Analysis of Regional Differences in Global Rail Projects by Cost, Length and Project stage

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Executive Summary

This paper presents the analysis of an extensive database of global railway infrastructure projects, maintained by International Railway Journal (IRJ). It explores the development of global investment in rail infrastructure, differentiating by region and rail type. Subsequently, current investment in rail is compared with estimates by the International Energy Agency for the investment required to achieve the climate change "Beyond-2-Degree Scenario" (B2DS) of holding the global average temperature increase to well below 2°C and striving for 1.5°C.

The analysis of investments yielded several important insights, such as the following:

- Globally, almost 1500 rail infrastructure projects worth at least $ 2.1 trillion are planned or under construction (not including about $ 80 billion for current rolling stock procurement projects), amounting to a total of 140'000km.
- Out of this, over 500 heavy rail projects account for 57'000km of track under construction (or expansion/renewal) 65'000km of track planned and $ 1.2 trillion of announced investments. The overwhelming share (85%) of both current and future developments falls on low and middle-income countries, particularly in Asia (almost 50%).
- China dominates current track under construction with 37% of all heavy rail, 61% of high-speed, 66% of metro and 21% of light rail track being built there.
- Cost per km of track under construction varies considerably by region, rail type and project status. Interestingly, heavy rail (excl. high-speed) and light rail projects in planning stage on average budget a lower cost per km than those already under construction (globally -50% and -21%, respectively). But the reverse is true for high-speed (+120%) and metro projects (+42%). This tendency can be observed across all regions, although the exact figures vary strongly.

Despite some impressive developments, particularly of high-speed rail in China, the comparison with the IEA's "Beyond-2-Degrees-Scenario" indicates that a massive increase in railway infrastructure investment is needed to achieve this ambitious target. While investments in high-speed and metro networks are already going in the right direction, there appears to be a significant lack of investment for regular heavy rail, particularly commuter rail. The investment gap is especially large for low- and mid-income countries with quickly urbanising societies, which would strongly benefit from high-capacity commuter rail systems to ease congestion and other transport related challenges. Early and strategic planning to integrate commuter rail into public transport systems is advisable, to avoid increasing costs as cities and economies develop.

Introduction

In an era of challenges such as rapid urbanisation and climate change, railways are a very efficient way to transport a large number of people or large amounts of goods. But as countries' and regions' challenges vary, so does their use of railways as a mode of transport. In order to explore these differences, the International Railway Union (UIC) has launched a cooperation with International Railway Journal (IRJ). Analysing IRJ's comprehensive database of rail infrastructure projects allows us to see which countries and regions prioritise rail as part of the solution to their current and future transport challenges.

The analysis focuses on four aspects of railway infrastructure projects: track length, cost, railway type and project status. Rather than providing a detailed analysis of regional transport policies, this data will produce a big picture: which countries invest heavily in rail or not at all? How does their approach differ between national and urban mobility? What can be said on project cost for each region?

These insights matter. Not only does the transportation sector make up a growing share of global CO_2 emissions from fuel combustion (IEA, 2017). Rapid urbanisation in many parts of the world poses great challenges for planning transport of goods and people within and between growing cities. Congested streets and air pollution can have a strongly detrimental effect on the quality of life, especially for city dwellers. Railways are an important part of the solution to these problems. Not only do they emit significantly less CO_2[1] and have a less adverse impact on air quality compared to other modes of transport, they also permit for far more efficient use of the available land (between 10 and 50 times compared to individual road transport, according to the Asian Development Bank and GIZ (2011)).

The results will be an indicator of progress on the expansion of sustainable transport systems in different regions of the world. Results are also compared with three estimates for the required expansion of rail infrastructure in order to limit global warming to two degrees or even to reach the more ambitious "Beyond-two-degree target".

About the IRJ Pro database

This analysis is based entirely on the data on railway infrastructure projects contained in the IRJ Pro database, maintained by International Railway Journal[2] (IRJ). The database is a collection of data on railway projects (infrastructure and rolling stock) around the world in various stages of planning or implementation. As of July 2017, it contained 2044 infrastructure projects and over 1000 rolling stock procurement projects of various sizes and scopes, not counting those marked as 'completed', which are currently not publicly available. For this paper, only infrastructure projects were considered; rolling stock was out of scope. Projects are characterised by a set of parameters, including location, type, project status, length and cost in both local currency and US$.

While the database in general is quite comprehensive – indeed probably the most comprehensive data source on railway infrastructure projects – not all data is available for every project. This depends to a large degree on the projects location and status. Also, while most projects represent newly-built railway

[1] In 2015, railways accounted for 6.3% of global passenger-kilometres and 6.7% of global tonne-kilometres (freight transport), but only 4.2% of CO_2 emissions from transportation (IEA / UIC, 2017). This disparity is set to increase as low-carbon energy makes up an ever-bigger share of the global electricity mix.

[2] The database is available at www.irjpro.com and it offers a free 14-day trial.

lines, some include mere track-doubling of existing lines. The number of track-kilometres built in a project thus does not always equal a line extension of the same length, which would depend on whether a single or double track is built.

Methodology

The present analysis is based on a database of railway track infrastructure projects around the world, assembled and maintained by the International Railway Journal (IRJ). The analysis provides a snapshot of projects worldwide in different stages of planning or completion as of July 2017.

