Air abatement average cost
a_Air
b_Air
c_Air
Air abatement cost
$100,000,000,000
$50,000,000,000
$0
01 Jan 1900
01 Jan 1950
01 Jan 2000
01 Jan 2050
01 Jan 2100
Accommodation abatement cost total
Air abatement cost total
Other abatement cost total
Car abatement cost total
per kg
$1.00
$0.50
$0.00
($0.50)
($1.00)
Acco abatement cost
Other electric abatement cost
Other non-electric abatement cost
Car electric abatement cost
Car fossil abatement cost
$0.05
($0.05)
($0.10)
Accommodatie abatement average cost
Air abatement average cost
Car fossil abatement average
Other electric abatement average
Other non-electric abatement average
Car fossil emission total factor
Car total fossil emissions
MU_Car fossil
Car fossil emission factor initial
Car fossil abatement cost total
Car fossil abatement average
Car abatement cost total
a_Car
b_Car
c_Car
Car fossil abatement cost
Car electric emission total factor
Car total electric emissions
Car electric emission factor initial
Car electric abatement cost total
MU_Car electric
Car electric abatement average
Car electric abatement cost
Other non-electric emission factor initial
Other non-electric emission factor
MU_Other non-electric
Other non-electric abatement average
Other non-electric abatement cost
Other electric emission factor
Other total emissions
MU_Other non-electric
Other electric emission factor initial
MU_Other electric
Other abatement cost total
Other share electric
Other electric abatement average
a_Electric
b_Electric
c_Electric
Other electric abatement cost
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Name	Dimensions	Unit	Type	Definition	Documentation
a_Acc		USD/kg	Real	-0.154*0.669<<USD/kg>>	Factors based on originally (Peeters & Dubois, 2010), but there giving credit to the fact that the table 3 gives for factor b the calculated b/(c+1) from equation (7) and not the original factor b. Then converted to $ as in table 2 of (Scott et al., 2016) for 2005$ and then converted to 1990$ with 0.669 from (Sahr, 2015).
a_Air		USD/kg	Real	0*0.669<<USD/kg>>	Ibid.
a_Car		USD/kg	Real	0*0.669<<USD/kg>>	Ibid.
a_Electric		USD/kg	Real	0*0.669<<USD/kg>>	Ibid.
Acco abatement cost				0*a_Acc+b_Acc*MU_Acc^c_Acc	The endogenous technology cannot be calculated from neative abatement cost. As there is a negative, and it apparently is not happening, then there must be other reasons (indirect costs like risks, insitutional, cultural) as for instance summed by (Ekins et al., 2011; Kesicki & Strachan, 2011). Therefore the initial value of abatement cost is set at 0.
Acco emission factor initial abatement				INITIF(YEAR(TIME)=Scenario start year,Accommodation emission factor)	
Accommodatie abatement average cost				IF(MU_Acc<0,0<<USD/kg>>, a_Acc+b_Acc/(c_Acc+1)*MU_Acc^c_Acc)	
Accommodation abatement cost total				Accommodatie abatement average cost*Accommodation emissions*MU_Acc*(1/(1-MU_Acc)-1)	
Accommodation emission factor				Accommodation emissions initial	
Accommodation emissions				Accommodation emission factor*Accommodation LOS*Total trips	
Air abatement average cost				IF(MU_Air<0,0<<USD/kg>>, a_Air+b_Air/(c_Air+1)*MU_Air^c_Air)	
Air abatement cost				a_Air+b_Air*MU_Air^c_Air	

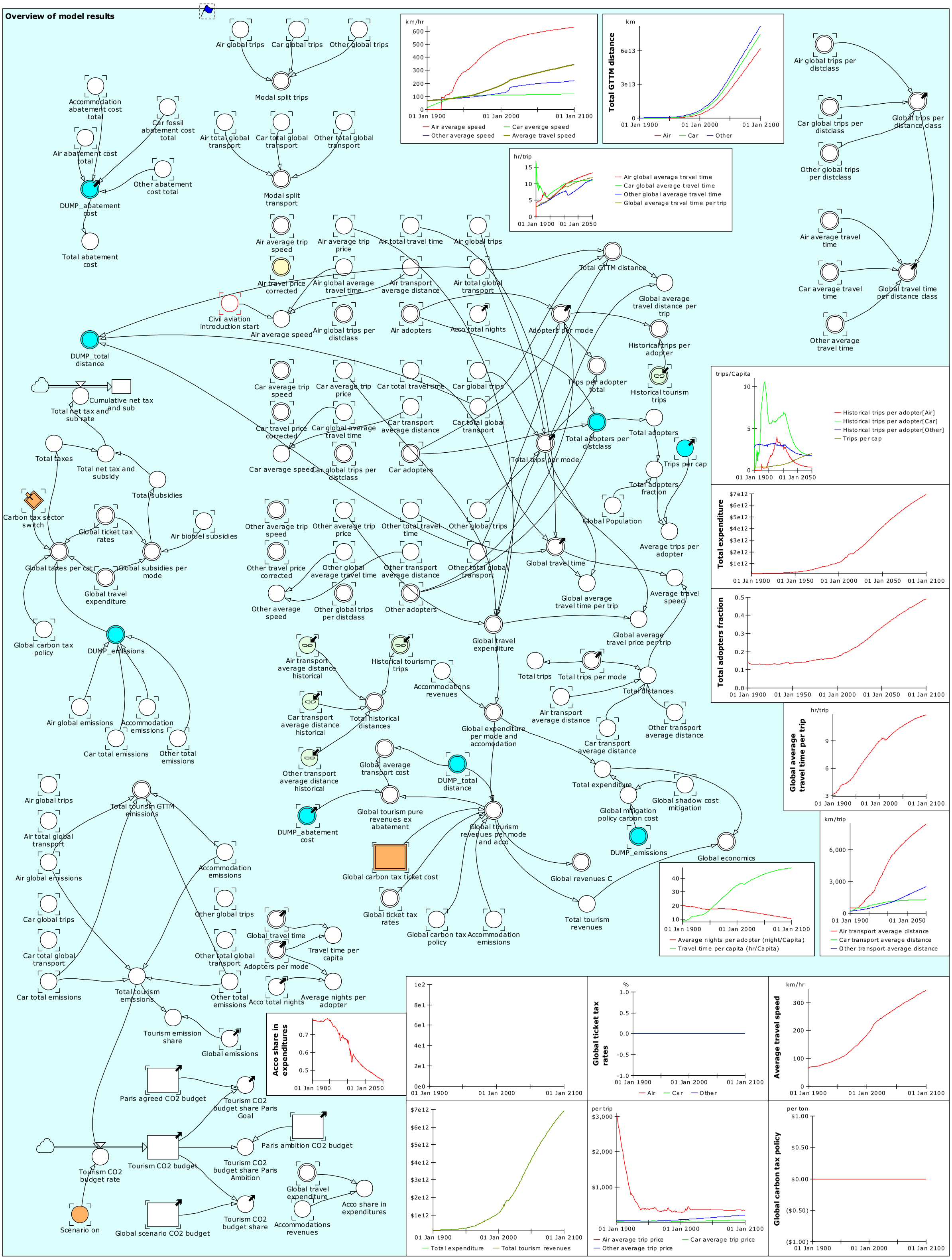
Name	Dimensions	Unit	Type	Definition	Documentation
Air abatement cost total				Air abatement average cost*Air global emissions*MU_Air*(1DIVZ0(1-MU_Air)-1)	
Air emission factor initial				INITIF(YEAR(TIME)=Scenario start year,Air fleet average emission factor)	
Air fleet average emission factor				Air global emissions/Air total global transport	
Air global emissions				Biofuel emission correction*ARRSUM(Emissions per dist class fossil based)	
b_Acc		USD/kg	Real	0.9727*0.669<<USD/kg>>	Factors based on originally (Peeters & Dubois, 2010), but there giving credit to the fact that the table 3 gives for factor b the calculated b/(c+1) from equation (7) and not the original factor b. Then converted to $ as in table 2 of (Scott et al., 2016) for 2005$ and then converted to 1990$ with 0.669 from (Sahr, 2015).
b_Air		USD/kg	Real	1.100*0.669<<USD/kg>>	Ibid.
b_Car		USD/kg	Real	1.100*0.669<<USD/kg>>	Ibid.
b_Electric		USD/kg	Real	1.100*0.669<<USD/kg>>	Ibid.
c_Acc			Real	1.455	Ibid.
c_Air			Real	1.552	Ibid.
c_Car			Real	2.585	Ibid.
c_Electric			Real	10.39	Ibid.
Car abatement cost total				Car electric abatement cost total+Car fossil abatement cost total	
Car electric abatement average				IF(MU_Car electric<0,0<<USD/kg>>, a_Electric+b_Electric/(c_Electric+1)*MU_Car electric^c_Electric)	
Car electric abatement cost				a_Electric+b_Electric*MU_Car electric^c_Electric	
Car electric abatement cost				Car electric abatement average*Car total electric emissions*MU_Car	

Name	Dimensions	Unit	Type	Definition	Documentation
total				electric*(1DIVZ0(1-MU_Car electric)-1)	
Car electric emission factor initial				INITIF(YEAR(TIME)=Scenario start year,Car electric emission total factor)	
Car electric emission total factor				Emissions submodel.Car electric emission factor	
Car fossil abatement average				IF(MU_Car fossil<0,0<<USD/kg>>, a_Car+b_Car/(c_Car+1)*MU_Car fossil^c_Car)	
Car fossil abatement cost				a_Car+b_Car*MU_Car fossil^c_Car	
Car fossil abatement cost total				Car fossil abatement average*Car total fossil emissions*MU_Car fossil*(1DIVZ0(1-MU_Car fossil)-1)	
Car fossil emission factor initial				INITIF(YEAR(TIME)=Scenario start year,Car fossil emission total factor)	
Car fossil emission total factor				Emissions submodel.Car fossil emission factor	
Car total electric emissions				Emissions submodel.Car total electric emissions	
Car total fossil emissions				Emissions submodel.Car total fossil emissions	
MU_Acc				IF(Scenario on,0, MAX(0,1-Accommodation emission factor/Acco emission factor initial abatement)) //Minimize to 0 to avoid abatement cost NANs where efficeincy reduces	
MU_Air				IF(Scenario on, MAX(0,1-Air fleet average emission factor/Air emission factor initial),0) //Minimize to 0 to avoid abatement cost NANs where efficeincy reduces	

