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### The environmental value of sustainable transport infrastructure

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## The Environmental Value of Sustainable Transport Infrastructure

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Ph.D.(cand) Civil Engineering





# Introduction



There is an ongoing debate on infrastructure investment priorities related to: Energy, Water, Transport, Waste, Communication

*(Hall et al., 2016; iBUILD, 2015; Liveable Cities, 2015; National Infrastructure Plan, 2013)*



Aims and Objectives (aligning with iBUILD & Liveable Cities projects)

- *Understand the Environmental Value Interdependencies of Transport Infrastructure*
- *Devise a new Transport Business Model that takes account on these interdependencies*



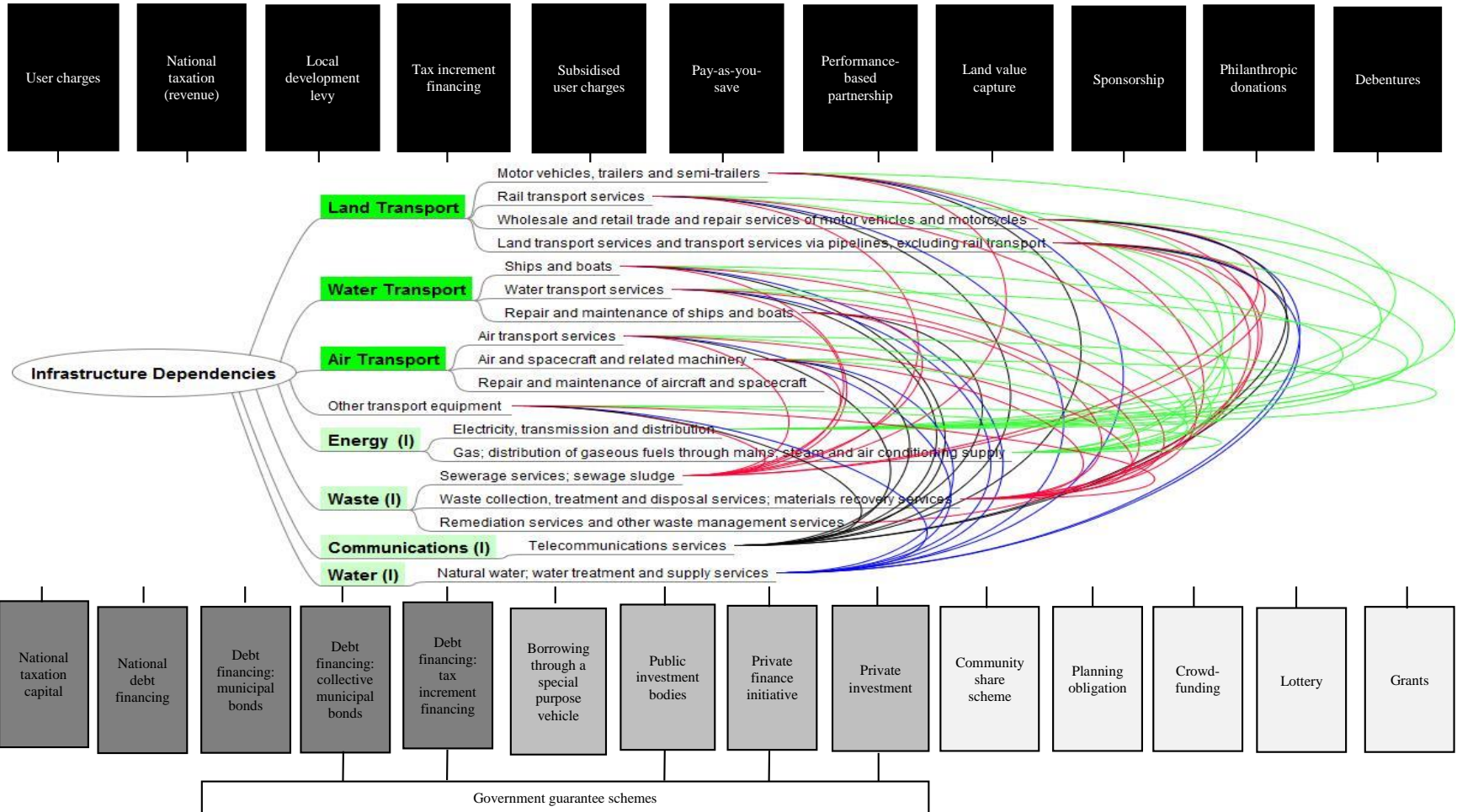
# Briefly Target Explanation



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## Environmental interdependencies