Filtering criteria

In order to analyse the raw data (and to prevent the data from changing as the database continues to be updated), it was imported to Microsoft Excel. Pivot tables were then used to filter and analyse the data (e.g. by continent, project status or track length). After excluding completed projects and those with high uncertainty regarding implementation, as explained below, a total of 1499 projects were analysed. Depending on the analysis, one or several of the following filtering criteria were then applied:

Length and cost

Projects were compared primarily based on track length and indicated project cost. The indicated track length was assumed to be fairly reliable, as the projected route can be easily verified. Project cost, on the other hand proved to be a major source of uncertainty. While 1371 entries contain a figure on track length (not counting excluded project statuses, see above), only 808 contain data on cost. Deliberately leaving these two fields blank allowed IRJ to eliminate a potential source of double counting in cases where subprojects or track sections were listed individually. In other cases, a simple lack of data might have been the reason. Generally, the cost indicated in the database includes all infrastructure-related expenses, including track-building, signalling, stations, bridges & tunnels etc. Some projects seem to factor in rolling stock, although these projects are probably the exception.

When comparing track length and cost per region, projects without indication of costs were included nevertheless at a cost of zero to cover as many projects as possible. **The cost figures calculated below are therefore to be seen as minimum values which would be higher if all data were available** (except cost per km, see below).

Outliers with implausibly high cost figures were verified using publicly available sources and corrected where necessary. Partly for this reason, monorail projects were not considered (10 in total).

Cost per km

This value was derived considering only projects with data for both track length and cost to avoid distortion. The remaining 1150 projects were then further divided to match the other sorting criteria.

Continent/country

Sorting by those two factors allowed to reveal regional differences. Countries were also classified according to their economic development. Thus, for every region there is a subcategory for countries that are not among the 78 “high-income countries” as defined by the World Bank (GNI per capita of $12.236 or more)[3].

[3] This definition includes all African countries, Latin America (excl. Chile and Uruguay), most of Asia (notably China, India, Turkey), Canada and the United States in North America and a few countries in Eastern Europe.

For technical reasons, the “Europe” region covers geographical Europe plus all of Russia. “Asia” also includes Western Asia and the Middle East, including all of Turkey. “North America” covers the USA, Canada, Mexico and the Dominican Republic (as well as other countries for which no projects are listed). “Australasia” covers mostly Australia and New Zealand.

Project type
This analysis considers six of the seven rail types between which the IRJ database distinguishes (monorail is excluded). These are grouped in different ways, depending on the context. Commuter rail is thus both heavy rail and urban rail. Please note that the database differentiates between metro and (other) light rail systems such as tramways. Heavy haul lines are dedicated to freight.

Heavy Rail	**Urban Rail**	**Excluded**
Main Line High-Speed Heavy Haul Commuter Rail	Metro Light Rail Commuter Rail	Monorail

Project phase groups
In order to account for different degrees of certainty of planned projects compared to those already in implementation, the analysis followed a two-tiered approach. Each project was allocated to either the **Planning group** (comprising project statuses planning, preliminary/detailed design, tendering and contract awarded) or the **Implementation group** (under construction or commissioning).
The distinction between the planning and implementation group was made based on an assessment of the confidence regarding a given project’s implementation. A project with awarded contract has incurred an initial investment, but this is a negligible part of the investment volume once construction has started. Assuming that a higher investment volume results in higher commitment, completion has thus become much more likely.
Project statuses “proposed” (274 projects), “feasibility study” (185 projects), “suspended” (80 projects) and “unknown”/blank (6 projects) were not included in any group or other consideration due to the low confidence in their implementation.

Construction start / completion
It would have been interesting to provide a time series of how project volumes developed over the years. However, this proved to be inconclusive due to a strong overrepresentation of current projects (data about past and future projects is less comprehensive).

Data Overview

The following pages present aggregated data according to project phase group, railway type and region. Since China and India more often than not make up an outsized portion of the world’s total, their data is also presented separately (they are both still included in the numbers for Asia though).

Please note that when it comes to cost per km, some figures are based on a very low number of projects. For this reason, the number of projects is mentioned as well. Also, while the IRJ database does include rolling stock procurement projects, these are not represented in the following tables (although some projects seem to include cost for rolling stock).

All Rail (excluding monorail) projects by region and implementation status

Track under construction & commissioning

Region	no. of projects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world
Africa	45	8'002	12%	8'002	12%	64	5%	64	5%
Asia	426	47'474	72%	45'132	68%	951	74%	200	16%
Australasia	8	112	0%	0	0%	12	1%	0	0%
Europe	117	4'473	7%	428	1%	166	13%	7	1%
North America	42	865	1%	128	0%	55	4%	4	0%
South America	26	4'979	8%	4'941	7%	34	3%	32	2%
World (constr.)	**664**	**65'905**	**100%**	**58'632**	**89%**	**1'283**	**100%**	**307**	**24%**
China	*237*			*26'218*	*40%*			*602*	*47%*
India	*57*			*6'191*	*9%*			*46*	*4%*

Track planned (incl. projects in stages of planning, preliminary/detailed design, tendering and awarded contract

Region	no. of projects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world
Africa	84	17'876	24%	17'876	24%	87	10%	87	10%
Asia	451	31'497	42%	26'557	36%	404	47%	276	32%
Australasia	11	1'786	2%	0	0%	27	3%	0	0%
Europe	186	11'261	15%	5'036	7%	229	27%	32	4%
North America	52	1'034	1%	20	0%	65	8%	1	0%
South America	39	10'658	14%	10'649	14%	41	5%	41	5%
World (plan.)	**823**	**74'111**	**100%**	**60'138**	81%	**852**	**100%**	**437**	51%
China	*194*			*7'402*	10%			*174*	*20%*
India	*87*			*6'211*	8%			*41*	*5%*