Name	Dimensions	Unit	Type	Definition	Documentation
MU_Car electric				IF(Scenario on, MAX(0,1-Car electric emission total factor/Car electric emission factor initial),0) //Minimize to 0 to avoid abatement cost NANs where efficeincy reduces	
MU_Car fossil				IF(Scenario on, MAX(0,1-Car fossil emission total factor/Car fossil emission factor initial),0) //Minimize to 0 to avoid abatement cost NANs where efficeincy reduces	
MU_Other electric				IF(Scenario on,1,0)* MAX(0,1-Other electric emission factor/Other electric emission factor initial) //Minimize to 0 to avoid abatement cost NANs where efficeincy reduces.	
MU_Other non-electric				IF(Scenario on, MAX(0,1-Other non-electric emission factor/Other non-electric emission factor initial),0) //Minimize to 0 to avoid abatement cost NANs where efficeincy reduces	
Other abatement cost total				(Other share electric* Other electric abatement average*MU_Other electric*(1DIVZ0(1-MU_Other electric)-1)+ (1-Other share electric)* Other non-electric abatement average*MU_Other non-electric*(1DIVZ0(1-MU_Other non-electric)-1)) *Other total emissions//)	
Other electric abatement average				IF(MU_Other electric<0,0<<USD/kg>>, a_Electric+b_Electric/(c_Electric+1)*MU_Other electric^c_Electric)	
Other electric abatement cost				a_Electric+b_Electric*MU_Other electric^c_Electric	
Other electric emission factor		kg/km	Real	0.024381219<<kg/km>>	This figure is based on (Jochem et al., 2015) for the marginal emission factor (as added because of the additional electric cars). This s a conservative assumption but still way below the global average.
Other electric emission factor initial				INITIF(YEAR(TIME)=Scenario start year,Other electric emission factor)	

Name	Dimensions	Unit	Type	Definition	Documentation
Other non-electric abatement average				IF(MU_Other non-electric<0,0<<USD/kg>>, a_Car+b_Car/(c_Car+1)*MU_Other non-electric^c_Car)	
Other non-electric abatement cost				a_Car+b_Car*MU_Other non-electric^c_Car	
Other non-electric emission factor		kg/km	Real	0.024381219<<kg/km>>	
Other non-electric emission factor initial				INITIF(YEAR(TIME)=Scenario start year,Other non-electric emission factor)	
Other share electric				Other conventional share electric*(1-Other HSR rail share)+Other HSR rail share	The assumption is that of all conventional speed other transport a constant amount is electric rail and that high speed is 100 electric.
Other total emissions				Other total emission factor*Other total global transport	
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)	

Overview model results


Overview of model results
Total GTTM distance
Total expenditure
Total adopters fraction
Global average travel time per trip
Acco share in expenditures
Global ticket tax rates
Average travel speed
Global carbon tax policy

Name	Dimensions	Unit	Type	Definition
Acco share in expenditures				Accommodations revenues/(ARRSUM(Global travel expenditure)+Accommodations revenues)
Acco total nights				Accommodation LOS*Total trips
Accommodation abatement cost total				Accommodatie abatement average cost*Accommodation emissions*MU_Acc*(1/(1-MU_Acc)-1)
Accommodation emissions				Accommodation emission factor*Accommodation LOS*Total trips
Accommodations revenues				Total trips*Acco revenues per trip+ Accommodation abatement cost total+ Global carbon tax policy*Accommodation emissions
Adopters per mode	Transport modes			{ARRSUM(Air adopters),ARRSUM(Car adopters),ARRSUM(Other adopters)}
Air abatement cost total				Air abatement average cost*Air global emissions*MU_Air*(1DIVZ0(1-MU_Air)-1)
Air adopters				Bass Model Air transport.Adopters
Air average speed				IF(Civil aviation introduction start, Air transport average distance/Air global average travel time, 0<<km/hr>>)
Air average travel time				IF(Air average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Air average trip speed)
Air average trip price				IF(Air global trips<.001<<trips>>,1<<USD/trip>>, ARRSUM(Air global trips per distclass*Air travel price corrected)/Air global trips)
Air average trip speed				1/Turboprop speed factor delayed* FOR(i=DIM(Average return distance per class,1)| IF(Scenario on,1+Global cruise speed policy factor Air/(-0.15)* ((Air Vc conversion[Vc_b]-1)*Average return distance per class[i]*1<<trip/km>>/ (Air Vc conversion[Vc_c]+Average return distance per class[i]*1<<trip/km>>)) ,1)* MIN(Air transport historical blockspeed*Air transport speed-dist constants[Block_max_conversion]/Turboprop speed factor delayed[i], Air transport speed-dist constants[C_v]* (Average return distance per class[i]/1<<km/trip>>)^Air transport speed-dist constants[B1_exp]*1<<km/hr>>))
Air biofuel subsidies				ARRSUM(Air total energy use*Air fuel emission factor* Biofuel shares Plus*Biofuel_plus prices after tax* CONCAT({Biofuel subsidy corr[Algae]}, {Biofuel subsidy corr[Jatropha]}, {Biofuel subsidy corr[Camelina]}, {Biofuel subsidy corr[Switchgrass]}, {Biofuel subsidy corr[Palm Oil]}, (European Tourism Forum 2002))) //It is a subsidy and therefore a negative number or zero.
Air global average travel time				IF(Air global trips<0.0001<<trips>>,1<<hr/trip>>, ARRSUM(Air average travel time*Air global trips per distclass)/Air global trips)
Air global emissions				Biofuel emission correction*ARRSUM(Emissions per dist class fossil based)

Name	Dimensions	Unit	Type	Definition
Air global trips				ARRSUM(Bass Model Air transport.Trips)
Air global trips per distclass				Bass Model Air transport.Adopters*Bass Model Air transport.Trips per adoption
Air total global transport				ARRSUM(Air global transport)
Air total travel time		yr		Air global average travel time*Air global trips
Air transport average distance				Bass Model Air transport.Overall average distance
Air transport average distance historical		km/trip	Real	0
Air travel price corrected				Bass Model Air transport.Air travel price corrected
Average nights per adopter				Acco total nights/ARRSUM(Adopters per mode)
Average travel speed		km/hr		Total distances/(ARRSUM(Global travel time)*1<<yr>>)
Average trips per adopter				Trips per cap/Total adopters fraction
Car adopters				Bass Model Car transport.Adopters
Car average speed				Car transport average distance/Car global average travel time
Car average travel time				IF(Car average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Car average trip speed)
Car average trip price				ARRSUM(Car global trips per distclass*Car travel price corrected)/Car global trips
Car average trip speed				IF(Scenario on,1+Global speed policy factor Car,1)* FOR(i=DIM(Average return distance per class,1)| MIN(Car historic speed*Car transport speed-dist constants[Block_max_conversion], Car transport speed-dist constants[C_v]* (Average return distance per class[i]/1<<km/trip>>)^Car transport speed-dist constants[B1_exp]*1<<km/hr>>))
Car fossil abatement cost total				Car fossil abatement average*Car total fossil emissions*MU_Car fossil*(1DIVZ0(1-MU_Car fossil)-1)
Car global average travel time				ARRSUM(Car average travel time*Car global trips per distclass)/ IF(Car global trips=0<<trips>>,1<<trips>>,Car global trips)
Car global trips				ARRSUM(Bass Model Car transport.Trips)
Car global trips per distclass				Bass Model Car transport.Adopters*Bass Model Car transport.Trips per adoption
Car total emissions				Car total electric emissions+Car total fossil emissions
Car total global transport				ARRSUM(Car global transport)

Name	Dimensions	Unit	Type	Definition
Car total travel time		yr		Car global average travel time*Car global trips
Car transport average distance				Bass Model Car transport.Overall average distance
Car transport average distance historical		km/trip	Real	0<<km/trip>>
Car travel price corrected				Car variable price*Average return distance per class
Carbon tax sector switch	Emission_cats		Integer	1
Civil aviation introduction start				IF(YEAR(TIME)>Civil aviation introduction year-1,TRUE,FALSE) //For fleet reproduction set at -1 year.
Cumulative net tax and sub		USD	Real	0<<USD>>
DUMP_abatement cost	Emission_cats			{Air abatement cost total, Car fossil abatement cost total, Other abatement cost total, Accommodation abatement cost total}
DUMP_emissions	Emission_cats			{Air global emissions,Car total emissions,Other total emissions,Accommodation emissions}
DUMP_total distance	Transport modes			{Air total global transport,Car total global transport,Other total global transport}
Global average transport cost	Modes			{Global tourism pure revenues ex abatement[Air]/DUMP_total distance[Air], Global tourism pure revenues ex abatement[Car]/DUMP_total distance[Car], Global tourism pure revenues ex abatement[Other]/DUMP_total distance[Other]}
Global average travel distance per trip				Total GTTM distance[Other]/ARRSUM(Total trips per mode)
Global average travel price per trip				ARRSUM(Global travel expenditure)/ARRSUM(Total trips per mode)
Global average travel time per trip		hr/trip		ARRSUM(Global travel time)*1<<yr>>/ARRSUM(Total trips per mode)
Global carbon tax policy				IF(Scenario on,1,0)* (Global tourism carbon tax+Global shadow cost mitigation)
Global carbon tax ticket cost	Modes	USD/km	Real	0<<USD/km>>
Global economics	Economic post			{Total tourism revenues,Total expenditure}
Global emissions				CO2 emission correction factor for population* Global scenario dependent emissions[INDEX(Global_economy_sc_switch), INDEX(Global mitigation scenario switch)]
Global expenditure per mode	Emissio			{Global travel expenditure[Air], Global travel expenditure[Car], Global travel

