UNECE Workshop on “Good practices and new tools for financing transport infrastructure”

2nd Session Benchmarking of Transport Infrastructure Construction Costs

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Estimating and Benchmarking Transport Infrastructure Costs

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Transport Infrastructure

- Vital social and economic asset.
- Construction and maintenance absorb significant resources.
- Investments are highly visible and public.
- Public Good

Objective

- Set out classification of infrastructure costs.
- Detail the various cost components for six modes of transportation.
- Identify key economic and financial parameters.
- Present indicative benchmark values and related source.

Transport Modes

- Different components of costs for infrastructure of different modes:
  - Road
  - Railway
  - Ports
  - Airport
  - Inland waterways
  - Terminals/freight villages
  - Pipelines (petrol, gas)

Infrastructure Costs

- **Capital costs** : yearly depreciation costs
  - Investment:
    - new infrastructure with a specified functionality and lifetime
    - expansion of existing infrastructure with respect to functionality and/or lifetime.
  - Renewal: replacing existing infrastructure, prolonging the lifetime without adding new functionalities.
  - Maintenance: maintaining functionality of existing infrastructure within its original lifetime
  - Yearly interest costs.
- **Operational costs**: Yearly recurring not relating to enhancing or maintaining lifetime and/or functionality of infrastructure.
- **Fixed vs variable**: with transport volume
- **Climatic change related ones**

Drivers for Infrastructure Costs

- Life-time expectancy
- Historical costs versus replacement costs
- Linear versus non-linear depreciation
- Time span between maintenance costs
- Interest rate

Parameters affecting costs

- Economic development of country
- Availability of natural resources for energy (fuel costs lower)
- Quality of construction
- Type of terrain/soil and topography
- Environmental related parameters crossing urban conurbations
- Expropriation costs

Road transport cost categories

- Road surfaces/pavement
- Superstructures, bridges, tunnels.
- Drainage works
- Road exploitation (buildings, sites, energy, research, etc.)
- Traffic provision for lightning, signposting, signalling.
- Landscape and Environment (minimizing detrimental effects, waste management)
- Engineering works

Estimating road unit construction costs

- **Surveying**
  - no of stakes set per hour and per km
- **Clearing and Piling**
  - production rate in km/hr: hectares per hour cleared and piled per hour divided by number of hectares per km to be cleared and piled.
- **Earthwork**
  - no of cubic meters of common material and rock moved to construct road
- **Finish Grading**
  - no of passes a grader must make for a certain width subgrade/ speed of the grader.
- **Surfacing**
  - type of surfacing material, quantity per sqm, length of haul
- **Drainage**
  - drainage dips (water bars), culverts, and bridges are often expressed as a cost per lineal meter

Suggested structure for road expenditures categories

Category	Investment expenditure		Current expenditure		
	Investments	Renewal	Maintenance	Operating	Total
	Capital costs		Capital costs / Running costs	Running costs	
	%fixed / %variable	%fixed / %variable	%fixed / %variable	%fixed / %variable	
Road surface	100% / 0%	a% / b%	c% / d%	e% / f%	
Superstructures / Drainage works	100% / 0%				
Bridges / Tunnels					
Lightning, Signposting, Signalling	100% / 0%				
Grass areas, Road edges	100% / 0%				
Road facilities	100% / 0%				
Winter clearance	100% / 0%				
Interest	100% / 0%				
Unallocated overhead					
Total	100% / 0%				

Note: Grey cells indicate non-existent combinations (e.g. interest is always capital costs)

Source: DG TREN Infrastructure expenditures and Costs: Practical guidelines to calculate total infrastructure costs for five modes of transport, Final report 2005

Railway transport cost categories

- Distinction among:
  - Dedicated freight lines.
  - High speed passenger lines.
  - Mixed network
- Buildings / Railway stations
- Civil engineering works
- Superstructure
- Transmission lines
- Signalling equipment
- Telecommunications equipment
- Safety installations
- rolling stock
- Plant and machinery

Suggested structure for rail expenditures categories

	Investment expenditure		Current expenditure		
	Investments	Renewal	Maintenance	Operational	Total
	Capital costs		Capital costs / Running costs	Running costs	
	%fixed / %variable	%fixed / %variable	%fixed / %variable	%fixed / %variable	%fixed / %variable
Buildings / Railway stations	100% / 0%	a% / b%	c% / d%	e% / f%	
Civil engineering works	100% / 0%				
Superstructure	100% / 0%				
New construction in progress *)	100% / 0%				
Transmission lines	100% / 0%				
Signalling equipment	100% / 0%				
Telecommunications equipment	100% / 0%				
Safety installations	100% / 0%				
Vehicles / rolling stock	100% / 0%				
Plant and machinery	100% / 0%				
Other fixed assets	100% / 0%				
Interest	100% / 0%				
Management of traffic, control and safety systems					
Train running diagrams					
Unallocated overhead					
Total	100% / 0%				