Heavy Rail excl. High-Speed projects by region and implementation status (main line, commuter rail, heavy haul)

Track under construction & commissioning

Region	no. of pro-jects	Track length (km): Total	Track length (km): % of world	Track length (km): low/mid-income countries	Track length (km): % of world	Min. estimated project cost (bn $): Total	Min. estimated project cost (bn $): % of world	Min. estimated project cost (bn $): low/mid-income countries	Min. estimated project cost (bn $): % of world	no. of projects counted	Cost per km in m$: Total	Cost per km in m$: low/mid-income countries
Africa	25	7'360	21%	7'360	21%	30	8%	30	8%	*16*	7.9	7.9
Asia	75	21'461	61%	20'568	59%	282	72%	185	47%	*60*	14.7	10.1
Australasia	4	58	0%	0	0%	4	1%	0	0%	*2*	322.5	N/A
Europe	28	928	3%	268	1%	50	13%	5	1%	*24*	61.0	19.3
North America	11	338	1%	58	0%	15	4%	2	0%	*6*	44.9	33.4
South America	9	4'757	14%	4'757	14%	9	2%	9	2%	*5*	2.9	2.9
World (constr.)	**152**	**34'902**	**100%**	**33'011**	**95%**	**390**	**100%**	**231**	**59%**	***113***	**14.2**	N/A
China	*20*			*7'599*	*22%*			*95*	*24%*	*20*		*12.5*
India	*21*			*5'587*	*16%*			*22*	*6%*	*14*		*4.6*

Track planned **(incl. projects in stages of planning, preliminary/detailed design, tendering and awarded contract)**

Region	no. of pro-jects	Track length (km): Total	Track length (km): % of world	Track length (km): low/mid-income countries	Track length (km): % of world	Min. estimated project cost (bn $): Total	Min. estimated project cost (bn $): % of world	Min. estimated project cost (bn $): low/mid-income countries	Min. estimated project cost (bn $): % of world	no. of projects counted	Cost per km in m$: Total	Cost per km in m$: low/mid-income countries
Africa	43	16'960	34%	16'960	34%	70	31%	70	31%	*18*	6.0	6.0
Asia	106	19'288	38%	16'091	32%	109	49%	71	32%	*45*	9.4	8.2
Australasia	6	1'730	3%	0	0%	8	4%	0	0%	*1*	4.7	N/A
Europe	46	1'634	3%	968	2%	14	6%	1	0%	*19*	20.2	9.9
North America	10	146	0%	0	0%	3	1%	0	0%	*5*	22.6	N/A
South America	21	10'421	21%	10'421	21%	19	8%	19	8%	*8*	3.1	3.1
World (plan.)	**232**	**50'179**	**100%**	**44'439**	89%	**223**	**100%**	**160**	72%	***96***	**7.0**	N/A
China	*20*			*2'043*	4%			*14*	*6%*	*6*		*13.5*
India	*37*			*4'193*	8%			*4*	*2%*	*14*		*2.1*

High-Speed projects by region and implementation status

Track under construction & commissioning

Region	no. of projects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world	no. of projects	Cost per km in m$ Total	low/mid-income countries
Africa	2	318	1%	318	1%	23.5	7%	23.5	7%	2	74.0	74.0
Asia	46	18'779	85%	17'973	81%	230.0	69%	178.6	54%	36	15.8	12.9
Australasia	0	0	0%	0	0%	0.0	0%	0.0	0%	0	N/A	N/A
Europe	23	2'954	13%	0	0%	77.3	23%	0.0	0%	21	31.4	N/A
North America	2	151	1%	0	0%	2.2	1%	0.0	0%	2	14.5	N/A
South America	0	0	0%	0	0%	0.0	0%	0.0	0%	0	N/A	N/A
World (constr.)	**73**	**22'203**	**100%**	**18'291**	**82%**	**333.1**	**100%**	**202.1**	**61%**	**61**	**19.0**	N/A
China	*29*			*13'442*	*61%*			*168.6*	*51%*	*24*		*13.8*
India	*0*			*0*	*0%*			*0.0*	*0%*	*0*		*n.a.*

Track planned (incl. projects in stages of planning, preliminary/detailed design, tendering and awarded contract)

Region	no. of projects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world	no. of projects	Cost per km in m$ Total	low/mid-income countries
Africa	4	390	3%	390	3%	11.6	4%	11.6	4%	1	57.7	57.7
Asia	26	5'535	37%	4'731	31%	78.6	29%	32.8	12%	11	35.0	22.7
Australasia	0	0	0%	0	0%	0.0	0%	0.0	0%	0	N/A	N/A
Europe	37	8'744	58%	3'750	25%	173.7	64%	25.0	9%	14	47.5	32.5
North America	2	353	2%	0	0%	8.3	3%	0.0	0%	2	23.6	N/A
South America	0	0	0%	0	0%	0.0	0%	0.0	0%	0	N/A	N/A
World (plan.)	**69**	**15'022**	**100%**	**8'871**	**59%**	**272.2**	**100%**	**69.4**	**25%**	**28**	**42.1**	N/A
China	*7*			*1'087*	*7%*			*17.3*	*6%*	*6*		*18.5*
India	*2*			*1'169*	*8%*			*15.5*	*6%*	*1*		*30.7*