Figure 1: Infrastructure business models







# Introduction

From ancient times until now:

- Use of the natural resources to cover human needs

What the environment offers:

- Raw materials
- Receiving the waste of human activities
- Life
- Recreation





# Introduction



Environment affects us all but... not everyone is concerned about it





# Introduction



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Causes of the environmental crisis:

- Natural Resource Scarcity
- Environmental Ethics
- Institutional Framework of Environmental Impact
- Economic value
- Unsaturated human needs (social value)



# Theoretical Methodology



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## **Sustainable Development Definition (1987):**

“...is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”

### **Key- concepts:**

- “...needs...”
- “...without compromising the ability of...” (limitation)





# Theoretical Frame of Reference



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## Environmental Value

- Environmental value may be defined by the natural and anthropogenic factors and elements which interact and influence the ecosystem, the quality of life, human well-being and human health (Riffat et al, 2016; Khatri & Tyagi, 2015; Summers et al, 2012).
- Environmental damaging actions may be considered or expressed with the followings: environmental pollution, environmental degradation, environmental contamination extraction of natural resources which causes depletion of natural resources etc. (FAO, 2017)



# Theoretical Frame of Reference



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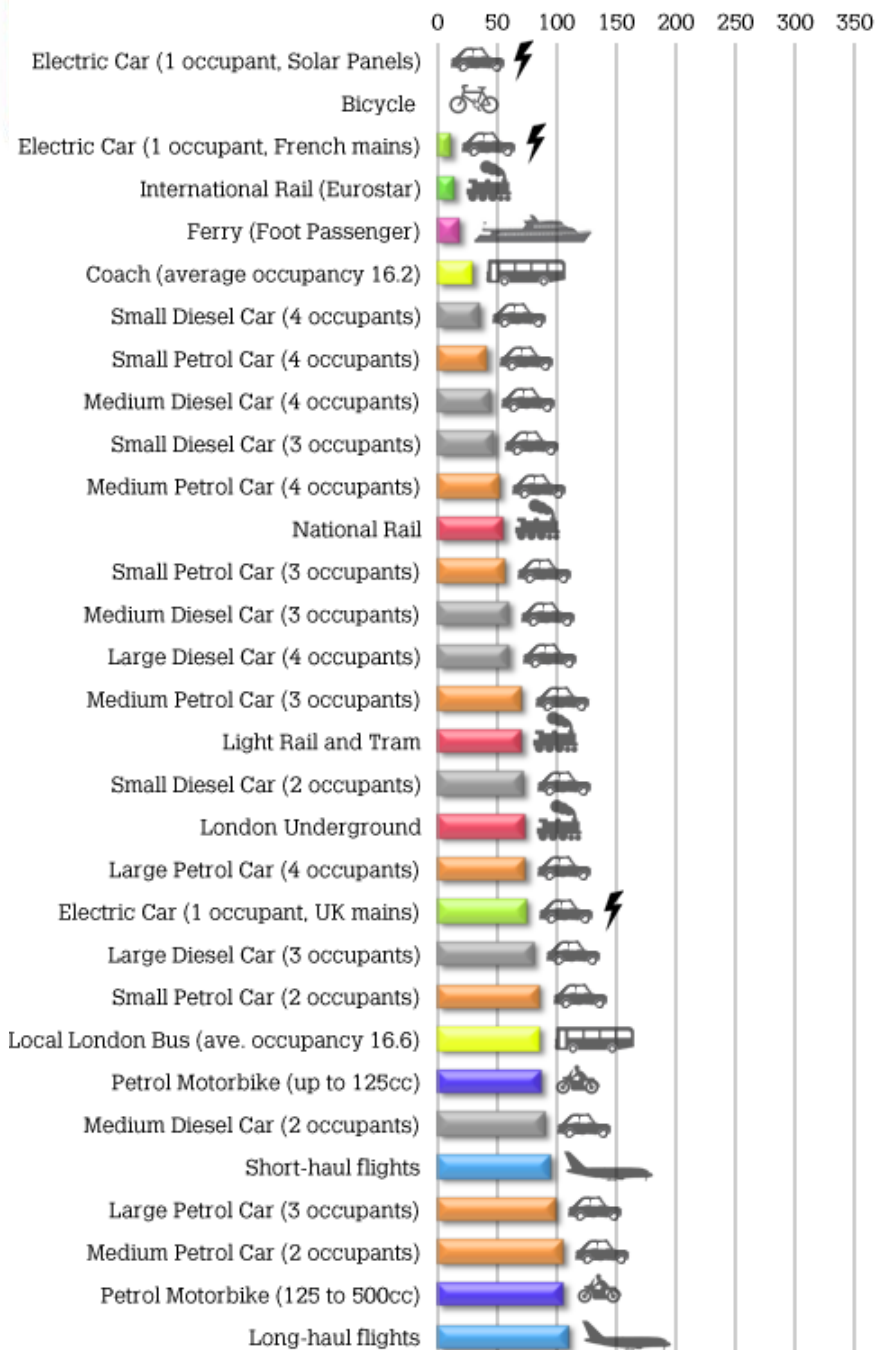
## Research proposition: Environmental Value