Source: DG TREN Infrastructure expenditures and Costs: Practical guidelines to calculate total infrastructure costs for five modes of transport, Final report 2005

Inland waterways cost categories

- Locks
- Bridges
- Canal Banks
- Radar, traffic guidance
- Beacons, buoys
- Service vessels (e.g. patrol service vessels)
- Dredging
- Housing (e.g. at locks)

Suggested structure for inland waterway expenditures categories

Category	Investment expenditure		Current expenditure		
	Investments	Renewal	Maintenance	Operating	Total
	Capital costs		Capital costs / Running costs	Running costs	
	%fixed / %variable	%fixed / %variable	%fixed / %variable	%fixed / %variable	
Locks	100% / 0%	a% / b%	c% / d%	e% / f%	
Bridges	100% / 0%				
Canal Banks	100% / 0%				
Radar, traffic guidance	100% / 0%				
Beacons, buoys	100% / 0%				
Service vessels (e.g. patrol service vessels)	100% / 0%				
Dredging	100% / 0%				
Housing (e.g. at locks)	100% / 0%				
Interest					
Unallocated overhead					
Total	100% / 0%				

Source: DG TREN Infrastructure expenditures and Costs: Practical guidelines to calculate total infrastructure costs for five modes of transport, Final report 2005

Air transport cost categories

- Land
- Terminal building and pier
- Other buildings, plants
- Airfield
  - Runway surface
  - Runway bases
  - Taxiways and aprons
- Access Roads, other fixed assets

Suggested structure for air transport expenditures categories

Category		Investment expenditure		Current expenditure			
		Investments	Renewal	Maintenance		Operational	Total
		Capital costs		Capital costs	Running costs	Running costs	
		%fixed / %variable	%fixed / %variable	%fixed / %variable		%fixed / %variable	%fixed / %variable
Land		100% / 0%	a% / b%	c% / d%		e% / f%	
Terminal building and pier		100% / 0%					
Other buildings, plants		100% / 0%					
Airfield	Runway surface	100% / 0%					
	Runway bases	100% / 0%					
	Taxiways and aprons	100% / 0%					
New construction in progress[a)]		100% / 0%					
Roads		100% / 0%					
Installations, equipment		100% / 0%					
Other fixed assets		100% / 0%					
Airport police		100% / 0%					
Interest		100% / 0%					
Management of traffic control and safety systems							
Unallocated overhead							
Total expenditures		100% / 0%					

Source: DG TREN Infrastructure expenditures and Costs: Practical guidelines to calculate total infrastructure costs for five modes of transport, Final report 2005

Maritime transport cost categories

- Quays & berthing
- Maritime access (fairway, dredging, signals)
- Land
- Superstructure (cranes, terminals, etc.)
- Land transport access
- Other civil engineering works (piping, etc)
- Equipment (e.g. Ice breakers, service vessels, etc.)

Suggested structure for seaport expenditures categories

Category	Investment expenditure		Current expenditure		
	Investments	Renewal	Maintenance	Operational	Total
	Capital costs		Capital costs / Running costs	Running costs	
	%fixed / %variable	%fixed / %variable	%fixed / %variable	%fixed / %variable	
Quays & berthing	100% / 0%	a% / b%	c% / d%	e% / f%	
Maritime access (fairway, dredging, signals)	100% / 0%				
Land	100% / 0%				
Superstructure (cranes, terminals, etc.)	100% / 0%				
Land access	100% / 0%				
Other civil engineering works (piping, etc)	100% / 0%				
Equipment (e.g. ice breakers, service vessels, etc.)	100% / 0%				
Interest	100% / 0%				
Unallocated overhead					
Total	100% / 0%				

Source: DG TREN Infrastructure expenditures and Costs: Practical guidelines to calculate total infrastructure costs for five modes of transport, Final report 2005