Commuter Rail projects by region and implementation status

Track under construction & commissioning

Region	no. of pro-jects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world	no. of pro-jects	Cost per km in m$ Total	low/mid-income countries
Africa	2	75	12%	75	12%	0.9	2%	0.2	0%	2	12.3	12.3
Asia	4	90	15%	90	15%	3.0	7%	3.0	7%	3	60.0	60.0
Australasia	4	58	10%	0	0%	3.8	9%	0.0	0%	2	322.5	N/A
Europe	8	199	33%	0	0%	30.0	71%	0.0	0%	7	150.7	N/A
North America	3	131	22%	0	0%	1.9	4%	0.0	0%	3	14.3	N/A
South America	2	49	8%	49	8%	2.9	7%	2.9	7%	1	77.0	77.0
World (constr.)	**23**	**602**	**100%**	**214**	**36%**	**42.4**	**100%**	**6.1**	**14%**	**18**	**90.3**	N/A
China	*1*			*9*	*1%*			*0.4*	*1%*	*1*		*43.3*
India	*0*			*0*	*0%*			*0.0*	*0%*	*0*		*N/A*

Track planned (incl. projects in stages of planning, preliminary/detailed design, tendering and awarded contract)

Region	no. of pro-jects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world	no. of pro-jects	Cost per km in m$ Total	low/mid-income countries
Africa	2	19	4%	19	4%	0.0	0%	0.0	0%	0	N/A	N/A
Asia	7	258	55%	189	40%	10.0	68%	5.0	34%	3	75.8	78.7
Australasia	1	10	2%	0	0%	0.0	0%	0.0	0%	0	N/A	N/A
Europe	10	53	11%	0	0%	1.5	10%	0.0	0%	3	19.9	N/A
North America	5	130	27%	0	0%	2.9	20%	0.0	0%	5	22.6	N/A
South America	1	5	1%	5	1%	0.2	2%	0.2	2%	1	52.6	52.6
World (plan.)	**26**	**474**	**100%**	**212**	**45%**	**14.6**	**100%**	**5.2**	**36%**	**12**	**44.9**	N/A
China	*0*			*0*	*0%*			*0.0*	*0%*	*0*		*N/A*
India	*2*			*47*	*10%*			*0.0*	*0%*	*0*		*N/A*

Metro projects by region and implementation status

Track under construction & commissioning

Region	no. of pro-jects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world	no. of pro-jects	Cost per km in m$ Total	low/mid-income countries
Africa	3	11	0%	11	0%	0.2	0%	0.2	0%	2	35.4	35.4
Asia	269	6'728	91%	6'212	84%	420.0	85%	374.9	76%	175	85.0	81.7
Australasia	1	23	0%	0	0%	6.3	1%	0.0	0%	1	272.3	N/A
Europe	35	350	5%	160	2%	30.9	6%	2.2	0%	26	142.5	56.1
North America	7	111	1%	48	1%	12.6	3%	470.0	95%	6	126.6	13.0
South America	14	192	3%	155	2%	24.5	5%	21.8	4%	13	127.7	140.8
World (constr.)	**329**	**7'415**	**100%**	**6'485**	**87%**	**494.4**	**100%**	**399.5**	**81%**	**223**	**90.3**	N/A
China	*172*			*4'892*	*66%*			*326.3*	*66%*	*119*		*87.2*
India	*35*			*604*	*8%*			*23.7*	*5%*	*21*		*66.0*

Track planned (incl. projects in stages of planning, preliminary/detailed design, tendering and awarded contract)

Region	no. of pro-jects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world	no. of pro-jects	Cost per km in m$ Total	low/mid-income countries
Africa	8	70	1%	70	1%	1.4	0%	1.4	0%	1	110.8	110.8
Asia	268	6'033	90%	5'418	80%	198.5	68%	167.0	58%	68	112.6	110.4
Australasia	2	40	1%	0	0%	17.7	6%	0.0	0%	2	441.4	N/A
Europe	43	319	5%	132	2%	30.9	11%	3.1	1%	20	123.3	64.8
North America	7	134	2%	20	0%	20.5	7%	0.9	0%	7	152.8	42.5
South America	11	136	2%	136	2%	20.9	7%	20.9	7%	3	366.7	366.7
World (plan.)	**339**	**6'732**	**100%**	**5'776**	**86%**	**289.9**	**100%**	**193.3**	**67%**	**101**	**128.5**	N/A
China	*146*			*4'059*	*60%*			*140.4*	*48%*	*39*		*126.3*
India	*48*			*849*	*13%*			*21.4*	*7%*	*18*		*65.9*

Light Rail projects by region and implementation status

Track under construction & commissioning

Region	no. of projects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world	no. of projects	Cost per km in m$ Total	low/mid-income countries
Africa	15	313	23%	313	22.6%	10.1	16%	10.1	15.6%	8	70.6	70.6
Asia	36	506	37%	380	27.4%	18.5	29%	12.3	19.0%	16	69.7	73.5
Australasia	3	31	2%	0	0.0%	2.4	4%	0.0	0.0%	3	75.5	N/A
Europe	31	240	17%	0	0.0%	8.1	13%	0.0	0.0%	29	33.9	N/A
North America	22	265	19%	23	1.6%	25.2	39%	1.4	2.2%	21	99.7	63.9
South America	3	30	2%	30	2.1%	0.5	1%	0.5	0.8%	3	18.5	18.5
World (constr.)	**110**	**1'386**	**100%**	**745**	**53.8%**	**64.8**	**100%**	**24.4**	**37.7%**	**80**	**67.4**	N/A
China	*16*			*286*	*21%*			*11.4*	*18%*	*8*		*88.8*
India	*0*			*0*	*0%*			*0.0*	*0%*	*0*		*N/A*