Name	Dimensions	Unit	Type	Definition
and accomodation	n_cats			expenditure[Other], Accommodations revenues}
Global mitigation policy carbon cost				ARRSUM(DUMP_emissions)*Global shadow cost mitigation
Global Population				Global_Population_UN_Scen[INDEX(Global_pop_sc_switch)]
Global revenues C	Emission_cats			{Global tourism revenues per mode and acco[Air], Global tourism revenues per mode and acco[Air]+Global tourism revenues per mode and acco[Car], Global tourism revenues per mode and acco[Air]+Global tourism revenues per mode and acco[Car]+Global tourism revenues per mode and acco[Other], Global tourism revenues per mode and acco[Air]+Global tourism revenues per mode and acco[Car]+Global tourism revenues per mode and acco[Other]+Global tourism revenues per mode and acco[Acco]}
Global scenario CO2 budget		GtCO2	Real	0<<kg>>
Global shadow cost mitigation				(Shadow cost coefficients[f_a]+ Shadow cost coefficients[f_b]*Emission reduction factor+ Shadow cost coefficients[f_c]* Shadow cost coefficients[f_d]^Emission reduction factor)*1<<USD/ton>>
Global subsidies per mode	Modes			{IF(Global ticket tax rates[Air]<=0, Global travel expenditure[Air]*Global ticket tax rates[Air]/(1+Global ticket tax rates[Air]))- Air biofuel subsidies,//negative alt fuel subsidies// IF(Global ticket tax rates[Car]<=0, Global travel expenditure[Car]*Global ticket tax rates[Car]/(1+Global ticket tax rates[Car])), IF(Global ticket tax rates[Other]<=0, Global travel expenditure[Other]*Global ticket tax rates[Other]/(1+Global ticket tax rates[Other]))}
Global taxes per cat	Emission_cats			{IF(Global ticket tax rates[Air]>0, Global travel expenditure[Air]*Global ticket tax rates[Air]/(1+Global ticket tax rates[Air]))+ DUMP_emissions[Air]*Global carbon tax policy, IF(Global ticket tax rates[Car]>0, Global travel expenditure[Car]*Global ticket tax rates[Car]/(1+Global ticket tax rates[Car]))+ DUMP_emissions[Car]*Global carbon tax policy, IF(Global ticket tax rates[Other]>0, Global travel expenditure[Other]*Global ticket tax rates[Other]/(1+Global ticket tax rates[Other]))+ DUMP_emissions[Other]*Global carbon tax policy, DUMP_emissions[Acco]*Global carbon tax policy}* Carbon tax sector switch
Global ticket tax rates	Modes			IF(Scenario on,1,0)* {Global ticket tax Air,Global ticket tax Car,Global ticket tax Other}
Global tourism pure revenues ex abatement				Global tourism revenues per mode and acco- DUMP_abatement cost
Global tourism revenues per mode and acco	Emission_cats			{Global expenditure per mode and accomodation[Air]- Global carbon tax ticket cost[Air]*DUMP_total distance[Air]- Global expenditure per mode and accomodation[Air]*Global ticket tax rates[Air]/(1+Global ticket tax rates[Air]), Global

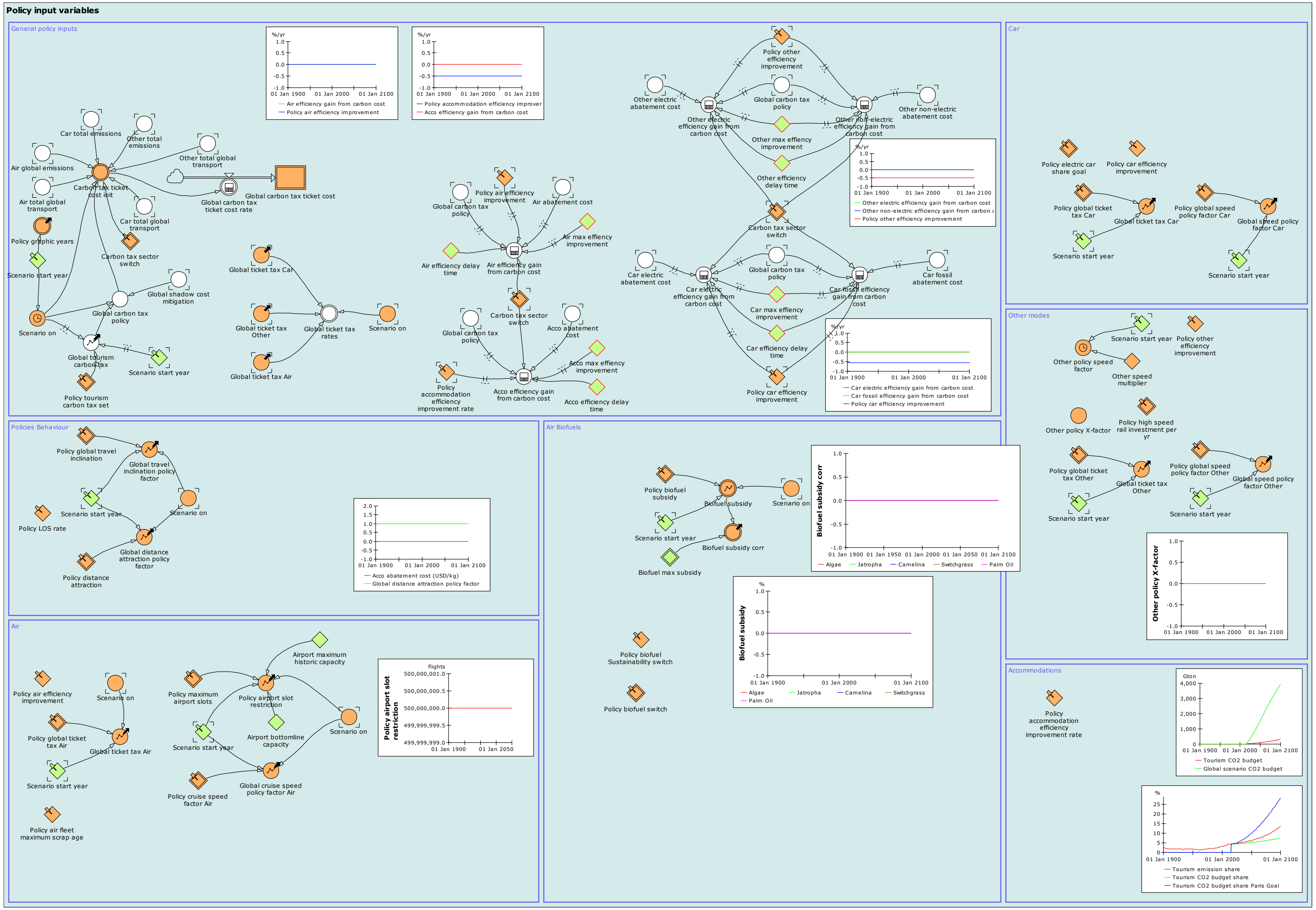
Name	Dimensions	Unit	Type	Definition
				expenditure per mode and accomodation[Car]- Global carbon tax ticket cost[Car]*DUMP_total distance[Car]- Global expenditure per mode and accomodation[Car]*Global ticket tax rates[Car]/(1+Global ticket tax rates[Car]), Global expenditure per mode and accomodation[Other]- Global carbon tax ticket cost[Other]*DUMP_total distance[Other]- Global expenditure per mode and accomodation[Other]*Global ticket tax rates[Other]/(1+Global ticket tax rates[Other]), Global expenditure per mode and accomodation[Acco]- Accommodation emissions*Global carbon tax policy}
Global travel expenditure	Transport modes			{Air average trip price*Total trips per mode[Air], Car average trip price*Total trips per mode[Car], Other average trip price*Total trips per mode[Other]}
Global travel time	Transport modes			{Air total travel time,Car total travel time,Other total travel time}*1<<1/yr>>
Global travel time per distance class				Global trips per distance class* {Air average travel time, Car average travel time, Other average travel time}
Global trips per distance class	Modes, Dist_class			{Air global trips per distclass, Car global trips per distclass, Other global trips per distclass}
Historical tourism trips	Transport modes	trip	Real	0<<trips>>
Historical trips per adopter				Historical tourism trips/Adopters per mode
Modal split transport	Modes			{Air total global transport, Air total global transport+Car total global transport, Air total global transport+Car total global transport+Other total global transport}/ (Air total global transport+Car total global transport+Other total global transport)*100<<%>>
Modal split trips	Modes			{Air global trips, Air global trips+Car global trips, Air global trips+Car global trips+Other global trips}/ (Air global trips+Car global trips+Other global trips)*100<<%>>
Other abatement cost total				(Other share electric* Other electric abatement average*MU_Other electric*(1DIVZ0(1-MU_Other electric)-1)+ (1-Other share electric)* Other non-electric abatement average*MU_Other non-electric*(1DIVZ0(1-MU_Other non-electric)-1)) *Other total emissions//)
Other adopters				Bass Model Other transport.Adopters
Other average speed				Other transport average distance/Other global average travel time
Other average travel time				IF(Other average trip speed=0<<km/hr>>,0<<hr/trip>>, Average return distance per class/Other average trip speed)

Name	Dimensions	Unit	Type	Definition
Other average trip price				IF(Other global trips<.001<<trips>>,1<<USD/trip>>, ARRSUM(Other global trips per distclass*Other travel price corrected)/Other global trips)
Other average trip speed				//conventioal speed part// IF(Scenario on,1+Global speed policy factor Other,1)* //'Other policy speed factor'*// ((1-Other historic high speed share)* FOR(i=DIM(Average return distance per class,1)| MIN(Other transport historical speeds*Other transport speed-dist constants[ConvSpRail,Block_max_conversion], Other transport speed-dist constants[ConvSpRail,C_v]* (Average return distance per class[i]/1<<km/trip>>)^Other transport speed-dist constants[ConvSpRail,B1_exp]*1<<km/hr>>)) //high speed part// +Other historic high speed share* FOR(i=DIM(Average return distance per class,1)| MIN(Other transport historical speeds*Other transport speed-dist constants[HighSpRail,Block_max_conversion], Other transport speed-dist constants[HighSpRail,C_v]* (Average return distance per class[i]/1<<km/trip>>)^Other transport speed-dist constants[HighSpRail,B1_exp]*1<<km/hr>>)))
Other global average travel time				IF(Other global trips<0.0001<<trips>>,1<<hr/trip>>, ARRSUM(Other average travel time*Other global trips per distclass)/Other global trips)
Other global trips				ARRSUM(Bass Model Other transport.Trips)
Other global trips per distclass				Bass Model Other transport.Adopters*Bass Model Other transport.Trips per adoption
Other total emissions				Other total emission factor*Other total global transport
Other total global transport				ARRSUM(Other global transport)
Other total travel time		yr		Other global average travel time*Other global trips
Other transport average distance				Bass Model Other transport.Overall average distance
Other transport average distance historical		km/trip	Real	0
Other travel price corrected				IF(Scenario on,1+Global ticket tax Other,1)* (Other ticket price historical +Global carbon tax ticket cost[Car]) *Average return distance per class
Paris agreed CO2 budget		GtCO2	Real	0<<kg>>
Paris ambition CO2 budget		GtCO2	Real	0<<kg>>
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)
Total abatement cost				ARRSUM(DUMP_abatement cost)