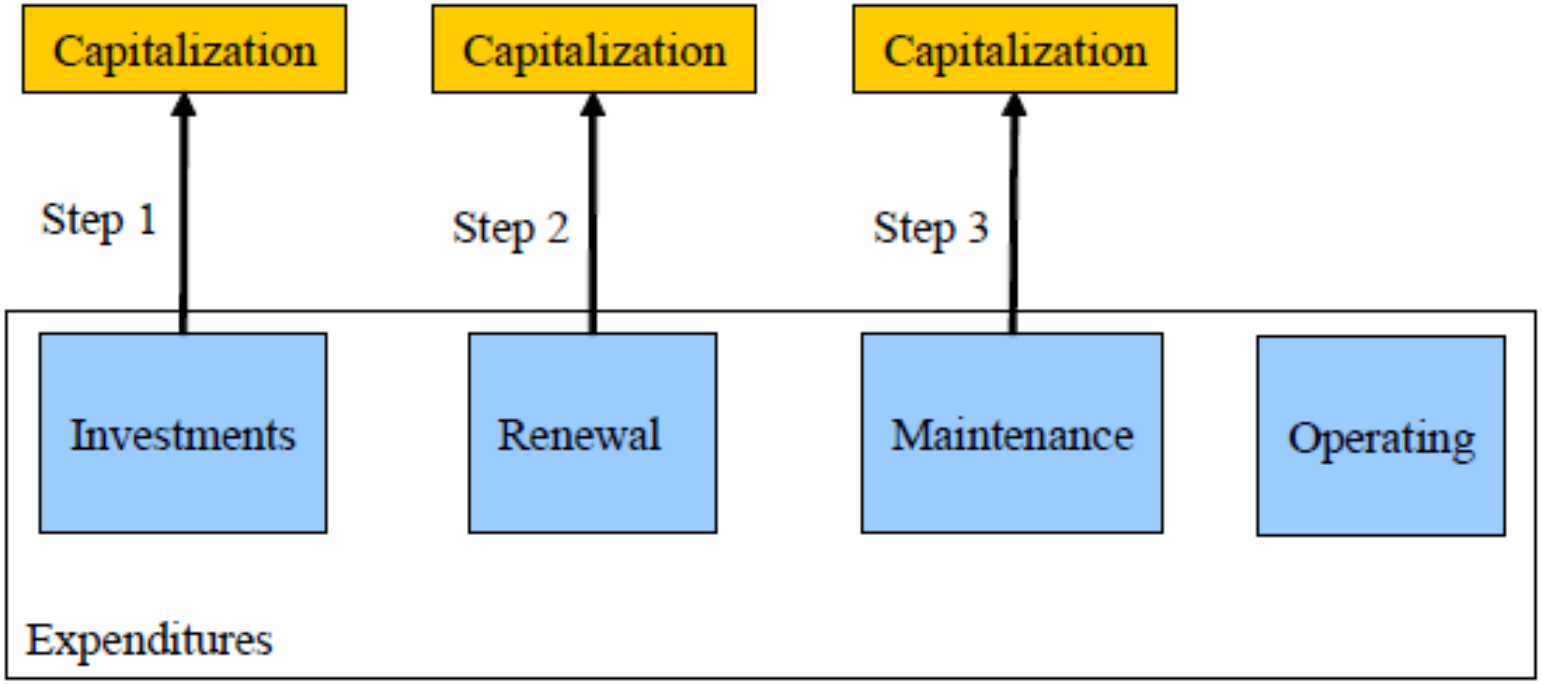
Terminal cost categories

- Facilities / Buildings
  - General Warehouses
  - Unaccompanied/transit storage
  - Special warehouses
- Administration building
- Ancillary spaces
- Customs office
- Restaurant/Café
- Garage/ Fuel station
- Mechanical equipment
- Miscellaneous/Contingency
- Rail terminal
- Internal road network

Pipeline network cost categories

- Transmission pipes
- Compressor stations
- Pumping facilities
- Valves and other regulators
- Control Stations and SCADA Systems
- Storage and distribution centers/hubs
- Supporting assets necessary to stabilize, condition, and perform bulk separation.
- Maintenance
- Monitoring/surveillance

Methodology for estimating costs



Source: DG TREN Infrastructure expenditures and Costs: Practical guidelines to calculate total infrastructure costs for five modes of transport, Final report 2005

Expenditures vs economic costs

- Take into account direct expenses plus the financing costs or the opportunity costs for not spending the resources for more profitable purposes.
- Financing and opportunity costs expressed by the interest on capital, where the interest rates vary with legal status of the investor.