Track planned (incl. projects in stages of planning, preliminary/detailed design, tendering and awarded contract)

Region	no. of projects	Track length (km) Total	% of world	low/mid-income countries	% of world	Min. estimated project cost (bn $) Total	% of world	low/mid-income countries	% of world	no. of projects	Cost per km in m$ Total	low/mid-income countries
Africa	29	456	21%	456	21%	4.1	6%	4.1	6%	2	21.0	21.0
Asia	51	641	29%	317	15%	18.2	27%	4.8	7%	13	65.6	33.7
Australasia	3	16	1%	0	0%	1.1	2%	0.0	0%	2	71.9	N/A
Europe	60	564	26%	187	9%	9.7	14%	3.3	5%	28	25.8	44.2
North America	33	401	18%	0	0%	32.9	49%	0.0	0%	30	89.1	N/A
South America	7	102	5%	93	4%	1.5	2%	1.3	2%	5	18.1	17.3
World (plan.)	**183**	**2'179**	**100%**	**1'052**	**48%**	**67.4**	**100%**	**13.5**	**20%**	**80**	**53.5**	N/A
China	*21*			*213*	*10%*			*2.8*	*4%*	*4*		*26.1*
India	*0*			*0*	*0%*			*0*	*0%*	*0*		*N/A*

Analysis: Key Insights

The following analysis compares shares of region's track kilometres and investments compared to the global total. Please note that the cost figures in general include all costs associated with building a railway line (i.e. including signalling, stations, tunnels etc., see methodology). Australasia (i.e. Australia & New Zealand) with their small population and even smaller amount of railway projects are not analysed separately.

Global observations on infrastructure projects

- **Globally, almost 1500 rail infrastructure projects worth at least $ 2.1 trillion are planned or under construction, amounting to a total of 140'000km**[4] (not including project status proposed, suspended and feasibility study). In comparison, the length of the global railway network was 1.05 million km in 2015 according to the World Bank (2017). Rolling stock procurement projects amount to an additional ca. $ 80 billion, but were not separately analysed.
- With $784bn worth of projects worldwide planned or under construction, **metro systems, although more expensive, attract the highest investments of any urban rail mode.** While there is over 7400km of metro track under construction, it is only 1800km for commuter rail and 1400km for light rail. Metro track is 2/3 more expensive than light rail track globally ($100m/km compared to about $60m/km, counting both track planned and under construction), although there are regional variations.
- **There are 57'000km of heavy rail track under construction (or expansion/renewal), with an additional 65'000km planned**. **The overwhelming share of both current and future developments falls on low and middle-income countries.** Looking at project cost, the difference is less pronounced, though still very clearly visible from the data. Light rail marks an exception, with only 50% being developed in low-/mid-income countries.
- Not surprisingly, **projects in high-income regions have considerably higher cost** per kilometre than in less developed countries. For instance, heavy rail (excl. HS) costs on average four times more per km in high-income Europe than in low-/mid-income Europe and eight times more than in low-/mid-income Asia.
- While the projects for regular heavy rail and light rail in planning stage on average budget a lower cost per km than those already under construction (globally -50% and -21%, respectively), the reverse is true for high-speed (+120%) and metro projects (+42%). This tendency can be observed across all regions, although the exact figures vary considerably. The reasons behind this insight remain unclear and warrant further investigation.

Asia is currently the main stage for railway development, with China being by far the biggest player

- **For most rail types, Asia accounts for 60-90% of worldwide track being under construction and project budget. The only** exception is light rail, where Asia makes up only a third of track and investment.
- **China dominates current track under construction** with 22% of all heavy rail, 61% of high-speed, 66% of metro and 21% of light rail track being built there.

[4] Numbers for investment and track kilometres do not include projects for which this figure was not available.

- When looking at track planned, Asia is not quite as dominant. Here, Asia's share of high-speed and heavy rail track in general drops to 37% and 38% respectively. With surging urban development, however 30% of planned light rail track and 90% of planned metro track are in Asia.
- **Very notable is also the minor role China seems to play in future heavy rail developments** with only 5% of the world's track planned there. Growing saturation for large railway projects might be one reason behind this observation. Still, China's project lead times have been very short in the past, since projects can get off the drawing board much faster than elsewhere. Regardless, 60% of all planned metro track globally is in Chinese cities.
- Other notable Asian players are India (16% of the world's heavy rail track under construction, excl. high-speed) and Turkey (9% of the world's high-speed track under construction).

Africa's priority is freight lines

- Africa has the second highest amount of heavy rail track under construction (13%). While the project portfolio consists mostly of mainline projects for mixed traffic, freight transport is a significant driver. This is further supported by Africa's big share of planned heavy haul track (56%).
- When it comes to urban development, **Africa invests more heavily in light rail** (more than 20% of the world's total track) **than metros** (around 1% or less), both when it comes to track under construction and track planned.