- Emissions are the wide accepted way to “calculate” the environmental damaging actions. Emission addresses the production of pollutants and the waste placement into the environment (FAO, 2017).

### Methodology:

- Correlate data of Input –Output tables EXIOBASE 3 (Stadler et al., 2018)
- Why is it difficult to use primary data?

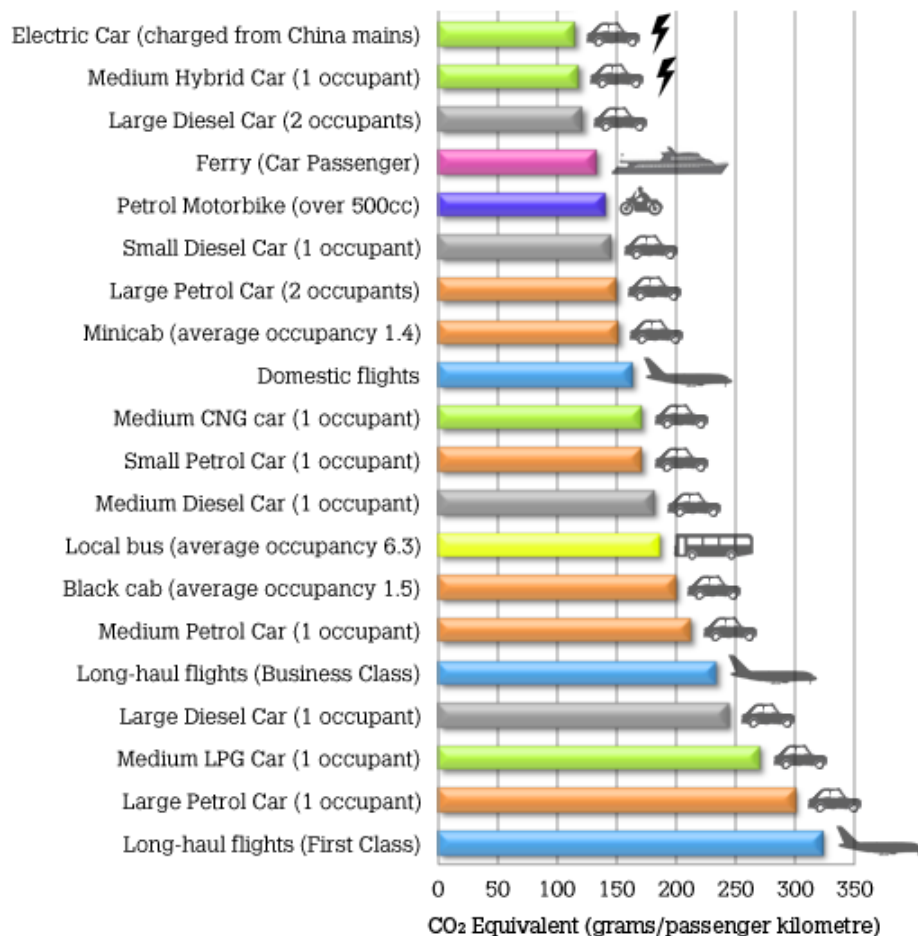
CO<sub>2</sub> Equivalent (grams/passenger kilometre)