Interest rate and depreciation

- Assets lose a certain share of their original (gross) investment value, linear or dependent on traffic loads.
- Determine actual depreciation by comparing asset's condition at beginning and end of accounting period.
- Statistically remaining value of asset reflects the capital commitment to be financed on capital market.
- **Capital costs are thus determined by the level of the real interest rate.**

Adaptation to climate change costs

				Area for cost quantification			
Mode	Transport system component	Typical infrastructure life	Chapter in this report	Asset at risk	Adaptation measure		*Avoided impacts*
					autonomous	Planned	
road	infrastructure	7-10 years maintenance cycle	Chapter 4	Mapping future changing risk for road pavemet cracking	changing asphalt binder (*)	-	*- reduce road pavement degradation - avoid accidents (vehicle damages, injuries, fatalities)*
rail	infrastructure and operation	50-100 years track life	Chapter 5	Mapping future changing risk for rail buckling	speed limitations changing track conditions	-	*- reduce rail track buckling damage - avoid accidents (vehicle damages, injuries, fatalities)*
road rail	infrastructure (bridges)	> 100 yr life	Chapter 6	Mapping future risk for river bridge scour		- rip rap, - strenghtening of bridge foundations with concrete	*- damages to bridges due to scour - accidents, fatalities*
road	infrastructure	.> 100 yr life	Chapter 7	Value of infrastructure at risk of permanent or temporary inundation		-	-

Source: EC JRC. Impacts of Climate Change on Transport: A focus on road and rail transport infrastructures, 2012

Cost Overruns

- Actual and estimated costs in transportation infrastructure differ in most cases.
- **Length of implementation (years)**
  - Cost escalation is highly dependent on length of project implementation phase and at a very high level of statistical significance.
- **Size** of project (costs)
  - For bridges and tunnels, larger projects have larger percentage cost escalations; for rail and road projects this does not appear to be the case.
- Type of ownership (public, private, PPP)
  - Certain type of public ownership (state-owned enterprises), lacking transparency and competitive pressure of private sector.

Reasons for benchmarking

- Justify an appropriate level of financing from government.
- Justify an appropriate level of charges from the regulator.
- Provide a better understanding and forecasting of costs and revenues, leading to better project predictability.
- Set target cost levels.
- Bring cost levels down and efficiency levels up.
- Monitor contractual performance.

Challenges in obtaining unit costs

- Transportation investment costs differ across sector, transport mode, investment type and country.
- Example:

Country	Network	Capacity enlargement	Investive maintenance	Routine maintenance	Operation, management & finance	Total
		Euro (2005 prices) per km of total network length				
Austria [1)]	ASFINAG network	331,134	197,917	108,406		637,456
Switzerland [2)]	National roads	783,502	288,239	78,867	99,053	1,249,661
	Canton roads	32,035	9,634	20,902	17,124	79,695
	Municipal roads	7,403	2,325	14,831	4,589	29,148
Germany [3)]	Federal motorways	197,528	83,826	39,383		320,737
	Federal trunk roads	23,410	21,173	11,576		56,159

Source: DG TREN Infrastructure expenditures and Costs: Practical guidelines to calculate total infrastructure costs for five modes of transport, Final report 2005

Data availability

- Most countries register **road** infrastructure expenditures (although every country applies its own definition).
- Limited/poor quality data available in national statistics on ***real (ex post)*** expenditures for transport infrastructure.
  - More detailed information found in **business accounts** of infrastructure managers, albeit confidential in most cases.

Recommended relevant sources/studies*

- World Bank ROCKS (Road Costs Knowledge System) database.
- World Bank's Africa Infrastructure Country Diagnostic (AICD).
- EC funded research project UNITE (2000 to 2003).
- Road infrastructure cost and revenue in Europe. Produced within the study Internalisation Measures and Policies for all external cost of Transport (IMPACT) – Deliverable 2, Delft, CE, 2008.
- European Commission Joint Research Centre. Impacts of Climate Change on Transport: A focus on road and rail transport infrastructures, 2012
- MEDPRO (Mediterranean Prospects) project
- National studies:
  - Germany (ProgTrans/IWW, 2007; Prognos/IWW, 2002 on behalf of BMVBS).
  - Switzerland (Bundesamt fuer Statistik, 2007).
  - Austria (Herry et al., 2002 on behalf of ASFINAG).
  - The Netherlands (CE, 2004).
  - The United Kingdom (ITS et al., 2001).