Europe is an active market, particularly for high-speed rail

- While shares of track under construction are relatively small (6.8% for all rail types), Europe seems to still have big plans for high-speed and light rail development (58% and 26%, respectively, of track planned worldwide in the respective categories).
- The cost of heavy rail (excl. High-Speed) per km is four times higher in rich European countries ($81m/km) compared to low-/mid-income ones ($19m/km). Compared to the Asian average ($14.7m/km), the difference is equally striking. There is a much smaller cost difference for high-speed projects under construction, which are 65% above the world average. These differences might be explained with the increased cost of land acquisition, but also higher regulatory requirements (e.g. health and safety as well as environmental protection).
- On the other hand, light rail developments cost about half the world's average in Europe. Considering Europeans' large experience in building light rail lines, this observation becomes less of a surprise. Also, Europe is probably a more competitive market for light rail with European suppliers competing keenly for light rail orders, thereby reducing costs.

North America remains a minor market in the foreseeable future

- **There is little sign of any significant expansion in rail activity in North America, where rail freight currently has a notably high market share whilst passenger transport is very low (UIC-IEA 2017).** Both projects planned and under construction amount to barely 2'000km of track over all rail types, notably this includes the first ever high-speed line in the Americas.
- The exceptionally high costs per kilometre for light rail in North America is striking (35% higher than in Asia and over triple the cost in Europe). Unlike other outliers in the data, it is based on a relatively high number of projects (8 in Canada and 22 in the United States). A larger scope of communicated investment costs in North America (e.g. including rolling stock) as well as federal requirements for local sourcing could explain part of this difference. Also, new light rail lines in North America tend to be built with heavy infrastructure - elevated sections, tunnels or grade

separation at road intersections are common features. Elsewhere in the world street running is more common.

South America is set to strengthen heavy rail

- **Although current heavy rail projects are few (8% of the world's total), that share is set to increase strongly with 16% of globally planned track kilometres.**
- Heavy haul makes up a significant portion, both of current and future railway developments.
- **In urban settings, however, rail continues to play a very minor role.** Rail-based urban transport modes all remain below 5% of the world's track planned/under construction in the respective categories. Cost certainly helps to explain this observation: at 128m$ per km, cost for metro under construction is on par with high-income regions, unlike construction cost for heavy rail (see below). Also, some Latin American countries have previously invested in bus rapid transit systems (BRT; see Replogle & Fulton, 2014, for more details). Compared to urban rail systems, however, BRT is less well suited to transport large amounts of passengers with the minimal space and energy requirements necessary for densely populated environments.
- Interestingly, **track cost per kilometre is several factors smaller in South America** than even in other low or middle-income regions. This could be due to low land acquisition costs in many of the areas where new mainline railways are under construction or planned.

The analysis in the context of climate goals

A key reason for expanding railway infrastructure is reducing CO_2 emissions from transport. In a 2016 working paper, the World Resources Institute compared estimates by different institutions for rail infrastructure investment over the next several decades. Two estimates, by the International Energy Agency (IEA, 2013) and ITDP/UC Davis (Replogle & Fulton, 2014), explicitly estimated the investment in rail infrastructure (freight and passenger) needed to limit global warming to two degrees (the 2-degree-scenario or 2DS). A more recent report, again by the IEA, provides rougher estimates, but for achieving warming of considerably less than two degrees (the beyond-2-degree-scenario or B2DS), according to the Paris Climate Agreement (IEA, 2017).

Comparison for heavy rail (IEA 2DS-estimates, 2013)

The IEA for instance reckoned that in order to achieve the 2DS, global rail investment and expenditure should increase by 20% over investment requirements for the 4DS, to nearly $6.9 trillion (CAPEX only) plus another $ 3.8 trillion for High-Speed investments until 2050. Also, the global railway network would have to reach about 1.25 million track kilometres by 2030[5] (1.5 million by 2050), plus about 65'000km for high-speed rail (130'000km by 2050).

The IRJ database shows that the world is on track to achieving the requirements for High-Speed. In 2015, almost 30'000km of high-speed lines were already operational (UIC, 2017) with another 37'000km planned or under construction (not including proposed lines), already about 50% of the IEA's projection until 2050. Currently announced high-speed investment until ca. 2030 stands at $ 600bn.

[5] The 2030 timeframe was chosen because most projects in the IRJ database are set to be completed until then. While not all those projects are guaranteed to complete in time or at all, some projects to be completed before 2030 may also not have been announced yet.

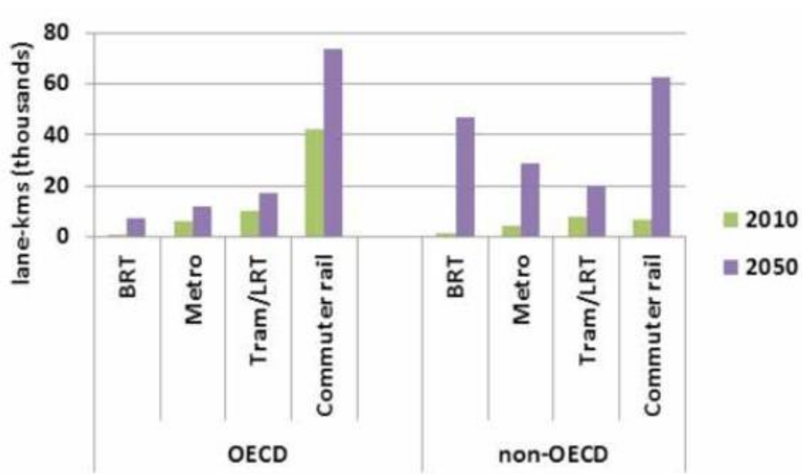
Regular heavy rail, however, might still fall short of the 2DS requirements. From a starting point of 1.051 million km in 2015 (World Bank, 2017), currently only about 85’000km are planned or under construction (this might include an unknown number of track-km to be upgraded). And while it is expected that more heavy rail projects with completion due before 2030 will be announced, they would still need to plug a gap of about 114’000km to satisfy the IEA’s 2DS.

