SA-TIED

Southern Africa – Towards Inclusive Economic Development

REPORT

A high-level long-term plan for the sequenced, phased, and feasibility-based development of a modern standard gauge national rail backbone in South Africa with connectivity to passenger and freight terminals

Jacob L. van der Merwe

April 2022

UNITED NATIONS UNIVERSITY UNU-WIDER
national treasury Department: National Treasury REPUBLIC OF SOUTH AFRICA
INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE IFPRI
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Abstract: The low rail market share for general freight and passenger transport along South Africa's long corridors negatively impacts the cost of logistics, restricts economic growth, and underutilizes rail capacity. Opportunities exist to technically improve capacity utilization of the existing narrow Cape gauge rail network and then attract lapsed and new rail customers. Access to rail-dominant market spaces depends on rail's ability to run long, heavy, trains, that exploit rail's genetic technologies. The wider standard gauge, with a lower centre of gravity than Cape gauge, allows for safe operation of heavy mineral and coal trains using high-side wagons, double-stack container trains and high-speed passenger trains. This report recommends a combination of continuous and breakthrough improvements on the existing narrow gauge rail network, together with construction of selected new standard gauge routes, to satisfy 2050 demand for freight and passenger transport by rail.

Key words: rail, modernization, reform, gauge, capacity, market spaces, improvement

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About the project

Southern Africa –Towards Inclusive Economic Development (SA-TIED)

SA-TIED is a unique collaboration between local and international research institutes and the government of South Africa. Its primary goal is to improve the interface between research and policy by producing cutting-edge research for inclusive growth and economic transformation in the southern African region. It is hoped that the SA-TIED programme will lead to greater institutional and individual capacities, improve database management and data analysis, and provide research outputs that assist in the formulation of evidence-based economic policy.

The collaboration is between the United Nations University World Institute for Development Economics Research (UNU-WIDER), the National Treasury of South Africa, the International Food Policy Research Institute (IFPRI), the Department of Monitoring, Planning, and Evaluation, the Department of Trade and Industry, South African Revenue Services, Trade and Industrial Policy Strategies, and other universities and institutes. It is funded by the National Treasury of South Africa, the Department of Trade and Industry of South Africa, the Delegation of the European Union to South Africa, IFPRI, and UNU-WIDER through the Institute's contributions from Finland, Sweden, and the United Kingdom to its research programme.

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Executive summary

A Terms of reference

The terms of reference (TOR) call for the 'development of a modern standard gauge national rail backbone strategy for South Africa' with four output deliverables, *viz.*:

- O1: '*High-level long-term plan* for the sequenced, phased and feasibility-based development of a modern standard gauge national rail backbone, built on the principles of open access, multiple concessions, private sector investment, and connectivity to passenger and freight terminals.'

- O2: '*Geographic overview* of how this could be achieved over time as well as a high-level assessment of what could be done first and subsequent sequencing.'

- O3: '*Route prioritization criteria* that should be applied for the incremental development of the modernized rail backbone, including the economic benefits and financial feasibility of the investments, in the context of the limited ability of the Fiscus and SOEs to provide the required funding.'

- O4: '*Recommendations* regarding institutional roles and responsibilities for the further development of this plan and the coordination of its implementation.'

The Department of Transport's 'National Rail Policy Draft White Paper: First draft June 2017' and the GAIN 2050 Freight Demand Model (published in 2021) are key inputs to the study.