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# Buenos Aires to London

(Source: <http://www.beagleybrown.com>)





# Primary data Methodology



- Questionnaire:

300 individuals

1								Evaluation															
Postcode	Age	Ethnic	Gend.	Indiv.	Cars/ Veh.	Income (x1000)	Distan (Km)		Percent	Goods	Main	Walking	Cycling	Rail	Bus	Car	Taxi		Travel Time	Excess Time	Travel Cost	Confort & Conven.	Safety & Security
Birmingham B191LL	20-29	White	F	2	0	0-10	7	Walking	15	x	Bus	4	-1	3	3	5	5	Walking	2	5	5	4	4
								Cycling										Cycling	0	4	1	-3	-3
								Rail										Rail	3	3	2	4	3
								Bus	80									Bus	3	4	4	-1	-1
								Car										Car	3	5	-1	4	4
								Taxi	5									Taxi	4	5	-2	4	4
Adjust to society:			Yes	Main reason:	Time		Trips	Distan															
Never cross the street if there is no zebra line								Air	1	311	General	Air			Water		Air	5	-1	0	4	4	
								Water	4	186		4			4	Water	3	2	2	3	5		

- The distance is not accurate
- We do not have data enough data for the car types
- Missing data from other transport modes too
- Worst case scenario assumption



# Primary data Methodology



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## Automobile emissions in the UK

Type of Vehicles	Emissions
Small motorbike/moped/scooter up to 125cc: 100000 km	10.19 tonnes of CO <sub>2</sub> e
Medium motorbike over 125cc up to 500cc:	12.41 tonnes of CO <sub>2</sub> e
Large motorbike over 500cc: 100000 km	16.28 tonnes of CO <sub>2</sub> e
Average petrol car (half full average car)	18.57 tonnes of CO <sub>2</sub> e
Average petrol hybrid car	11.79 tonnes of CO <sub>2</sub> e





# Primary data Methodology



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This study		Worst case scenario	(£ 12.90 incl. 20% VAT per tonne)
<b>Walking</b>	Walking: 100000 km	0 tonnes of CO2e	£ 0
<b>Cycling</b>	Cycling: 100000 km	0 tonnes of CO2e	£ 0
<b>Rail</b>	Tube / Subway: 100000 km	7.52 tonnes of CO2e	£ 97.01
	Tram: 100000 km		
	International rail: 100000 km		
	National rail: 100000 km		
<b>Bus</b>	Coach: 100000 km	10.26 tonnes of CO2e	£ 132.35
	Bus: 100000 km		
<b>Car</b>	Average petrol car	18.57 tonnes of CO2e	£ 239.56
<b>Car (Hybrid)</b>	Average petrol hybrid car	11.79 tonnes of CO2e	£ 152.09
<b>Taxi</b>	Taxi: 100000 km	15.62 tonnes of CO2e	£ 201.5
<b>Air</b>	Short-haul flight	28.54 tonnes of CO2e	£ 368.17
	Long-haul flight		
	Domestic flights		
<b>Water</b>		0.61 tonnes of CO2e	£ 7.89