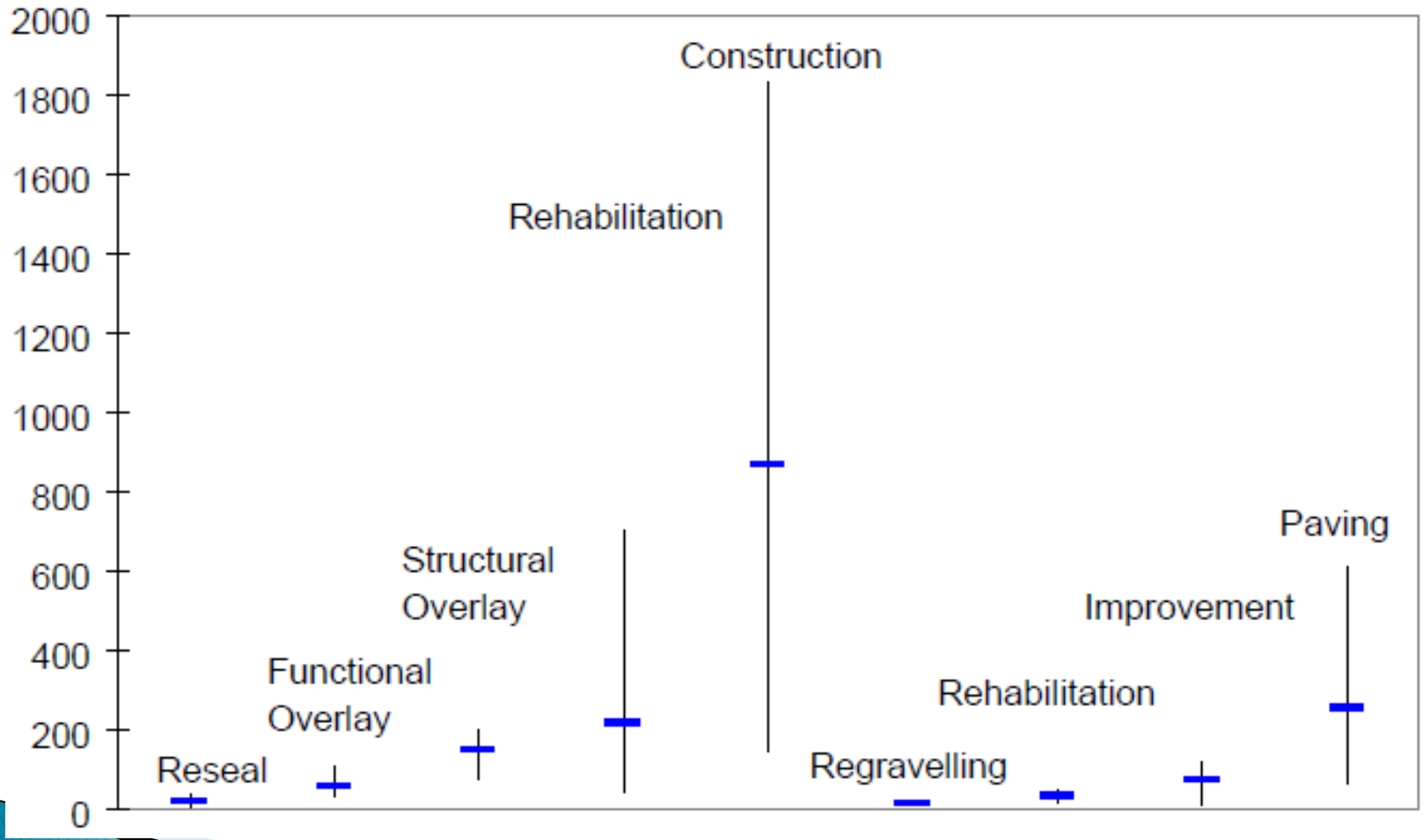
** non-exhaustive*

Indicative Road Works Costs

- Paved Roads
  - Seals: 5,000 – 32,000 $/km
  - Functional Overlays: 30,000 – 107,000 $/km
  - Structural Overlays: 74,000 – 198,000 $/km
  - Rehabilitation : 45,000 – 700,000 $/km
  - Construction : 142,000 – 1,832,000 $/km
- Unpaved Roads
  - Regravelling : 9,000 – 13,000 $/km
  - Rehabilitation : 17,000 – 47,000 $/km
  - Improvement : 11,000 – 114,000 $/km
  - Paving : 62,000 – 609,000 $/km