Name	Dimensions	Unit	Type	Definition
Total adopters				ARRSUM(Total adopters per distclass)
Total adopters fraction				Total adopters/Global Population
Total adopters per distclass				Air adopters+Car adopters+Other adopters
Total distances				Total trips per mode[Air]*Air transport average distance +Total trips per mode[Car]*Car transport average distance +Total trips per mode[Other]*Other transport average distance
Total expenditure				ARRSUM(Global expenditure per mode and accomodation)+Global mitigation policy carbon cost
Total GTTM distance	Transport modes			{Air total global transport, Air total global transport+Car total global transport, Air total global transport+Car total global transport+Other total global transport}
Total historical distances	Transport modes	km	Real	{Air transport average distance historical*Historical tourism trips[Air], Air transport average distance historical*Historical tourism trips[Air] +Car transport average distance historical*Historical tourism trips[Car], Air transport average distance historical*Historical tourism trips[Air] +Car transport average distance historical*Historical tourism trips[Car] +Other transport average distance historical*Historical tourism trips[Other]}
Total net tax and sub rate				Total net tax and subsidy/1<<yr>>
Total net tax and subsidy				Total subsidies+Total taxes
Total subsidies				ARRSUM(Global subsidies per mode)
Total taxes				ARRSUM(Global taxes per cat)
Total tourism emissions		GtCO2		Accommodation emissions+ Air global emissions+ Car total emissions+ Other total emissions
Total tourism GTTM emissions	Emission_cats			{Air global emissions, Air global emissions+Car total emissions, Air global emissions+Car total emissions+Other total emissions, Air global emissions+Car total emissions+Other total emissions+Accommodation emissions}
Total tourism revenues				ARRSUM(Global tourism revenues per mode and acco)
Total trips				ARRSUM(Total trips per mode)
Total trips per mode	Transport modes			{Air global trips,Car global trips,Other global trips}
Tourism CO2 budget		GtCO2	Real	0
Tourism CO2 budget rate				IF(Scenario on,1,0)* Total tourism emissions*1<<1/yr>>

Name	Dimensions	Unit	Type	Definition
Tourism CO2 budget share		%	Real	IF(Global scenario CO2 budget=0<<GtCO2>>,0<<%>>, Tourism CO2 budget/Global scenario CO2 budget)
Tourism CO2 budget share Paris Ambition		%	Real	IF(Paris ambition CO2 budget=0<<GtCO2>>,0<<%>>, Tourism CO2 budget/Paris ambition CO2 budget)
Tourism CO2 budget share Paris Goal		%	Real	IF(Paris agreed CO2 budget=0<<GtCO2>>,0<<%>>, Tourism CO2 budget/Paris agreed CO2 budget)
Tourism emission share		%		IF(Global emissions<0<<kg>>,1, MIN(Total tourism emissions/Global emissions,1))
Travel time per capita		hr/ Capita		ARRSUM(Global travel time)*1<<yr>>/ARRSUM(Adopters per mode)
Trips per adopter total				Total trips per mode/Adopters per mode
Trips per cap				Global travel inclination policy factor* Pop at max frac*Max glob trips p cap +IF(Pop at max frac<Share rich, alpha*(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap) *(Share rich*(beta/Share rich)^(1/alpha)-Pop at max frac*(beta/Pop at max frac)^(1/alpha)) /(alpha-1) +(EXP(Factor k)*EXP(-Share rich*Factor k)-1) *(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap) /(EXP(Factor k)-1), (EXP(Factor k)*EXP(-Pop at max frac*Factor k)-1) *(Global travel inclination policy factor*C_cy glob tour+ Global travel inclination policy factor*Alpha_cy glob tour*GDP per cap)/(EXP(Factor k)-1))

Policy Input Variables



Name	Dimensions	Unit	Type	Definition
Acco abatement cost				0*a_Acc+b_Acc*MU_Acc^c_Acc
Acco efficiency delay time		yr	Real	6.7<<yr>>
Acco efficiency gain from carbon cost				Carbon tax sector switch[Acco]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Acco abatement cost)DIVZ0Global carbon tax policy *Acco max effiency improvement-Policy accommodation efficiency improvement rate), Acco efficiency delay time,6)
Acco max effiency improvement		%/yr	Real	-2.5<<%/yr>> //CHANGE ALSO IN POLICY TECHNOLOGY ACCO EFFICIENCY GRAPH.
Air abatement cost				a_Air+b_Air*MU_Air^c_Air
Air efficiency delay time		yr	Real	20<<yr>>
Air efficiency gain from carbon cost				Carbon tax sector switch[Air]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Air abatement cost)DIVZ0Global carbon tax policy *Air max effiency improvement-Policy air efficiency improvement), Air efficiency delay time,6)
Air global emissions				Biofuel emission correction*ARRSUM(Emissions per dist class fossil based)
Air max effiency improvement		%/yr	Real	-0.2686<<%/yr>> //CHANGE ALSO IN POLICY TECHNOLOGY AIR EFFICIENCY GRAPH.
Air total global transport				ARRSUM(Air global transport)
Airport bottomline capacity		flight	Real	10000000<<flights>> //Always set also the infrastrucure policy input graph to a minum of the value above!
Airport maximum historic capacity		flight	Real	500000000<<flights>> //Always set also the infrastrucure policy input graph to a minum of the value above!
Biofuel max subsidy	Biofuels		Real	.9//also adjust input graph!
Biofuel subsidy	Biofuels	%	Real	IF(Scenario on, {GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy biofuel subsidy[*,Algae]), GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy biofuel subsidy[*,Jatropha]), GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy biofuel subsidy[*,Camelina]), GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy biofuel subsidy[*,Switchgrass]), GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy biofuel subsidy[*,Palm Oil])}, 0)

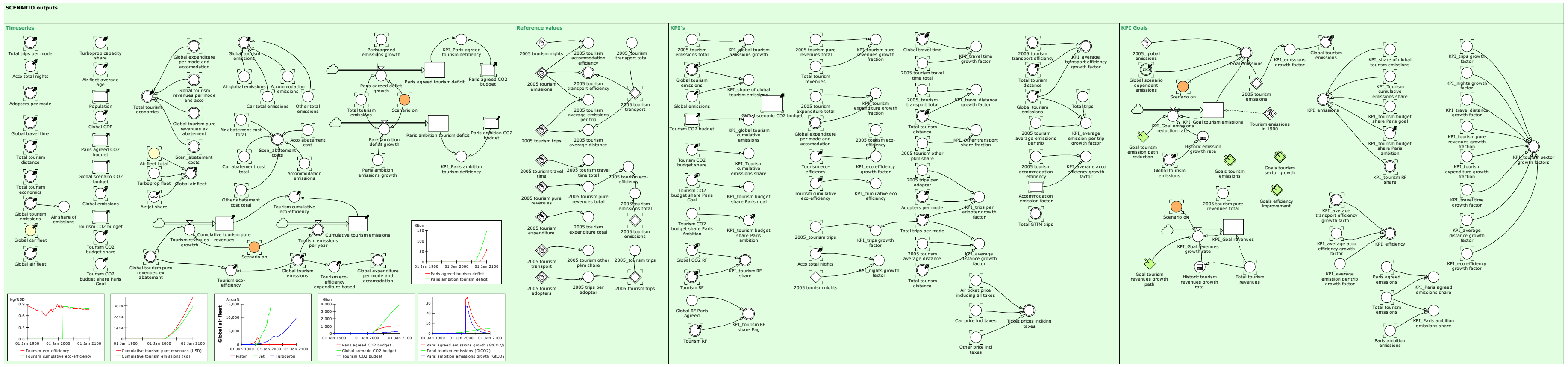
Name	Dimensions	Unit	Type	Definition
Biofuel subsidy corr	Biofuels		Real	MIN(Biofuel max subsidy,MAX({0,0,0,0,0},Biofuel subsidy))
Car efficiency delay time		yr	Real	6.7<<yr>>
Car electric abatement cost				a_Electric+b_Electric*MU_Car electric^c_Electric
Car electric efficiency gain from carbon cost				Carbon tax sector switch[Car]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Car electric abatement cost)DIVZ0Global carbon tax policy *Car max effiency improvement-Policy car efficiency improvement), Car efficiency delay time,6)
Car fossil abatement cost				a_Car+b_Car*MU_Car fossil^c_Car
Car fossil efficiency gain from carbon cost				Carbon tax sector switch[Car]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Car fossil abatement cost)DIVZ0Global carbon tax policy *Car max effiency improvement-Policy car efficiency improvement), Car efficiency delay time,6)
Car max effiency improvement		%/yr	Real	-2<<%/yr>> //CHANGE ALSO IN POLICY TECHNOLOGY CAR EFFICIENCY GRAPH.
Car total emissions				Car total electric emissions+Car total fossil emissions
Car total global transport				ARRSUM(Car global transport)
Carbon tax sector switch	Emission_cats		Integer	1
Carbon tax ticket cost init	Modes			{Carbon tax sector switch[Air],Carbon tax sector switch[Car],Carbon tax sector switch[Other]}* IF(Scenario on,1,0)* {Air global emissions/Air total global transport, Car total emissions/Car total global transport, Other total emissions/Other total global transport}* Global carbon tax policy
Global carbon tax policy				IF(Scenario on,1,0)* (Global tourism carbon tax+Global shadow cost mitigation)
Global carbon tax ticket cost	Modes	USD/km	Real	0<<USD/km>>
Global carbon tax ticket cost rate	Modes			DERIVN(Carbon tax ticket cost init)
Global cruise speed policy factor Air		%	Real	IF(Scenario on,1,0)* GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy cruise speed factor Air)
Global distance attraction policy factor			Real	IF(Scenario on, GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy distance attraction), 1)