# Primary data Methodology



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Survey	Day (Km)	Year (Km)/300	Year (%)	Cost (£) /10 <sup>5</sup> Km	Year (Km) Metropolitan areas	Cost (£) Metropolitan areas/Year
Walking	489.7	178740.5	5.27%	0	0	0
Cycling	357.9	137791.5	4.05%	0	0	0
Rail	1273.1	464681.5	13.69%	97.01	50426240412.65	48918495.82
Bus	810.9	295978.5	8.72%	132.35	32118952439.42	42509433.55
Car	4392.1	1603116.5	47.23%	239.56	?	?
Hybrid	?	?	?	152.09	?	?
Taxi	79.3	28944.5	0.85%	201.5	3140995102.29	6329105.13
Air	-	676412	19.93%	368.17	73402780463.61	270247016.8
Water	-	8658	0.26%	7.89	939547603.02	74130.31
Total	7403	3394323	100%	-		?



# Methodology



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EXIOBASE 3 (Stadler et al., 2018):

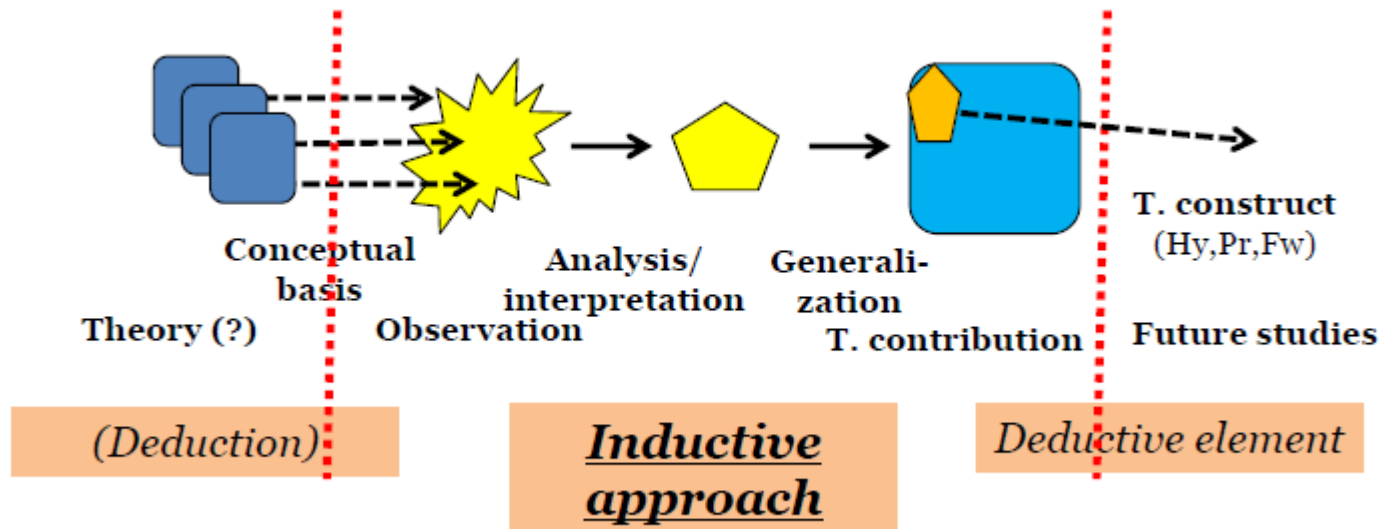
- 85 types of emissions (air & water) per demand in euros
- 44 countries (28 EU member plus 16 major economies)
- Same year 2007 (2018 under issue):  
48 counties/areas x 85 emission



# Methodology

Inductive approach:

- Based on the observation only 29 emission are produced by the industries of interest