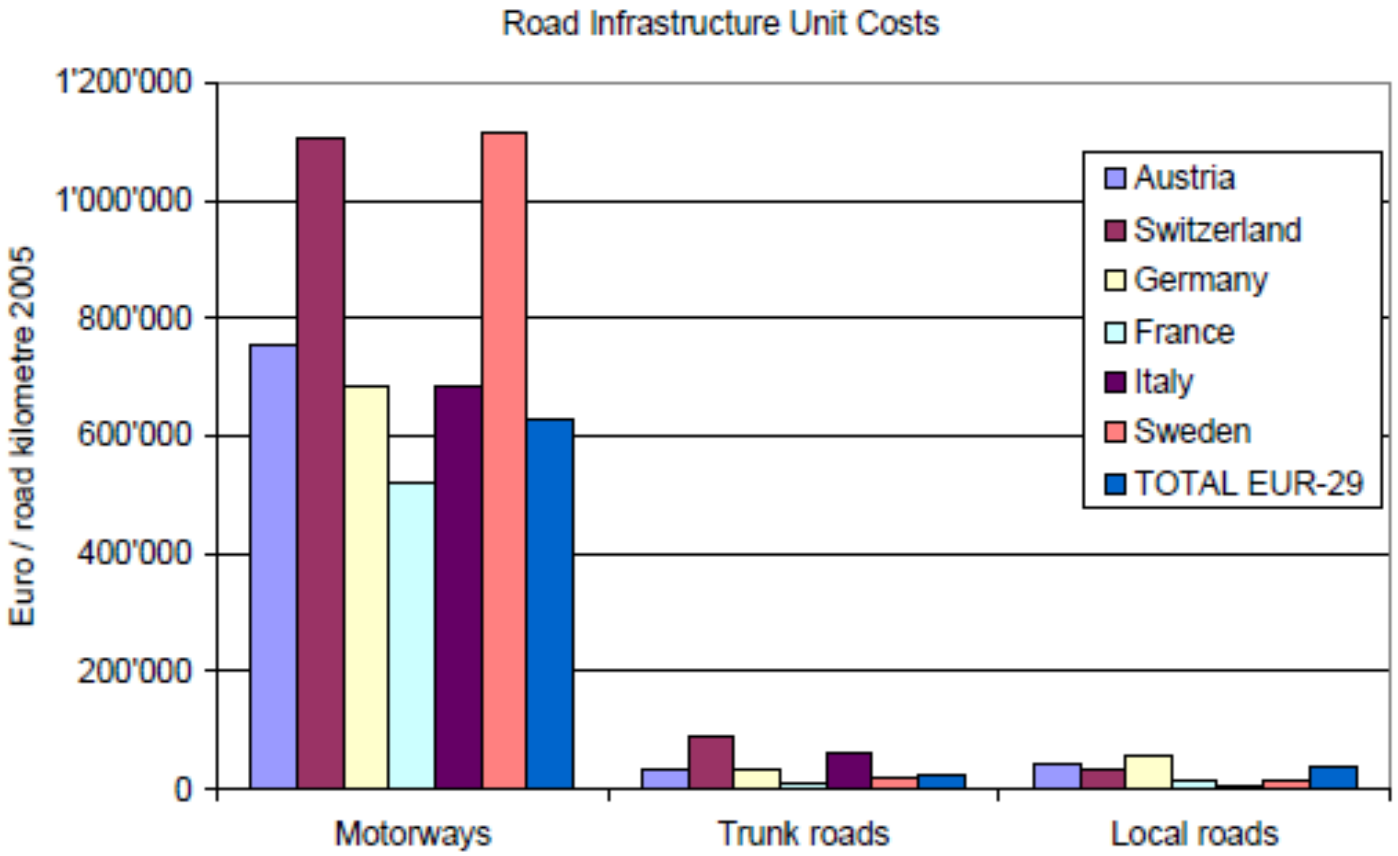
Source: World Bank

Average and Range of Roads Works Costs per km ('000$)



Source: World Bank

Unit road infra costs for 3 road types



Source: IMPACT- Deliverable 2 Delft, CE, 2008

Unit costs of new infrastructure

Type of infrastructure	Unit	Unit cost (US$)
4-lane divided paved road	US$/km	3,500,000
2-lane paved road	US$/km	1,000,000
1-lane paved road	US$/km	150,000
Railway single track, 25t axle load, diesel	US$/km	750,000
Railway single track, 25t axle load, electric	US$/km	1,000,000
Railway signalling	US$/km	350,000
Airport runway, 3000m	US$/m	30,000,000
Airport passenger terminal	US$/$m^2$	500
Container berth	US$/berth of 300m	16,000,000

Source: MEDPRO Project, Report No3, 2013

Unit costs of maintaining transport infrastructure

Periodic activity	Unit	Total cost in US$	Periodicity	Annual cost in US$
Resurfacing a 4-lane road	US$/km	1,000,000	8	125,000
Resurfacing a 2-lane road	US$/km	50,000	8	6,250
Reballasting a railway	US$/track km	15,000	5	3,000
Resurfacing a runway	US$/runway	5,000,000	10	500,000
Rehabilitating a container berth	US$/berth	10,000,000	10	1,000,000
Refurbishing an air passenger terminal	US$/$m^2$	200	5	40