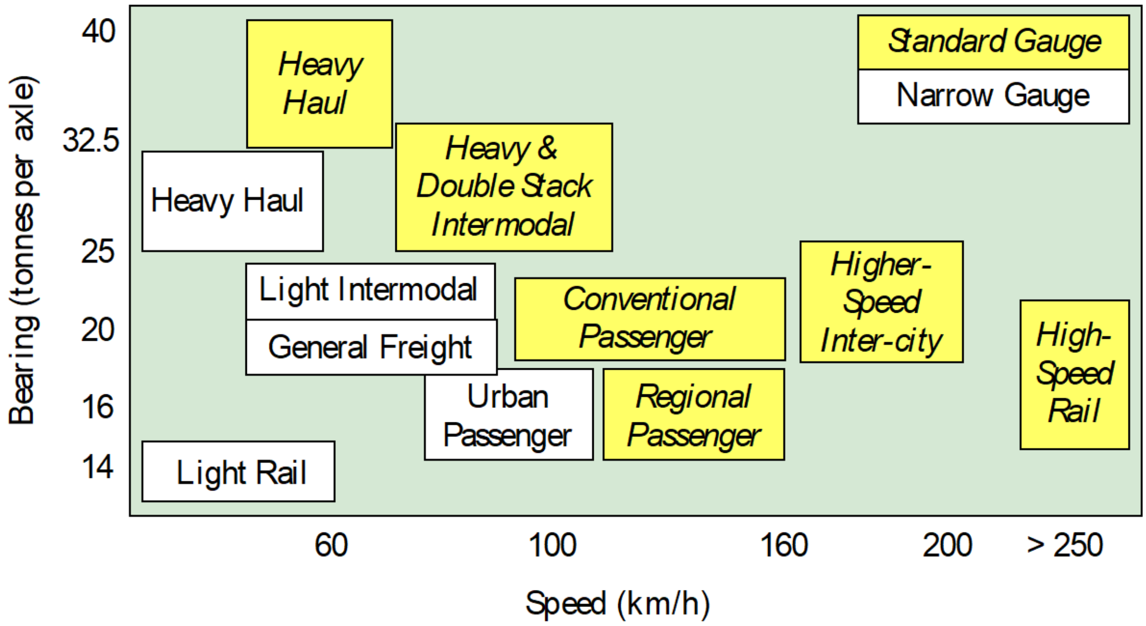
B Key tenets to the study

The research outcomes are systemically anchored in the following tenets: i) rail genetic technologies (RGT); ii) economies of density; iii) rail capacity; iv) S-curves; and v) rail access principles.

Rail genetic technologies (RGT)

The successful exploitation of rail genetic technologies (RGT) (Figure 1) lies at the heart of a breakthrough improvement in the performance of traditional railway systems. Competitive and sustainable rail market spaces are identified that exploits rail's ability to run long, heavy, and fast trains each based on a rail genetic technology: i) '**Bearing** (the ability to carry heavy axle load); ii) **Guiding** (the ability to run at high speed); and iii) **Coupling** (the ability to couple vehicles together to achieve capacity).' Together, bearing and guiding support the heavy intermodal market space for transportation of domestic bulk mineral containers (BMCs) and double stack ISO-compliant shipping containers. Coupling leverages all three market spaces to provide requisite capacity at very low energy consumption and endows urban rail with its strength of high capacity for mass transit. The successful exploitation of rail genetic technologies must be seen a hygiene factor for the design of any new railway system.

Figure 1: Competitive rail market spaces based on rail's genetic technologies



Source: author's elaboration.

Economies of density

'Railways reveal constant returns to scale but increasing returns to density.'[2] In 2018 the Author and Roland Berger verified with a global survey based on a number of data sources that economically sustainable freight rail corridors achieve the lowest practical operating cost when the corridor traffic density exceeds 8.8 million tonne-km per route-km (Van der Merwe et al. 2017). Note that South Africa is borderline self-funded, arguably to the positive impact of the low-cost high-density heavy-haul ore and coal export lines offsets the loss-making low-density corridors. Taken together, it is fair to claim then that a corridor with an operating ratio (O/R) of 100 per cent typically costs US$0.001 per net tonne-km to operate, which operating cost requires in the order of 8 million tonne-km per available route-km. Once any corridor O/R approaches 75 per cent, there should be enough profit to secure capital funding for the corridor. The implication therefore is that we need to densify freight corridors to exceed 10 million tonne-km per route-km to attract (private sector) capital.

Rail capacity

There are various types of capacity associated with a railway system: i) *Theoretical capacity*, a purely mathematical calculation, is greatly affected by infrastructure (number of tracks, signals, etc.), track features (speed of trains, heterogeneity, etc.), and operating requirements (commercial stops, maximum trip time, etc.); ii) *Practical capacity*, which represents the practical limit of running trains reliably, usually between 60 and 75 per cent; iii) *Used capacity*, which is the actual level of traffic on a network that is normally less than the practical capacity; and iv) *Available capacity*, which is the difference between the practical and used capacities (Abril et al. 2008).

[2] This was coined by Graham et al. (2003) for passenger rail and corroborates seminal research by Robert Harris (1977) for freight rail.

S-curves

For both passenger and freight rail the existing capacity model can be exploited through a combination of continuous improvement ('completing puzzles'), breakthrough improvement ('addressing problems'), and selective idealized design ('dealing with messes'). Change is effected on a small scale through continuous improvement (CI), this extending the life of the current business 'S-curve'. Once diminishing returns are reached, railroads should achieve breakthrough improvement (the 'next S-curve') by implementing new technologies, which 'next S-curve' then becomes subjected to CI. For totally new systems, an idealized design is used to innovate, which then creates a 'new S-curve', essentially displacing all previous S-curves on a clean-slate basis.