	Time horizon	Heavy Rail	High-Speed
Current projects planned or under construction according to IRJ database (including existing track in 2015)	2030 (ca.)	1.136 million km $613 bn investment	67’000 km $605 bn investment
IEA projections (2-degree-scenario)	2030	1.25 million km	65’000km
	2050	1.5 million km $ 6900 bn investment	130’000km $ 3000 bn investment

Comparison for Urban Rail (ITDP/UC Davis estimates, 2014)

A different estimate covering investment in urban rail infrastructure was produced by ITDP/UC Davis for both OECD and non-OECD countries (Replogle & Fulton, 2014). The authors point out the high growth required to achieve a High Shift scenario[6], especially in non-OECD countries. While, in terms of line kilometres, metro and light rail developments seem to be roughly on track especially in low-/mid-income countries, the gap for commuter rail is striking. Based on the ITDP’s estimates, a massive investment surge to expand commuter rail networks would be necessary to reach their High Shift scenario.

Urban Rail infrastructure requirements by 2050



Urban Rail infrastructure planned or under construction (2017)

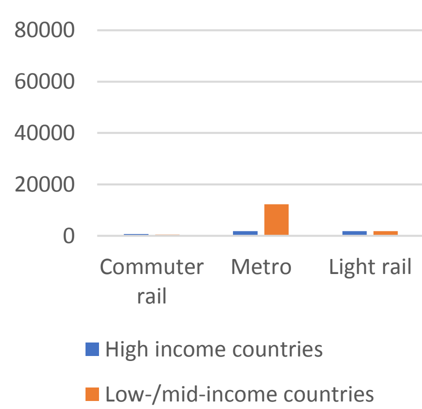


Figure 1. Urban rail infrastructure requirements by 2050 to reach the ITDP's High Shift scenario (left) and urban rail infrastructure currently planned or under construction according to the IRJ database (right). Developments between 2010 and 2017 are not included.

[6] Although not the exactly same, the HS-scenario is considered here as an equivalent to the 2DS.

Comparison for all Rail (IEA B2DS-estimates, 2017)

The IEA's 2017 edition of "Energy Technology Perspectives" provides less detail on the investment requirements for rail compared to the 2013 report mentioned above. But it also includes investment estimates until 2060 to limit global warming below two degrees (Beyond-2-degrees scenario or B2DS). This higher ambition requires a much more pronounced modal shift and hence also higher investment in rail infrastructure. According to the IEA, a significant shift from aviation to high-speed rail is essential for achieving the B2DS, particularly in areas with high population densities where HSR can best play its strengths. This would mean an 11-fold increase in high-speed passenger-kilometres (pkm) compared to today's ca. 600bn pkm (IEA / UIC, 2017).

Requirements for global investment in rail infrastructure in a B2DS are again about two thirds higher than in the 2DS scenario, a cumulated $ 115 trillion higher until 2060 than in the reference scenario. This requirement dwarfs the currently announced investments of $ 2.1 trillion[7]. The IEA estimates that currently expected investments would need to triple. Expanding and maintaining metro and intercity networks would make up the lion's share of this sum, while investment requirements in High-Speed would be about one order of magnitude lower.

$ 115 trn of additional investment is a formidable sum, even if the IEA reckons it to be overcompensated by reduced spending in roads and parking as well as fuel savings. Nevertheless, current investment in rail is nowhere near the requirements for a B2DS, although the exact shortcoming is hard to numeralise based on the information currently available through the IRJ database.

Rail infrastructure expanding, but much more investment needed to reach climate goals

Comparison of the findings drawn from the analysis of the IRJ database with IEA and ITDP estimates indicate that from a global point of view, currently expected investment in rail is insufficient to reach current climate goals. The data also suggests, that some types of rail need particular boosting: While announced investments in high-speed and metro systems are already quite high (together about 80% of total rail investment), the analysis presented here suggests a substantial deficit for investment in regular rail, particularly commuter rail. Today, commuter rail projects are few and concentrated in Europe, where coverage is already relatively good. While Asia instead strongly invests in metro systems, the two other low- and mid-income regions lag behind in terms of urban rail investments (2.9% of the world's total for South America and 4.3% for Africa).

North America deserves particular attention as well. The region sees little track being constructed, despite very high CO_2 emissions from transport, for instance in the USA (IEA/UIC 2017). A large-scale modal shift towards rail appears unlikely in the near future (according to projects planned). Certainly, rail networks in North America are already quite extensive, but they appear not currently adequate (or adequately used) for passenger transport.

In short, while Europe and Asia may well be on their way to reach the amount of rail needed for a low-carbon transport system (if not yet for a B2DS), other regions need more investment in rail or develop low-carbon alternatives.