Name	Dimensions	Unit	Type	Definition
Global shadow cost mitigation				(Shadow cost coefficients[f_a]+ Shadow cost coefficients[f_b]*Emission reduction factor+ Shadow cost coefficients[f_c]* Shadow cost coefficients[f_d]^Emission reduction factor)*1<<USD/ton>>
Global speed policy factor Car		%	Real	GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global speed policy factor Car)
Global speed policy factor Other		%	Real	GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global speed policy factor Other)
Global ticket tax Air		%	Real	IF(Scenario on, GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global ticket tax Air),0)
Global ticket tax Car		%	Real	GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global ticket tax Car)
Global ticket tax Other		%	Real	GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global ticket tax Other)
Global ticket tax rates	Modes	%	Real	IF(Scenario on,1,0)* {Global ticket tax Air,Global ticket tax Car,Global ticket tax Other}
Global tourism carbon tax		USD/ton	Real	MAX(0<<USD/ton>>, DELAYINF(IF(Scenario on,1,0)* GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy tourism carbon tax set),5<<yr>>,3))
Global travel inclination policy factor			Real	IF(Scenario on, GRAPHCURVE(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy global travel inclination), 1)
Other efficiency delay time		yr	Real	15<<yr>>
Other electric abatement cost				a_Electric+b_Electric*MU_Other electric^c_Electric
Other electric efficiency gain from carbon cost				Carbon tax sector switch[Other]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Other electric abatement cost)DIVZ0Global carbon tax policy *Other max effiency improvement-Policy other efficiency improvement), Other efficiency delay time,6)
Other max effiency improvement		%/yr	Real	-2.5<<%/yr>> //CHANGE ALSO IN POLICY TECHNOLOGY OTHER EFFICIENCY GRAPH.
Other non-electric abatement cost				a_Car+b_Car*MU_Other non-electric^c_Car
Other non-electric efficiency gain from carbon cost				Carbon tax sector switch[Other]* DELAYMTR(MIN(0<<%/yr>>,MAX(0<<USD/kg>>,Global carbon tax policy-Other non-electric abatement cost)DIVZ0Global carbon tax policy *Other max effiency

Name	Dimensions	Unit	Type	Definition
				improvement-Policy other efficiency improvement), Other efficiency delay time,6)
Other policy speed factor			Real	IF(YEAR()>Scenario start year,Other speed multiplier,1)
Other policy X-factor			Real	0
Other speed multiplier			Real	1
Other total emissions				Other total emission factor*Other total global transport
Other total global transport				ARRSUM(Other global transport)
Policy accommodation efficiency improvement rate		%/yr	Real	-0.5
Policy air efficiency improvement		%/yr	Real	0
Policy air fleet maximum scrap age			Real	50
Policy airport slot restriction		flight	Real	IF(Scenario on, MAX(Airport bottomline capacity, GRAPH(YEAR(TIME),Scenario start year, (YEAR(STOPTIME)-Scenario start year)/4, Policy maximum airport slots)), Airport maximum historic capacity)
Policy biofuel subsidy	Policy_Years,Biofuels	%	Real	0<<%>>
Policy biofuel Sustainability switch			Integer	1
Policy biofuel switch	Biofuels		Integer	0
Policy car efficiency improvement		%/yr	Real	-55.00%
Policy cruise speed factor Air	Policy_Years	%	Real	0<<%>>
Policy distance attraction	Policy_Years		Real	1
Policy electric car share goal	Policy_ecar_share_transition		Real	{.1,.15}
Policy global speed policy factor Car	Policy_Years	%	Real	0<<%>>

Name	Dimensions	Unit	Type	Definition
Policy global speed policy factor Other	Policy_Years	%	Real	0<<%>>
Policy global ticket tax Air	Policy_Years	%	Real	0<<%>>
Policy global ticket tax Car	Policy_Years	%	Real	0<<%>>
Policy global ticket tax Other	Policy_Years	%	Real	0<<%>>
Policy global travel inclination	Policy_Years		Real	1
Policy graphic years	Policy_Years		Real	INTEGER({Scenario start year ,YEAR(STOPTIME)-3/4*(YEAR(STOPTIME)-Scenario start year) ,YEAR(STOPTIME)-2/4*(YEAR(STOPTIME)-Scenario start year) ,YEAR(STOPTIME)-1/4*(YEAR(STOPTIME)-Scenario start year) ,YEAR(STOPTIME) })
Policy high speed rail investment per yr	Policy_Years	USD/yr	Real	{10285338005.29 ,16141947447.40 ,14851500121.30 ,29791303930.28 ,26421905147.43} <<USD/yr>>
Policy LOS rate		yr^-1	Real	-0.0051<<1/yr>>
Policy maximum airport slots	Policy_Years	flight	Real	0.5*10^9*1<<flight>>
Policy other efficiency improvement		%/yr	Real	-0.5
Policy tourism carbon tax set	Policy_Years	USD/ton	Real	0<<USD/ton>>
Scenario on			Logical	IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)
Scenario start year			Integer	2015

Scenario Output Variables



Name	Dimensions	Unit	Type	Definition
2005 tourism accommodation efficiency		kg/night	Real	2005 tourism emissions[Acco]/2005 tourism nights
2005 tourism adopters	Modes	Capita	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C6:R107C8")// <<Capita>>
2005 tourism average distance		km/trip	Real	ARRSUM(2005 tourism transport)/ ARRSUM(2005 tourism trips)
2005 tourism average emissions per trip		kg/trip	Real	ARRSUM(2005 tourism emissions)/ ARRSUM(2005 tourism trips)
2005 tourism eco-efficiency		kg/USD	Real	2005 tourism emissions total/2005 tourism pure revenues total
2005 tourism emissions	Emission_cats	kg	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C31:R107C34")// <<kg>>
2005 tourism emissions total		kg	Real	ARRSUM(2005 tourism emissions)
2005 tourism expenditure	Emission_cats	USD	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C15:R107C18")// <<USD>>
2005 tourism expenditure total		USD	Real	ARRSUM(2005 tourism expenditure)

Name	Dimensions	Unit	Type	Definition
2005 tourism nights		night	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C5")// <<nights>>
2005 tourism other pkm share		%	Real	2005 tourism transport[Other]/ ARRSUM(2005 tourism transport)
2005 tourism pure revenues	Emission_cats	USD	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C23:R107C26")// <<USD>>
2005 tourism pure revenues total		USD	Real	ARRSUM(2005 tourism pure revenues)
2005 tourism transport	Modes	km	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C12:R107C14")// <<km>>
2005 tourism transport efficiency	Modes	kg/km	Real	{2005 tourism emissions[Air]/2005 tourism transport[Air], 2005 tourism emissions[Car]/2005 tourism transport[Car], 2005 tourism emissions[Other]/2005 tourism transport[Other]}
2005 tourism travel time	Modes	yr	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C9:R107C11")// <<yr>>
2005 tourism travel time total		yr	Real	ARRSUM(2005 tourism travel time)
2005 tourism trips	Modes	trip	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C2:R107C4")// <<trips>>
2005 trips per adopter		trip/ Capita	Real	ARRSUM(2005 tourism trips)/ ARRSUM(2005 tourism adopters)
2005_global emissions		GtCO2	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R107C45")// <<Gton>>
2005_tourism transport total		km	Real	ARRSUM(2005 tourism transport)
2005_tourism trips		trip	Real	ARRSUM(2005 tourism trips)
Acco abatement cost				0*a_Acc+b_Acc*MU_Acc^c_Acc
Acco total nights				Accommodation LOS*Total trips
Accommodation emission				Accommodation emissions initial

Name	Dimensions	Unit	Type	Definition
factor				
Accommodation emissions				Accommodation emission factor*Accommodation LOS*Total trips
Adopters per mode	Transport modes			{ARRSUM(Air adopters),ARRSUM(Car adopters),ARRSUM(Other adopters)}
Air abatement cost total				Air abatement average cost*Air global emissions*MU_Air*(1DIVZ0(1-MU_Air)-1)
Air fleet average age				ARRSUM(Air fleet per age class*Aircraft lifetime in age class)/ ARRSUM(Air fleet per age class)
Air fleet total				ARRSUM(Air fleet per age class)
Air global emissions				Biofuel emission correction*ARRSUM(Emissions per dist class fossil based)
Air jet share			Real	0
Air share of emissions		%		Global tourism emissions[Air]/ARRSUM(Global tourism emissions)
Air ticket price including all taxes				Air global trip expenses/Air total global transport
Car abatement cost total				Car electric abatement cost total+Car fossil abatement cost total
Car price incl taxes				Car global trip expenses/Car total global transport
Car total emissions				Car total electric emissions+Car total fossil emissions
Cumulative tourism emissions		kg	Real	0<<kg>>
Cumulative tourism pure revenues		USD	Real	0<<USD>>
Global air fleet	Air fleet			{(1-Air jet share)*Air fleet total, Air jet share*(Air fleet total-Turboprop fleet), Turboprop fleet}
Global car fleet				Bass Model Car Ownership.Car Adopters*Bass Model Car Ownership.Cars per adopter
Global CO2 RF				Base 1900 RF+RF CO2 constant*LN(Global CO2 ppmv/Global CO2 concentration 1900)
Global emissions				CO2 emission correction factor for population* Global scenario dependent emissions[INDEX(Global_economy_sc_switch), INDEX(Global mitigation scenario switch)]
Global expenditure per mode and accomodation	Emission_cats			{Global travel expenditure[Air], Global travel expenditure[Car], Global travel expenditure[Other], Accommodations revenues}
Global GDP				GDP per cap*Global Population
Global RF Paris Agreed		W/m^2	Real	2.69

Name	Dimensions	Unit	Type	Definition
Global scenario CO2 budget		GtCO2	Real	0<<kg>>
Global scenario dependent emissions	Global_GDP_scenarios,Global mitigation scenarios	GtCO2	Real	1<<GtCO2>>
Global tourism emissions	Emission_cats			{Air global emissions,Car total emissions,Other total emissions,Accommodation emissions}
Global tourism pure revenues ex abatement				Global tourism revenues per mode and acco- DUMP_abatement cost
Global tourism revenues per mode and acco	Emission_cats			{Global expenditure per mode and accomodation[Air]- Global carbon tax ticket cost[Air]*DUMP_total distance[Air]- Global expenditure per mode and accomodation[Air]*Global ticket tax rates[Air]/(1+Global ticket tax rates[Air]), Global expenditure per mode and accomodation[Car]- Global carbon tax ticket cost[Car]*DUMP_total distance[Car]- Global expenditure per mode and accomodation[Car]*Global ticket tax rates[Car]/(1+Global ticket tax rates[Car]), Global expenditure per mode and accomodation[Other]- Global carbon tax ticket cost[Other]*DUMP_total distance[Other]- Global expenditure per mode and accomodation[Other]*Global ticket tax rates[Other]/(1+Global ticket tax rates[Other]), Global expenditure per mode and accomodation[Acco]- Accommodation emissions*Global carbon tax policy}
Global travel time	Transport modes			{Air total travel time,Car total travel time,Other total travel time}*1<<1/yr>>
Goal emissions	KPI_Goal emissions	%		IF(Scenario on, {KPI_Goal tourism emissions/ARRSUM(2005 tourism emissions), Global scenario dependent emissions[SRES_A1,Paris Agreed]/2005_global emissions, Global scenario dependent emissions[SRES_A1,Paris Ambition]/2005_global emissions}, {KPI_Goal tourism emissions/ARRSUM(2005 tourism emissions), KPI_Goal tourism emissions/ARRSUM(2005 tourism emissions), KPI_Goal tourism emissions/ARRSUM(2005 tourism emissions)})
Goal tourism emission path reduction		%/yr	Real	0<<%/yr>>
Goal tourism revenues growth path		%/yr	Real	1.563<<%/yr>>
Goals efficiency improvement	KPI_efficiency		Real	0.1
Goals tourism emissions	KPI_emissions	%	Real	0<<%>>