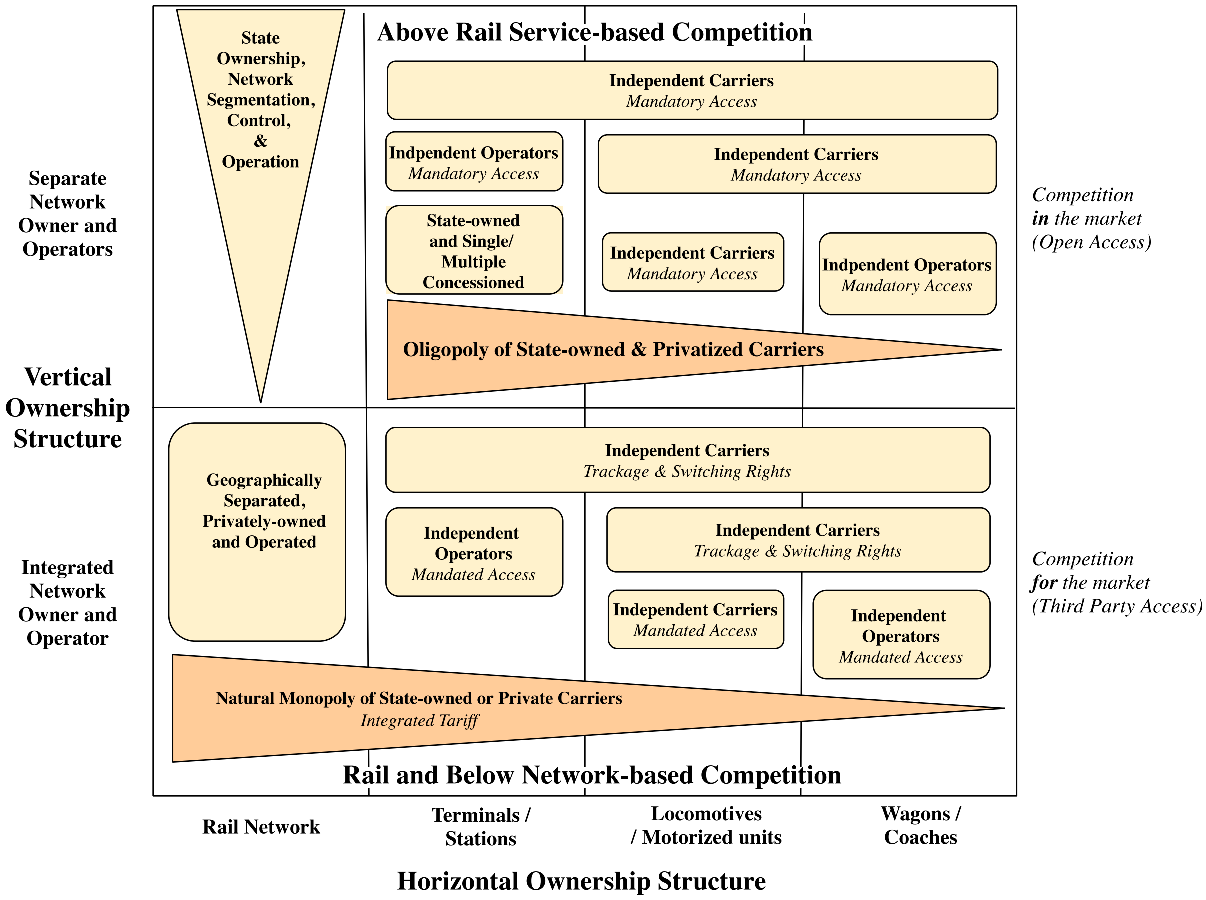
Prospering railroads seek breakthrough improvements (that often result in a redesign using a new breakthrough technology) to exploit these RGTs. Once implemented, a period of continuous improvement follows until they reach diminishing returns, whereupon the rail sector will once again be faced with the option to either accept the system is 'as good as it gets' or implement a new breakthrough improvement. Save from taking the best from RGT in diminishing returns, a new design looks into the future with a clean slate. Since there is no 'ideal design' we plan for an 'idealized design' that will be subjected to continuous improvement as its predecessor was.