[7] The IEA estimate appears to include maintenance cost, which is not included in the $ 2.1 trillion.

Limitations of the analysis

- Where individual project entries actually represent different phases of a bigger project, length and cost are usually either mentioned for one subproject, which then represents the length and cost of the entire project, or split up over the subprojects. Since there is no single way on how this was handled, this has led to double counting in a few instances.
- A (relatively small) number of projects merely include the upgrade of an existing railway line (e.g. track-doubling, electrification), without adding any length to the railway network. This was not accounted for. Hence, the terms "line-kilometre" and "track-kilometre" are used interchangeably, usually meaning the length of a line.
- The "planning" project status, comprising 649 projects, is not clearly defined. It generally serves as a catch-all for projects with unknown planning status. Since this stage makes up 50% of all projects that are not yet being implemented ("planning group" as defined before) and 27% of all projects in the database, the "planning" project status was still included in the analysis. In an attempt to compensate for the uncertainty, projects with little available data were excluded for some analyses, such as cost per km.
- While most projects' cost figures seem to include only the cost of track building and related infrastructure, some also include rolling stock. This increases the projects total cost, thereby skewing the final result.
- The available data focuses on projects in the present and near future, which does not allow reliable time series (e.g. on how investment for high-speed rail developed over time).

Topics for further study

Financing

Although the IRJ database contains a few comments on how projects are financed, financing is not systematically analysed. For instance, 29 Public-Private Partnerships (PPP) were identified, 20 of which are for light rail and metro. A more systematic approach would allow tracing the current investment flows which in turn might lead to insights regarding the effectiveness of different financing methods.

Comparability

A number of other reports and analyses cover similar topics, such as the IEA's "Global land transport infrastructure requirements" (2013) or the "World Rail Market study" by Roland Berger Strategy Consultants (2014). Validation of results is difficult, however, due to differing assumptions and scopes, resulting sometimes in considerable variation. For this reason, no systematic comparison with other analyses has been conducted for this paper.

Conclusion: Significant, but unevenly distributed investment in rail infrastructure

The investments in rail infrastructure that are currently under way (worth $ 1.28 trillion) and already being planned (worth $ 850 bn) are significant. High-speed rail continues to be rapidly developed, particularly in Asia and Europe, and attracts both lots of attention and potential investment (global project value: $605 bn). At the same time, projects for regular heavy rail may often be less glamorous, but they have equally high investment needs (global project value: $613 bn). The numbers for metro systems are even higher (global project value: $784 bn), driven by rapid urbanisation in many parts of the world, and the need for high-capacity inner-city transport.

Overall however, these numbers are very likely far below the investment required to achieve the modal shift necessary to limit global warming to well below two degrees. Some experts argue that more investment should flow into heavy rail, especially commuter rail, which currently seems neglected: projects in the IRJ database amount to barely over 1000km in total and merely $57 bn in project value. At the same time, commuter rail could be an important tool to cope with both rapid urbanisation and climate change, providing high-capacity transit from suburbs to city centres, while minimising land use and energy consumption.

Looking at track-kilometres currently under construction/renewal, most activity is concentrated in Asia (72% of all track), although Africa and South America already make up 20% of the global total. However, planned track in Africa and South America is twice the length of the track currently being built in these regions, meaning that activity can be expected to pick up, although some plans might yet prove to be too ambitious for implementation. North America, on the other hand, continues to show very low activity for most rail types. Considering the high share of CO_2 emissions from transportation (35.1% of all emissions from fuel combustion in the USA), North America is in dire need for low-carbon transportation. And while rail freight is well-positioned in the region, rail passenger transport has a modal share of negligible 0.1% (IEA/UIC, 2017).

Finally, the analysis of the IRJ database has yielded some important insights on the cost of rail infrastructure projects. The correlation between a country's economic development and the cost of its railway infrastructure projects comes as no surprise. But there seems to be no easy answer to the question, why high-speed and metro projects currently in the planning stage budget significantly higher cost than those already being implemented. Considering that the reverse is true for regular heavy and light rail and that these observations can be made worldwide, this may warrant further investigation.

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References

Asian Development Bank, GiZ. (2011). *Changing Course in Urban Transport - an illustrated guide.* Manila: Asian Development Bank. Retrieved from https://www.adb.org/sites/default/files/publication/29352/changing-course-urban-transport-illustrated-guide.pdf

IEA / UIC. (2017). *Railway Handbook 2017.* Paris: UIC.

IEA. (2013). *Global land transport infrastructure requirements.* Paris: International Energy Agency.

IEA. (2017). *Energy Technology Perspectives 2017 - Catalysing Energy Technology Transformations.* Paris: International Energy Agency.

Replogle, M., & Fulton, L. (2014). *A Global High Shift Scenario: Impacts And Potential For More Public Transport, Walking, And Cycling With Lower Car Use.* Davis: Institute for Transportation and Development Policy, University of California Davis.

Roland Berger. (2014). *World Rail Market study.* Brussels: UNIFE - The European Rail Industry.

UIC. (2017). *High Speed.* Retrieved October 10, 2017, from UIC Homepage: http://uic.org/highspeed

World Bank. (2017). *Rail lines (total route-km)*. Retrieved October 10, 2017, from World Bank Data: https://data.worldbank.org/indicator/IS.RRS.TOTL.KM

WRI. (2016). *The Trillion Dollar Question II: Tracking Investment Needs In Transport.* Washington DC: World Resources Institute.