Source: MEDPRO Project, Report No3, 2013

Adaptation to higher temperatures (Road pavement cost)

grade	Tmaxp_7day (°C)	cost (USD/lane miles)	cost (€/km lane)
PG-46	46	197 000	94 182
PG-52	52	210 000	100 397
PG-58	58	225 000	107 568
PG-64	64	241 000	115 217
PG-70	70	258 000	123 345
PG-76	76	276 000	131 950
PG-82	82	295 000	141 034

PG-Performance grade

Source: EC JRC. Impacts of Climate Change on Transport: A focus on road and rail transport infrastructures, 2012

Pipeline Unit Cost ($M/200 miles)

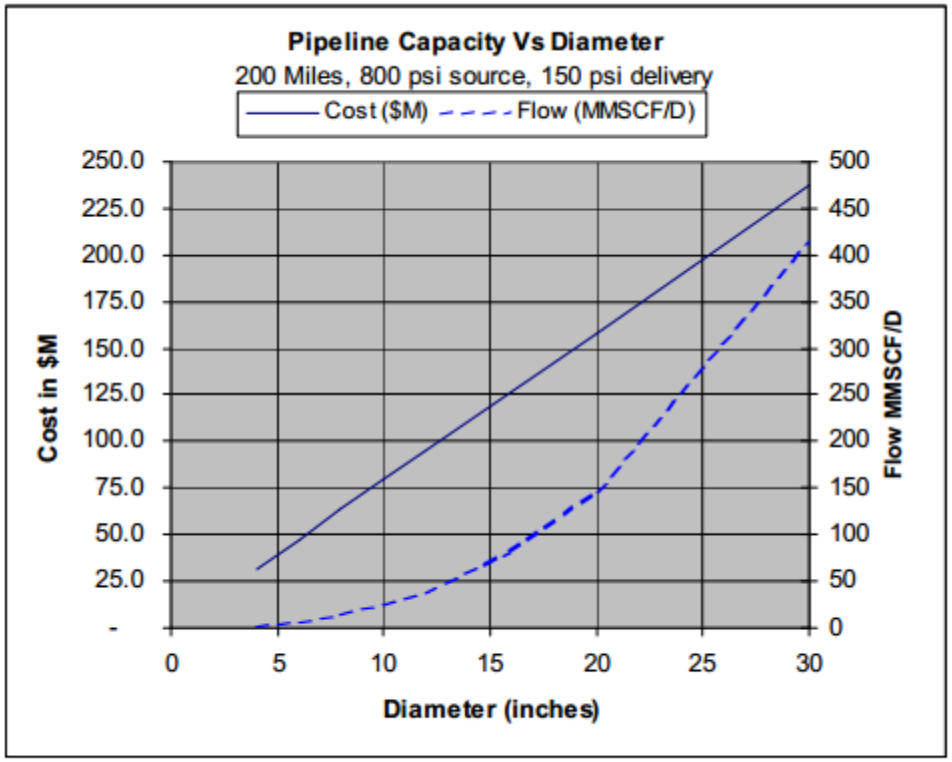
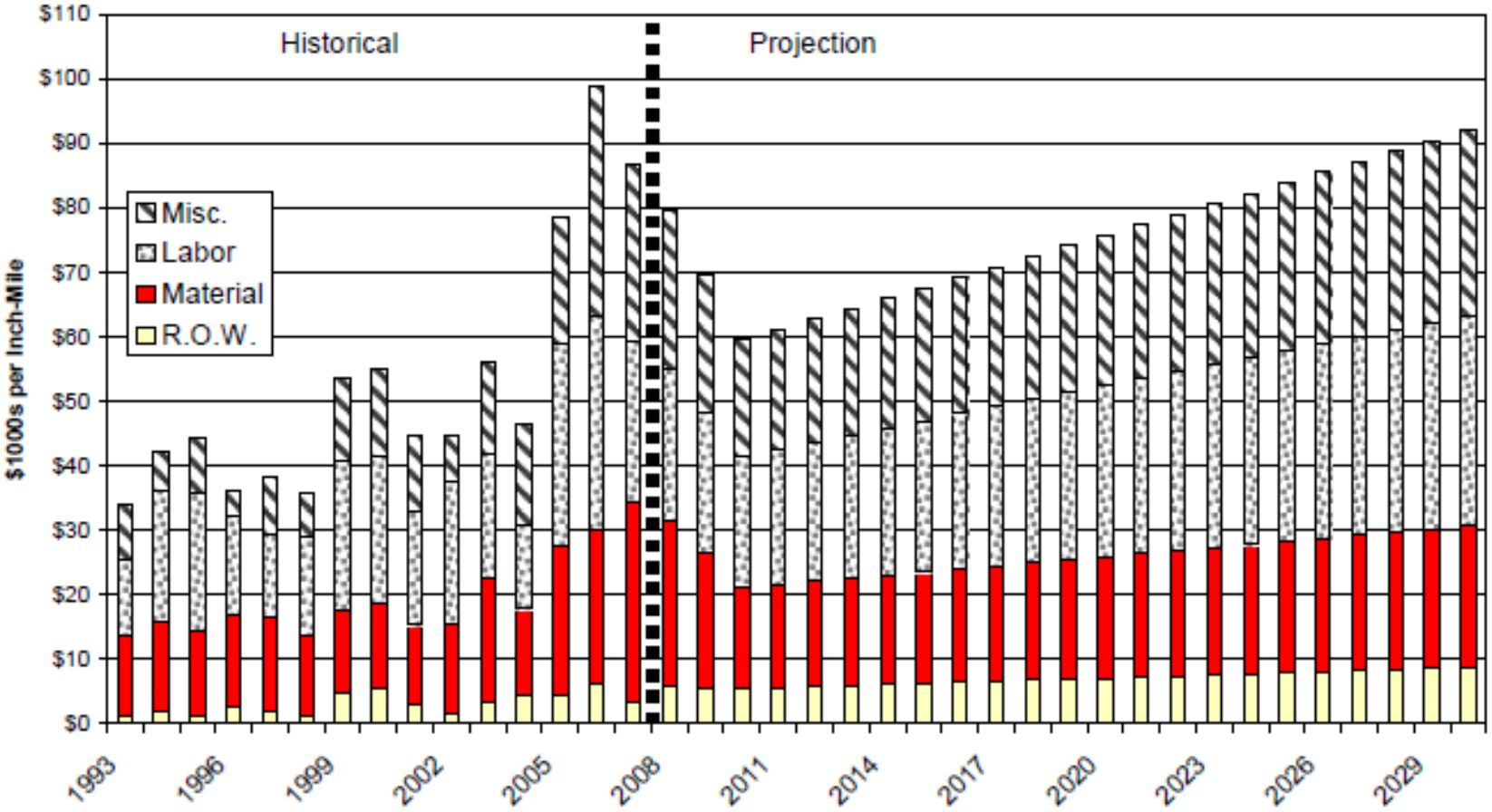