Rail access principles

State-owned railways enjoy either *de jure* or *de facto* monopoly status, typically characterized as a vertically and horizontally integrated monolithic entity, *viz*. South African transport services prior to the establishment of Transnet and the SARCC in 1990. Total liberalization of rail eventually results in vertical separation between rail-and-below infrastructure managers (IMs) and above rail train operating companies (TOCs), or 'carriers', and specialized 'operators'. Whereas competition *for* the market requires horizontal separation of the network, either into passengers and freight, and/or geographically; competition *in* the market requires competitive access by TOCs to the same network—best facilitated by vertical separation managed by specialized IMs. Horizontal separation tend to result in networked monopolies, typical of the private class 1 freight railroads in the USA and Canada. These horizontally separated and vertically integrated railroads are profitable and attract investment. They allow network-traversing by competing railroads, and government-owned passenger services. Once an integrated railway has achieved Accounting Separation between infrastructure management and train operations, vertical access can be fairly priced, and vertical separation can take place institutionally. Whereas mainland Europe is typical of country-specific oligopolies, the UK is arguably the best example of a free-market railway system with state-owned network rail providing access to 28 private operators.

Figure 2 illustrates the many models to establish competition *for* and *in* markets through ownership, control and operations of all or parts of the network, terminals, locomotives, motorized passenger units, freight wagons and passenger coaches. Network industries, such as high fixed-cost railways, respond to: i) economies of scale that invariably leads to competition *for* the market; and ii) to economies of density, often resulting in competition *in* the market, also known as *open access* in a vertically separated market. In railways, competition *for* the market typically results in *natural monopolies* or *networked monopolies*; and competition *in* the market typically results in *regulated oligopolies* or a *regulated free market*. Market power tends to arise where vertically integrated 'rail-and-below' network providers are also involved with provisions of 'above-rail' train operating services. *Ex ante* regulated *third party access* founded on the essential facilities doctrine of antitrust law mitigates against such market power.

Figure 2: Restructuring options for railways



Source: author's own synthesis.