# Environmental Value



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Transport		GB	GB	GB	GB	GB	GB
		Transport via railways	Other land transport	Transport via pipelines	Sea and coastal water transport	Inland water transport	Air transport
Combustion	/M.EUR						
CO2	kg	111343.9	75817.3	71681.49	1108655.203	1.83E+07	1862350.55
CH4	kg	6.238257	4.54647	4.298415	78.72147886	1256.948296	14.3246283
N2O	kg	42.21357	28.65806	27.09408	73.19358565	4603.169686	53.2051471
SOx	kg	17.04783	1.969464	1.861975	17143.43579	152268.3867	568.83487
NOx	kg	1811.144	519.2538	490.9285	25327.8992	408003.4647	6118.75415
NH3	kg	0.270514	1.05822	1.000488	0.05264327	0.047646388	0.17962125
CO	kg	371.9159	178.2455	168.5243	2609.062487	41939.39313	11860.3205
Benzo(a)-pyrene	kg	0.001062	0.00117	0.001106	6.13E-05	5.55E-05	0.0020887
Benzo(b)-fluoranthene	kg	0.001836	0.004233	0.004003	0.007221654	0.113501983	0.00240859
Benzo(k)-fluoranthene	kg	9.78E-04	6.61E-04	6.25E-04	2.80E-05	2.54E-05	1.22E-04
Indeno(1,2,3-cd)pyrene	kg	6.25E-04	4.27E-04	4.04E-04	0.003532855	0.056681484	6.18E-05
PCDD_F	kg I-TEQ	2.70E-09	2.46E-09	2.33E-09	1.13E-10	1.02E-10	4.57E-10
NM VOC	kg	160.2165	28.55117	26.99358	844.7898495	13600.89201	435.243209
PM10	kg	50.23377	30.27385	28.62203	2122.43322	18402.08881	12.4706341
PM2.5	kg	47.76662	27.92559	26.40159	2122.333157	18402.00751	57.8458301
TSP	kg	53.38177	44.33343	41.91496	2123.055043	18402.64132	14.1566342
As	kg	0	0	0	154.8712546	1086.557878	0
Cd	kg	3.51E-04	2.74E-04	2.59E-04	9.292351941	65.21871018	9.31E-05
Cr	kg	0.001817	0.003572	0.003377	0.063771562	0.574430091	7.68E-04
Cu	kg	0.06095	0.092727	0.087669	154.87521	1086.561458	0.02219303
Hg	kg	0	0	0	6.197080476	43.62924232	0
Ni	kg	0.002449	0.001726	0.001632	9.294917712	65.42838692	6.47E-04
Pb	kg	0.009344	0.006423	0.006072	0.066397099	0.784160389	0.00138649
Se	kg	3.51E-04	3.02E-04	2.85E-04	0.132253666	1.567866517	9.63E-05
Zn	kg	0.035647	0.047423	0.044836	0.301652597	3.70419127	0.01178429
NM VOC (non combustion)	kg	94.03963	117.3346	1.142945	11.18485141	22.71792767	44.9018179





# Environmental Interdependencies



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Correlation using SPSS software:

Transport

Waste

Water

Energy

and Communication

Next steps:

- Exclude zeros and missing values
- Exclude same type of input

WLPaper - WLWood	0.888	W-W
WIOil - WLMetal	0.887	W-W
WIFood - WIPaper	0.874	W-W
WLTextile - WLWood	0.872	W-W
EnergyCoal - EnergyDistrib	0.846	E-E
EnergyTransm - NWaterDistrib	0.841	E-N
EnergyCoal - EnergyTransm	0.828	E-E
WWFood - WWOther	0.816	W-W
TManufMotor - TPipelines	0.803	T-T
EnergyNuclear - EnergyWind	0.767	E-E
EnergyDistrib - NWaterDistrib	0.761	E-N
WLPaper - WLPlastic	0.753	W-W
WIFood - WLPlastic	0.750	W-W
EnergyOcean - WCPaper	0.731	E-W
TSaleFuel - Communic	0.725	T-C
WLPlastic - WLTextile	0.715	W-W
EnergyCoal - NWaterDistrib	0.707	E-N
TRail - Communic	0.617	T-C
EnergyPetrol - TAir	0.598	T-E
WWFood - WLFood	0.591	W-W
TSea - WIPlastic	0.591	T-W
TSea - WITextile	0.591	T-W
EnergyGeoth - TPipelines	0.589	E-T
WWFood - WLPaper	0.579	W-W