Figure 1 – Pipeline Capacity as a Function of Pipe Diameter

Source: Gary Choquette, Pipeline Hydraulics, Design, Fuel, and Costs, 2010, Optimized Technical Solutions, LLC

Natural Gas Pipeline Costs ($1000 per inch-mile)



Source: Natural Gas Pipeline and Storage Infrastructure Projections Through 2030, The INGAA Foundation, Inc, Washington DC, 2009

Transport Infrastructure cost projections 2050

		Infrastructure (thousands of units, to the left)		Expenditures (billion USD)	
		4DS	2DS	4DS	2DS
OECD	Road (paved lane-km)	3 300	-500	29 600	24 100
	BRT (trunk-km)	0.26	2.4	27	84
	Rail (track-km)	136	210	4 100	4 600
	HSR (track-km)	11	34	580	1 300
	Parking (km^2)	4 700	-6 000	18 900	13 600
	Total	-	-	53 200	43 700
Non-OECD	Road (paved lane-km)	22 000	15 300	45 800	36 700
	BRT (trunk-km)	0.36	21 100	21	322
	Rail (track-km)	198	324	3 700	4 500
	HSR (track-km)	18	83	820	2 800
	Parking (km^2)	39 700	23 600	14 700	10 200
	Total	-	-	65 000	54 500
World	Road (paved lane-km)	25 300	14 800	75 400	61 100
	BRT (trunk-km)	0.62	24.5	48	406
	Rail (track-km)	334	534	7 800	9 300
	HSR (track-km)	29	117	1 400	4 100
	Parking (km^2)	44 400	17 600	33 600	24 000
	Total	-	-	118 200	98 200

Source: International Energy Agency: GLOBAL LAND TRANSPORT INFRASTRUCTURE REQUIREMENTS Estimating road and railway infrastructure capacity and costs to 2050

Recommendations

- National Accounts/Public Sector Accounting (PSA) could provide a useful framework.
- **But** Business account' approach has further advantages:
  - lack of data at national level on maintenance and operation expenditures
  - lack of data at national level on the distinction between fixed and variable expenditures can be bypassed in case accurate data are retrieved;
  - no need for detailed information regarding the purpose of expenditures
  - business reports contain information about aggregated capital costs but expenditures are not disaggregated at the level of these reports.

Thank you for your attention!