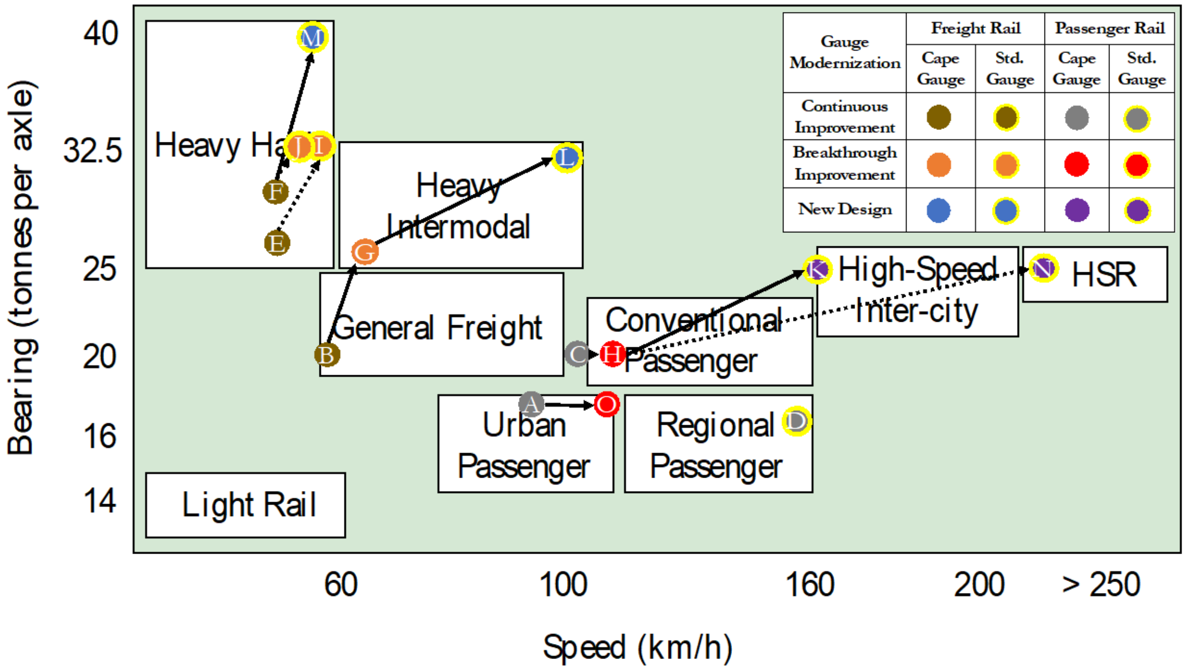
C Research framework

Various resources are used during the research including legislation, domestic and global frameworks and models, as well as a number of stakeholder interviews. The output of this research publication is to be styled as a *SA-TIED Report*. Five research questions are addressed in this study for each of freight and passenger rail in South Africa. They are: 1) What is the existing rail capacity? 2) What is the traffic demand? 3) Is there enough capacity? 4) How can we improve the existing system? 5) When, where, and why do we need a standard gauge railway? The research methodology is anchored in five independent perspectives. Three are quantitative (review of metadata from existing studies, analysis of original data, and benchmarking data) in nature and two are qualitative (stakeholder interviews, and railway reference models) in nature. The research process follows a typical analysis and synthesis process.

D Research outcomes

Figure 3 sums up the modernization strategy that resulted from the research as detailed in this report.

Figure 3: Modernization roadmap for South African rail market spaces



Source: author's elaboration.

Table 1 and Table 2 provide the detail for the modernization roadmap. Figure 4 and Table 3 show the geographic breakdown of the recommended freight rail modernization strategy for South Africa derived from the existing freight flows, the 2050 freight demand model, the performance gap, and available railway engineering opportunities to exploit rail's genetic technologies.

Table 1: Quantified modernization roadmap for South African Passenger rail market spaces

Market Space	Description	From Volumes	To Volumes	Roadmap Vector	Continuous Improvement				Breakthrough Improvement				New Idealized Design			
		TKM; PKM; Mtpa; Mpax pa	TKM; PKM; Mtpa; Mpax pa		OPEX	Time	Rail	Corridor	CAPEX	Time	Rail	Corridor	CAPEX	Time	Rail	Corridor
					Rbn; Level	(years)	IRR	EIRR	Rbn; Level	(years)	IRR	EIRR	Rbn; Level	(years)	IRR	EIRR
Urban Passenger	Metrorail post-COVID Lockdown Rehabilitation	10m Ppa	270m Ppa	A	Low (R1,9bn)	2	2014/15	2014/15								
	120kph Modernization Program	270m Ppa	1bn Ppa	A → O					High (R76,8bn)	10	2023/24	2023/24				
		1bn Ppa	1,1bn Ppa	O	Low	10	2034/35	2034/35								
Regional Passenger	Gautrain Rapid Rail Link Continuous Improvement	14m Ppa	14m Ppa	D	Low	6	2026/27	2026/27								
		14m Ppa	30m Ppa	D									High	10	2049/50	2049/50
		TBD	TBD										High	10	2049/50	2049/50
Conventional Passenger	Shosholoza Meyl post-COVID Lockdown	0,2m Ppa	2,8m Ppa	C	Low	2	2009/10	2009/10								
	Shosholoza Meyl speed & safety improvement (120kph; ATP)	2,8m Ppa	3m Ppa	C → H					Low	2	2014/15	2014/15				
	Shosholoza Meyl CI	3m Ppa	3,3m Ppa	H	Low	3	2014/15	2014/15								
High Speed Inter-City	Shosholoza Meyl 160kph	3,3m Ppa	5m Ppa	H → K									High	10	2049/50	2049/50
	Shosholoza Meyl 160kph CI	5m Ppa	5,5m Ppa	K	Med	10	2049/50	2049/50								
HSR	Gauteng - Tthekwini HSR	3,7m Ppa	3,7m Ppa	H → N									High	10	2049/50	2049/50
				N	High	10	2049/50	2049/50								

Source: author’s analysis.

Table 2: Quantified modernization roadmap for South African freight rail market spaces