Name	Dimensions	Unit	Type	Definition
Goals tourism sector growth	KPI_tourism sector		Real	100.00%
Historic emission growth rate				DERIVN(ARRSUM(Global tourism emissions))
Historic tourism revenues growth rate				DERIVN(Total tourism revenues)
KPI_average acco efficiency growth factor				Accommodation emission factor/2005 tourism accommodation efficiency
KPI_average distance growth factor				ARRSUM(Total tourism distance)/ARRSUM(Total trips per mode)/2005 tourism average distance
KPI_average emission per trip growth factor				ARRSUM(Global tourism emissions)/Total trips/2005 tourism average emissions per trip
KPI_average transport efficiency growth factor	Modes			{Global tourism emissions[Air]/Total tourism distance[Air]/2005 tourism transport efficiency[Air], Global tourism emissions[Car]/Total tourism distance[Car]/2005 tourism transport efficiency[Car], Global tourism emissions[Other]/Total tourism distance[Other]/2005 tourism transport efficiency[Other]}
KPI_cumulative eco efficiency		kg/USD	Real	Tourism cumulative eco-efficiency
KPI_eco efficiency growth factor				Tourism eco-efficiency/2005 tourism eco-efficiency
KPI_efficiency	KPI_efficiency			{KPI_average transport efficiency growth factor[Air], KPI_average transport efficiency growth factor[Car], KPI_average transport efficiency growth factor[Other], KPI_average acco efficiency growth factor, KPI_average emission per trip growth factor}
KPI_emissions	KPI_emissions			{KPI_share of global tourism emissions, KPI_Tourism cumulative emissions share, KPI_tourism budget share Paris goal, KPI_tourism budget share Paris ambition, KPI_tourism RF share[Without cirrus], KPI_tourism RF share[With cirrus]}
KPI_emissions growth factor				ARRSUM(Global tourism emissions)/ARRSUM(2005 tourism emissions)
KPI_global tourism cumulative emissions		GtCO2	Real	Tourism CO2 budget
KPI_global tourism emissions growth		%		ARRSUM(Global tourism emissions)/2005 tourism emissions total
KPI_Goal emissions reduction rate				IF(Scenario on, Goal tourism emission path reduction*KPI_Goal tourism emissions, Historic emission growth rate)
KPI_Goal revenues				Total tourism revenues
KPI_Goal revenues growth rate				IF(Scenario on, Goal tourism revenues growth path*KPI_Goal revenues, Historic tourism revenues growth rate)

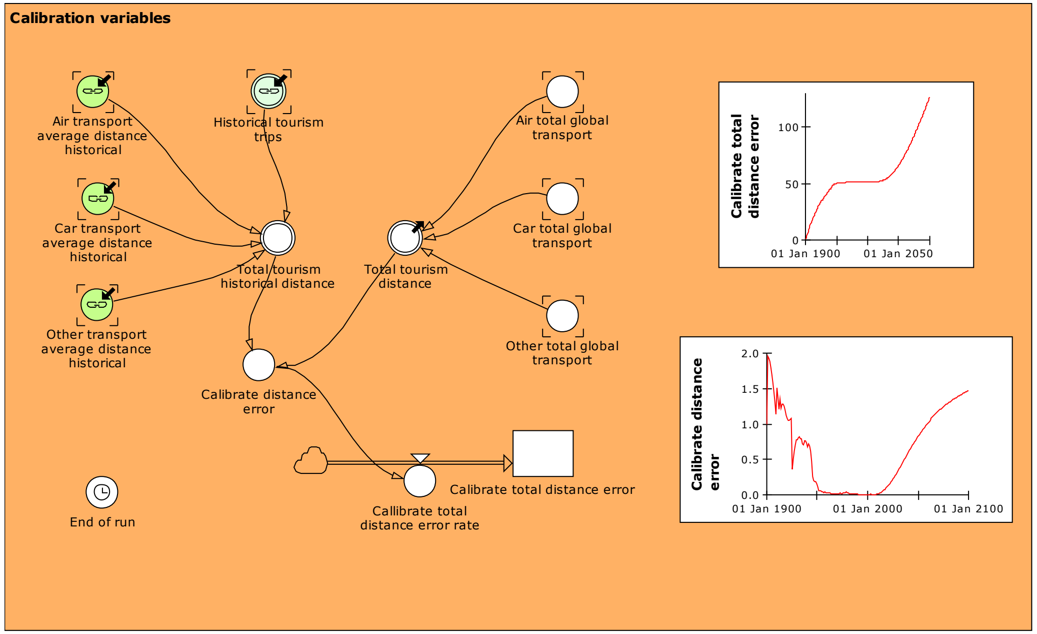
Name	Dimensions	Unit	Type	Definition
KPI_Goal tourism emissions		kg	Real	ARRSUM(Tourism emissions in 1900)
KPI_nights growth factor				Acco total nights/2005 tourism nights
KPI_Other transport share fraction				Total tourism distance[Other]/ARRSUM(Total tourism distance)/ 2005 tourism other pkm share
KPI_Paris agreed emissions share		%		Total tourism emissions/Paris agreed emissions
KPI_Paris agreed tourism deficiency		%	Real	Paris agreed tourism deficit/Paris agreed CO2 budget
KPI_Paris ambition emissions share		%		Total tourism emissions/Paris ambition emissions
KPI_Paris ambition tourism deficiency		%	Real	Paris ambition tourism deficit/Paris ambition CO2 budget
KPI_share of global tourism emissions		%		ARRSUM(Global tourism emissions)/Global emissions
KPI_tourism budget share Paris ambition		%	Real	Tourism CO2 budget share Paris Ambition
KPI_tourism budget share Paris goal		%	Real	Tourism CO2 budget share Paris Goal
KPI_Tourism cumulative emissions share		%	Real	Tourism CO2 budget share
KPI_tourism expenditure growth fraction				ARRSUM(Global expenditure per mode and accomodation)/2005 tourism expenditure total
KPI_tourism pure revenues growth fraction				Total tourism revenues/2005 tourism pure revenues total
KPI_tourism RF share		%		Tourism RF/Global CO2 RF
KPI_tourism RF share Pag		%		Tourism RF/Global RF Paris Agreed
KPI_tourism sector growth factors	KPI_tourism sector			{KPI_trips growth factor, KPI_nights growth factor, KPI_travel distance growth factor, KPI_tourism pure revenues growth fraction, KPI_tourism expenditure growth fraction, KPI_travel time growth factor, KPI_average distance growth factor, KPI_eco efficiency growth factor}
KPI_travel distance growth factor				ARRSUM(Total tourism distance)/2005_tourism transport total
KPI_travel time growth factor				ARRSUM(Global travel time)/2005 tourism travel time total*1<<yr>>

Name	Dimensions	Unit	Type	Definition
KPI_trips growth factor				ARRSUM(Total trips per mode)/2005_tourism trips
KPI_trips per adopter growth factor				ARRSUM(Total trips per mode)/ARRSUM(Adopters per mode)/2005 trips per adopter
Other abatement cost total				(Other share electric* Other electric abatement average*MU_Other electric*(1DIVZ0(1-MU_Other electric)-1)+ (1-Other share electric)* Other non-electric abatement average*MU_Other non-electric*(1DIVZ0(1-MU_Other non-electric)-1)) *Other total emissions//)
Other price incl taxes				Other global trip expenses/Other total global transport
Other total emissions				Other total emission factor*Other total global transport
Paris agreed CO2 budget		GtCO2	Real	0<<kg>>
Paris agreed deficit growth				IF(Scenario on,1,0)* MAX(Total tourism emissions*1<<1/yr>>-Paris agreed emissions growth,0<<Gton/yr>>)
Paris agreed emissions		GtCO2	Real	Global scenario dependent emissions[SRES_A1,Paris Agreed]* 1//'CO2 emission correction factor for population'
Paris agreed emissions growth				IF(Scenario on,1,0)* Global scenario dependent emissions[SRES_A1,Paris Agreed]*1<<1/yr>>
Paris agreed tourism deficit		GtCO2	Real	0 <<Gton>>
Paris ambition CO2 budget		GtCO2	Real	0<<kg>>
Paris ambition deficit growth				IF(Scenario on,1,0)* MAX(Total tourism emissions*1<<1/yr>>-Paris ambition emissions growth,0<<Gton/yr>>)
Paris ambition emissions		GtCO2	Real	Global scenario dependent emissions[SRES_A1,Paris Ambition]* 1//'CO2 emission correction factor for population'
Paris ambition emissions growth				IF(Scenario on,1,0)* Global scenario dependent emissions[SRES_A1,Paris Ambition]*1<<1/yr>>
Paris ambition tourism deficit		GtCO2	Real	0 <<Gton>>
Population		Capita		Global Population
Scen_abatement costs	Emission_cats			{Acco abatement cost*Accommodation emissions, Air abatement cost total, Car abatement cost total, Other abatement cost total}
Scenario on				IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)
Ticket prices incldng taxes	Modes			{Air ticket price including all taxes, Car price incl taxes, Other price incl taxes}
Total GTTM trips	Transport modes			{Air global trips, Air global trips+Car global trips, Air global trips+Car global trips+Other global trips}