# Environmental Interdependencies



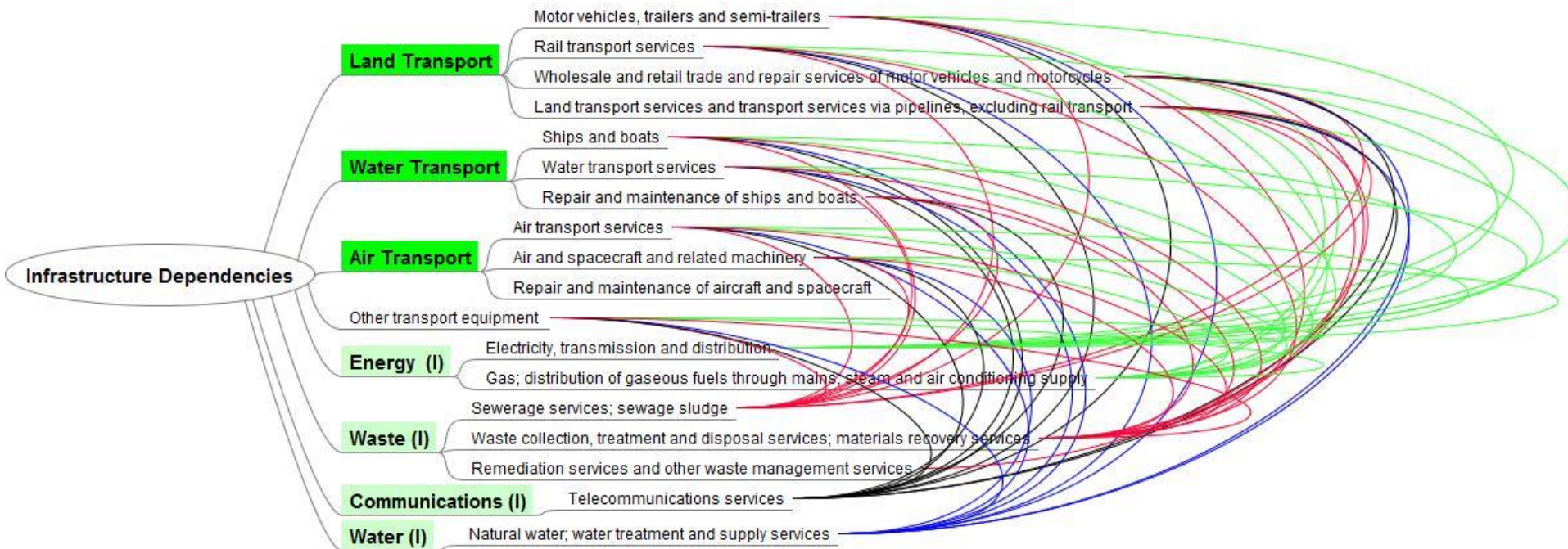
Emission	Transport Dependency	Other Dependency
CO <sub>2</sub>	Energy-Transport; Communication-Transport (Pipelines, Rail); Water-Transport; Waste-Transport	Energy-Water; Water-Waste; Energy-Communication; Energy-Waste
CH <sub>4</sub>	Energy-Transport; Communication-Transport (Manufacture)	Energy-Water; Energy-Communication
N <sub>2</sub> O	Energy-Transport; Communication-Transport	Energy-Water; Water-Waste
SO <sub>x</sub>	Energy-Transport; Communication-Transport (Pipelines); Water-Transport (Sales); Waste-Transport	Energy-Waste
NO <sub>x</sub>	Waste-Transport (Sales; Transport through Water with Wastewater)	
NH <sub>3</sub>	Communication-Transport; Energy-Transport; Waste-Transport	Energy-Water; Water-Waste;
etc	(The rest 23 are calculated now)	



# Next step



Create a model of the interdependencies





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## Infrastructure Management:

Devise of a Business Model for Transport Infrastructure  
Interdependencies Management

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