Name	Dimensions	Unit	Type	Definition
Total tourism distance	Transport modes			{Air total global transport,Car total global transport,Other total global transport}
Total tourism economics	Tourism_economy			{Global expenditure per mode and accomodation[Air], Global expenditure per mode and accomodation[Car], Global expenditure per mode and accomodation[Other], Global expenditure per mode and accomodation[Acco], Global tourism pure revenues ex abatement[Air], Global tourism pure revenues ex abatement[Car], Global tourism pure revenues ex abatement[Other], Global tourism pure revenues ex abatement[Acco], Global tourism revenues per mode and acco[Air], Global tourism revenues per mode and acco[Car], Global tourism revenues per mode and acco[Other], Global tourism revenues per mode and acco[Acco], Scen_abatement costs[Air], Scen_abatement costs[Car], Scen_abatement costs[Other], Scen_abatement costs[Acco]}
Total tourism emissions		GtCO2		Accommodation emissions+ Air global emissions+ Car total emissions+ Other total emissions
Total tourism revenues				ARRSUM(Global tourism revenues per mode and acco)
Total trips				ARRSUM(Total trips per mode)
Total trips per mode	Transport modes			{Air global trips,Car global trips,Other global trips}
Tourism CO2 budget		GtCO2	Real	0
Tourism CO2 budget share		%	Real	IF(Global scenario CO2 budget=0<<GtCO2>>,0<<%>>, Tourism CO2 budget/Global scenario CO2 budget)
Tourism CO2 budget share Paris Ambition		%	Real	IF(Paris ambition CO2 budget=0<<GtCO2>>,0<<%>>, Tourism CO2 budget/Paris ambition CO2 budget)
Tourism CO2 budget share Paris Goal		%	Real	IF(Paris agreed CO2 budget=0<<GtCO2>>,0<<%>>, Tourism CO2 budget/Paris agreed CO2 budget)
Tourism cumulative eco-efficiency		kg/USD	Real	IF(Cumulative tourism pure revenues=0<<USD>>,0<<kg/USD>>, Cumulative tourism emissions/Cumulative tourism pure revenues)
Tourism eco-efficiency				ARRSUM(Global tourism emissions)/ARRSUM(Global tourism pure revenues ex abatement)
Tourism eco-efficiency expenditure based				ARRSUM(Global tourism emissions)/ARRSUM(Global expenditure per mode and accomodation)
Tourism emissions in 1900	1..4	kg	Real	XLDATA("//Mac/Home/Documents/0DOC/PAUL/NHTV/A_Promotie/Model/GTTM_dyn model/Main model files/GTTM_Dyn_v1.02_v53/./Datafiles/Scenario outputs/Reference 2005.xlsx", "Timeseriesdata", "R2C31:R2C34")// <<kg>>
Tourism emissions per year				IF(Scenario on,1,0)* Global tourism emissions*1<<1/yr>>

Name	Dimensions	Unit	Type	Definition
Tourism revenues growtrh				IF(Scenario on,1,0)* ARRSUM(Global tourism pure revenues ex abatement)*1<<1/yr>>
Tourism RF		W/m^2		Aviation non-CO2 RF+ RF CO2 constant*LN((Global CO2 ppmv+Tourism CO2 concentration)/Global CO2 ppmv)
Turboprop capacity share				IF(YEAR(TIME)<Turboprop share calculation start year,0.02, Turboprop transport pkm capacity/Air transport pkm capacity)
Turboprop fleet		Aircraft		Transport capacity submodel.Turboprop fleet

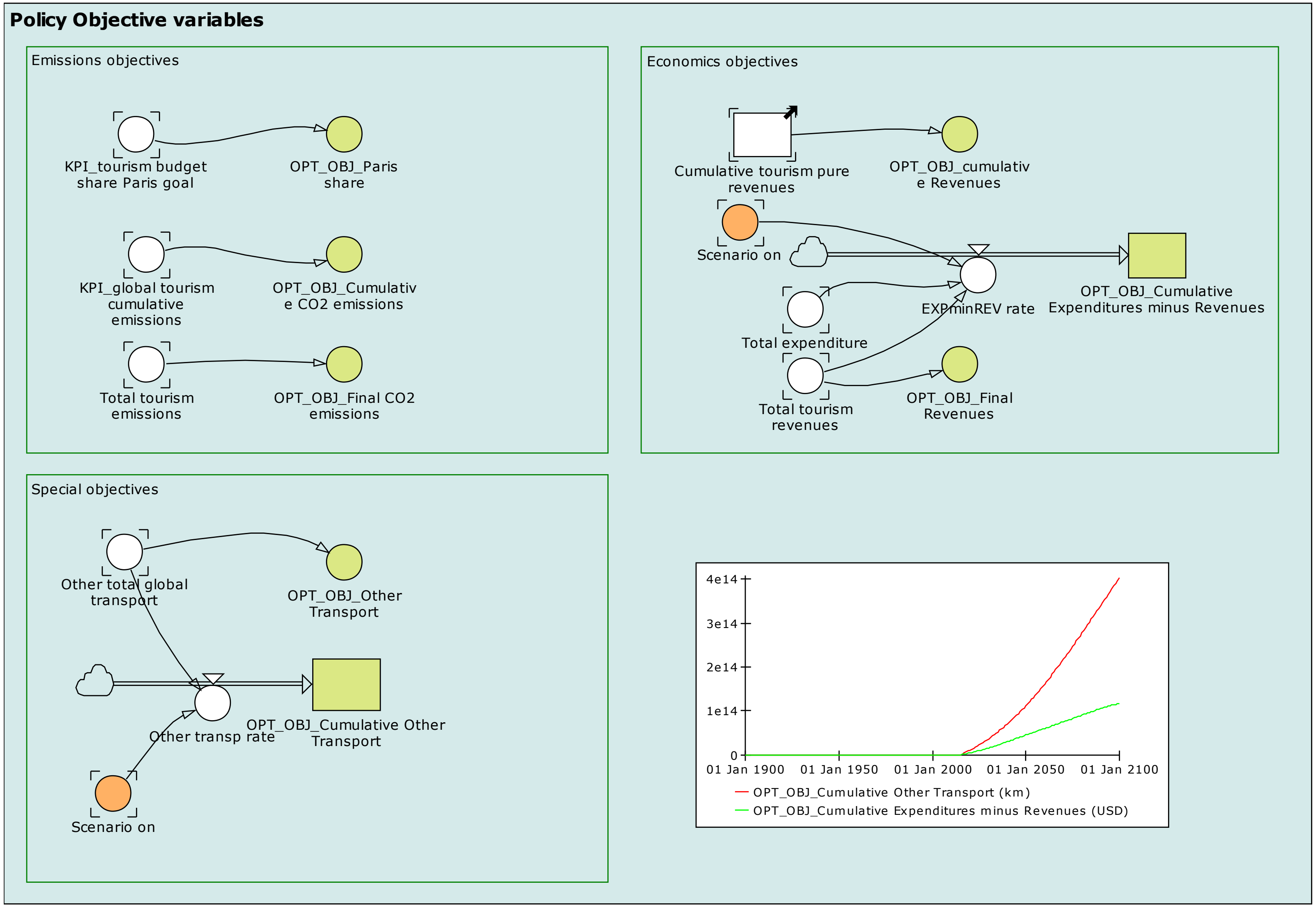
Calibration variables



Name	Dimensions	Unit	Type	Definition
Air total global transport				ARRSUM(Air global transport)
Air transport average		km/trip	Real	0

Name	Dimensions	Unit	Type	Definition
distance historical				
Calibrate distance error				ARRSUM(FOR(i=DIM(Total tourism historical distance)| IF(Total tourism historical distance[i]+Total tourism distance[i]=0<<km>>,0, (Total tourism historical distance[i]-Total tourism distance[i])/ (Total tourism historical distance[i]+Total tourism distance[i]))^2))
Calibrate total distance error			Real	1
Callibrate total distance error rate				Calibrate distance error*1<<1/yr>>
Car total global transport				ARRSUM(Car global transport)
Car transport average distance historical		km/trip	Real	0<<km/trip>>
End of run			Logical	IF(TIME=STOPTIME,TRUE,FALSE)
Historical tourism trips	Transport modes	trip	Real	0<<trips>>
Other total global transport				ARRSUM(Other global transport)
Other transport average distance historical		km/trip	Real	0
Total tourism distance	Transport modes			{Air total global transport,Car total global transport,Other total global transport}
Total tourism historical distance	Transport modes	km	Real	{Air transport average distance historical*Historical tourism trips[Air], Car transport average distance historical*Historical tourism trips[Car], Other transport average distance historical*Historical tourism trips[Other]}

Policy Objective variables



Name	Unit	Type	Definition
Cumulative tourism pure revenues	USD	Real	0<<USD>>
EXPminREV rate			IF(Scenario on, MAX(Total expenditure-Total tourism revenues,0<<USD>>), 0<<USD>>)*1<<1/yr>>
KPI_global tourism cumulative emissions			Tourism CO2 budget
KPI_tourism budget share Paris goal			Tourism CO2 budget share Paris Goal
OPT_OBJ_Cumulative CO2 emissions			KPI_global tourism cumulative emissions
OPT_OBJ_Cumulative Expenditures minus Revenues	USD	Real	0<<USD>>
OPT_OBJ_Cumulative Other Transport	km	Real	0
OPT_OBJ_cumulative Revenues	USD	Real	Cumulative tourism pure revenues
OPT_OBJ_Final CO2 emissions			Total tourism emissions
OPT_OBJ_Final Revenues			Total tourism revenues
OPT_OBJ_Other Transport			Other total global transport
OPT_OBJ_Paris share			KPI_tourism budget share Paris goal
Other total global transport			ARRSUM(Other global transport)
Other transp rate			IF(Scenario on,Other total global transport,0<<km>>)*1<<1/yr>>
Scenario on			IF(YEAR(TIME)<Scenario start year,FALSE,TRUE)
Total expenditure			ARRSUM(Global expenditure per mode and accomodation)+Global mitigation policy carbon cost
Total tourism emissions	GtCO2		Accommodation emissions+ Air global emissions+ Car total emissions+ Other total emissions
Total tourism revenues			ARRSUM(Global tourism revenues per mode and acco)

Dimensions

Name	Definition
Air emissions decay factors	a, b, c, d, g, h, k
Air fleet	Piston, Jet, Turboprop
Air Vcruise conversion	Vc_b, Vc_c
Air_Capacity	Air transport volume, Fleet growth rate
Aircraft_EI_constants	EI_0, CE_I, C_1, C_2, Gamma, Y_ref
Aircraft_EI_curve	IPCC, Lee, Piston fleet
Biofuels	Algae, Jatropha, Camelina, Switchgrass, Palm Oil
Biofuels_Plus	Algae, Jatropha, Camelina, Switchgrass, Palm Oil, Fossil
Carbon cost factors	CCF_a, CCF_b, CCF_c, CCF_Max
Dist_class	50-100, 100-125, 125-175, 175-225, 225-300, 300-400, 400-525, 525-675, 675-900, 900-1175, 1175-1550, 1550-2025, 2025-2650, 2650-3500, 3500-4600, 4600-6025, 6025-7925, 7925-10425, 10425-13700, 13700-18000
Economic post	Revenues, Climate taxes
Emission_cats	Air, Car, Other, Acco
Global mitigation scenarios	Unlimited, Moderate mitigation, Paris Agreed, Paris Ambition
Global_GDP_scenarios	SRES_A1, SRES_A2, SRES_B1, SRES_B2, SRES_FLAT
Global_GINI_scenarios	1..8
Global_pop_scenarios	C_Fertility_Sc, High_Sc, Medium_Sc, Low_Sc, Flat_Sc
Goal_seek	Strong, Medium, Shallow
In_Out_rates	In, Out
Investments	Airports, High speed rail, Abatement
k_constants	a, b, c, d, e, f
KPI_efficiency	Air transport, Car transport, Other transport, Accommodations, Per trip
KPI_emissions	CO2 emissions, Cumulative CO2, Paris Agreed, Paris Ambition, RF without cirrus, RF with cirrus
KPI_Goal emissions	User goal, Paris Agreed, Paris Ambition
KPI_tourism sector	Trips, Nights, Distance, Revenues, Expenditures, Travel time, Average distance, Eco-efficiency
Markets	Int, Dom_Rich, Dom_Poor

Name	Definition
Modes	Air, Car, Other
Policy infrastructure start years	Airports, HSR investments, Accommodations
Policy_ecar_share_transition	Policy goal, Policy change factor
Policy_Years	0001, 0002, 0003, 0004, 0005
Psych Value kinds	PV_Distance, PV_Cost
PV_constants	Alpha, Beta, Labda
Rail kinds	ConvSpRail, HighSpRail
RFI	Without cirrus, With cirrus
Shadow cost coeff	f_a, f_b, f_c, f_d
Speed_dist_constants	Block_max_conversion, C_v, B1_exp
Swan_cost_constants	C_SH, E_SH, C_LH, E_LH
Test_switches	Rail cost, Car cost
Tourism_economy	Expenditure Air, Expenditure Car, Expenditure Other, Expenditure Acco, Revenues Air, Revenues Car, Revenues Other, Revenues Acco, Revenues ex abatement Air, Revenues ex abatement Car, Revenues ex abatement Other, Revenues ex abatement Acco, Abatement cost Air, Abatement cost Car, Abatement cost Other, Abatement cost Acco
Transport modes	Air, Car, Other
Transport modes ext	Air_ext, Car_ext, Other_conv, Other_HST
Vehicle Age	1..50
Vehicle age group	0-10, 11-20, above 21

Units

Name	Definition	Plural Name	Documentation	Note
%	0.01	%	Percent	System Unit
activity	ATOMIC	activity	One tourism activity (e.g. visit to a museum, hike in a nature reserve)	
Adopter	ATOMIC	Adopters	A person using a product (somewhere) during one year (e.g. the owner of a car or the person that buys flight tickets)	

Name	Definition	Plural Name	Documentation	Note
Aircraft	ATOMIC	Aircraft	Airliners are defined in this unit (not private jets nor small private aircraft, helicopters, sailplanes or military aircraft	
bednight	ATOMIC	bednights	Number of nights tourists stay in an accommodation bed	
Capita	ATOMIC	Capita	One human being	
Car	ATOMIC	Cars		
da	24hr	da	Day	System Time Unit
deg	(3.14159265358979323846/180)rad	deg	Degrees - Plane angle	System Unit
Euro	ATOMIC	Currency		
flight	ATOMIC	flights	A flight is a flight by an aircraft (not an individual)	
grad	(3.14159265358979323846/200)rad	grad	Gradians - Plane angle	System Unit
GtC	(10^12)kg	GtC		
GtCO2	(10^12)kg	Gton		
ha	10000m^2	ha		
hr	60min	hr	Hour	System Time Unit
J	N*m	J	Joule - Energy	
kg	__KILOGRAM	kg	Kilogram - Mass	
km	1000*m	km	Kilometer - Length	
m	__METER	m	Meter - Length	
min	60s	min	Minute	System Time Unit
MJ	1000000J	MJ		
mo	30da	mo	Month	System Time Unit
N	kg*m/s^2	N	Newton - Force	
night	ATOMIC	nights		
period	__TIME	periods	Project Time Unit	System Time Unit
ppmv	ATOMIC	ppmv		
ppmv	ATOMIC	ppmv		
qtr	90da	qtr	Quarter	System Time Unit

Name	Definition	Plural Name	Documentation	Note
rad	__RADIAN	rad	Radians - Plane angle	System Unit
s	__SECOND	s	Second	System Time Unit
seat	ATOMIC	seats		
ton	1000kg	tonnes		
Tourist	ATOMIC	Tourists		
trip	ATOMIC	trips	One trip is defined as a full return trip from home to destination to home	
unit	ATOMIC	units		
USD	__CURRENCY("USD")	USD	1990 Geary-Khamis dollars (Maddison, 2010)	
W	J/s	W	Watt - Power	
wk	7da	wk	Week	System Time Unit
yr	360da	yr	Year	System Time Unit

Data connections

Name	Dataset	Location
Connection of GDP_growthrates*	INP_GDP_growthrates	GDP_growthrates!A2
Connection of Global_GDP_initial	INP_Global_GDP_initial	GDP_per_capita!A2
Connection of Historic global car ownership	INP_Historic global car ownership	Global car ownership!A1
Connection of INP_Accommodation cost	INP_Accommodation cost	Accommodation cost!A1
Connection of INP_Air delivery delay times	INP_Air delivery delay times	Air historic fleet!N1
Connection of INP_Air distance class distribution*	INP_Air distance class distribution	Air distance class distribution!A1
Connection of INP_Air globaltrips per distclass BASE RUN*	INP_Air globaltrips per distclass BASE RUN	Sheet1!A1
Connection of INP_Air historic fleet	INP_Air historic fleet	Air historic fleet!F1
Connection of INP_Air historic fleet age distribution*	INP_Air historic fleet age distribution	Air historic fleet!A1
Connection of INP_Air historic fleet growtgh rates	INP_Air historic fleet growth rates	Air historic fleet!Q1

Name	Dataset	Location
Connection of INP_Air historic seat occupation	INP_Air historic seat occupation	Air seat occupation!A1
Connection of INP_Air piston jet transition	INP_Air piston jet transition	Air piston jet transition!A1
Connection of INP_Air vehicle size	INP_Air vehicle size	Air vehicle size!A1
Connection of INP_Aircraft productivity	INP_Aircraft productivity	Air historic fleet!K1
Connection of INP_BF costs*	INP_BF costs	BF costs!A1
Connection of INP_Car average distance	INP_Car average distance	Car average distance!A1
Connection of INP_Car dist distribution*	INP_Car dist distribution	Car dist distribution!A1
Connection of INP_Car fleet X-factor	INP_Car fleet X-factor	Car fleet X-factor!A1
Connection of INP_Car fuel efficiency	INP_Car fuel efficiency	Car fuel efficiency!A1
Connection of INP_Car historic speed	INP_Car historic speed	Car historic speed!A1
Connection of INP_Car transport pkm	INP_Car transport pkm	Car transport pkm!A1
Connection of INP_Car transport X-factor	INP_Car transport X-factor	Car transport X-factor!A1
Connection of INP_Car weight	INS_Car weight	Car weight!A1
Connection of INP_CO2 concentration	INP_CO2 concentration	CO2 concentration!A44
Connection of INP_Global air ticket cost	INP_Global air ticket cost	Air ticket cost!A1
Connection of INP_Global air transport	INP_Global air transport	Air transport pkm!A1
Connection of INP_Global air transport speed	INP_Global air transport speed	Air transport speed!A1
Connection of INP_Global average flight distance	INP_Global average flight distance	Air average distance!A1
Connection of INP_Global car cost	INP_Global car cost	Global car cost!A1
Connection of INP_Global carbon*	INP_Global carbon	Global carbon!A55
Connection of INP_Global gasoline cost*	INP_Global gasoline cost	Global gasoline cost!A1
Connection of INP_Global_GINI*	INP_Global_GINI	GINI_data!A2
Connection of INP_Historic airport capacity	INP_Historic airport capacity	Historic airport capacity!A3
Connection of INP_Historic tourism trips*	INP_Historic tourism trips	TOTAL TRIPS!A1
Connection of INP_Oil and Jet A cost*	INP_Oil and Jet A cost	Oil and Jet A cost!A4
Connection of INP_Other average distance	INP_Other average distance	Other average distance!A1
Connection of INP_Other dist distribution*	INP_Other dist distribution	Other dist distribution!A1

Name	Dataset	Location
Connection of INP_Other global rail track	INP_Rail historic global rail track	Other infrastructure!A1
Connection of INP_Other global trips	INP_Other global trips	Other global trips!A1
Connection of INP_Other historic emission factors	INP_Other historic energy factor	Other CO2 emissions!e1
Connection of INP_Other historic energy emission factors	INP_Other historic energy emission factors	Other CO2 emissions!C1
Connection of INP_Other ticket cost	INP_Other ticket cost	Other ticket cost!A1
Connection of INP_Other transport high speed share	INP_Other transport high speed share	Other transport speed!E1
Connection of INP_Other transport pkm	INP_Other transport pkm	Other transport pkm!A1
Connection of INP_Other transport speed*	INP_Other transport speed	Other transport speed!A1
Connection of INP_Other transport X-factor	INP_Other transport X-factor	Other transport X-factor!A1
Connection of INP_POP_Global_Birthrates*	INP_POP_Global_Birthrates	Global_Birthrates!A1
Connection of INP_POP_Global_Deathrates*	INP_POP_Global_Deathrates	Global_Deathrates!A1
Connection of INP_POP_Global_Population*	INP_POP_Global_Population	Global_Population!A1
Connection of INP_Rail historic global HSR track	INP_Rail historic global HSR track	Other infrastructure!c1
Connection of INP_VoTT_inital*	INP_VoTT_inital	VoTT_inital!A1
Connection of OUT_Global travel time per distance class	OUT_Global travel time per distance class	Sheet1!A1
Connection of SCEN_Timeseriesdata	SCEN_Timeseriesdata	Timeseriesdata!A1

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