Market Space	Description	From Volumes	To Volumes	Roadmap Vector	Continuous Improvement				Breakthrough Improvement				New Idealized Design			
		TKM; PKM; Mtpa; Mpax pa	TKM; PKM; Mtpa; Mpax pa		OPEX Rbn; Level	Time (years)	Rail IRR	Corridor EIRR	CAPEX Rbn; Level	Time (years)	Rail IRR	Corridor EIRR	CAPEX Rbn; Level	Time (years)	Rail IRR	Corridor EIRR
General Freight	Corridor traffic excluding Manganese Exports via Saldanha	14b TKM	28b TKM	B	Low	2 – 3	2019/20	2019/20								
	Domestic Intermodal	nil	8bn TKM	B → G					Med	03-Feb	2019/20	2019/20				
Heavy Inter-modal	Domestic Intermodal	8bn TKM	9bn TKM	G	Low	2 – 3	2019/20	2019/20								
		9bn TKM	14b TKM	G → L									High	> 5	2049/50	2049/50
		14b TKM	16b TKM	L	Low	>10	2049/50	2049/50								
Heavy Haul	Coal Export	72 Mtpa	81 Mpta	E	Low	1 – 2	2010	2010								
		81 Mpta	91 Mtpa	E → I	High	5 – 7	2020	2020								
		91 Mpta	91 Mtpa	I	Low	1	2025	2025								
	Iron Ore Export	60 Mtpa (52bn TKM)	65Mtpa (55bn TKM)	F	Low	1 – 2	2010	2010								
		65Mtpa (55bn TKM)	78Mtpa (67bn TKM)	F → J					Med	2– 3	2025	2025				
		78Mtpa (67bn TKM)	78Mtpa (67bn TKM)	J	Low	1	2025	2025								
		78Mtpa (67bn TKM)	123 Mtpa (76,16b TKM)	J → M									High	5	2049/50	2049/50
		123 Mtpa (76,16b TKM)	123 Mtpa (76,16b TKM)	M									High	5	2049/50	2049/50

Source: author’s analysis.

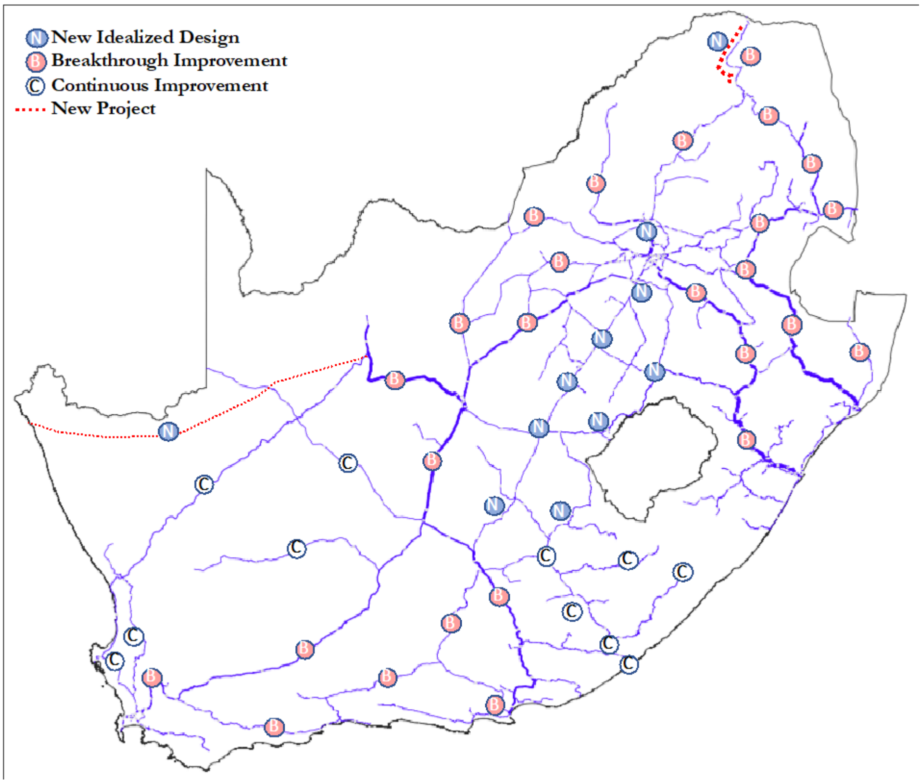
Table 3: Breakdown of the recommended freight rail modernization strategy for freight corridors in South Africa

Existing Freight Corridors Density Projections (NTK million per Route-km)	Density FY 2018	Max. Link Density FDM 2050	Anticipated Gap in Corridor Density 2018 to 2050	Anticipated 2050 Operating Ratio	Anticipated Variance in Density 2018 to 2050	Recommended Modernization Strategy
Mokopane - Mopane EMSEZ line	n/a	57,00	n/a	20%	New Project	New Idealized Design
Sentracor	3,55	34,60	31,05	28%	875%	New Idealized Design
Postmasburg - Boegoebaai Corridor	n/a	21,00	n/a	50%	New Project	New Idealized Design
Freestate	0,25	14,30	14,05	59%	5620%	New Idealized Design
Natalcor	6,26	35,10	28,84	27%	461%	Breakthrough Improvement
Richards Baycor (General Freight)	10,87	37,50	26,63	25%	245%	Breakthrough Improvement
North Westcor	4,07	24,00	19,93	41%	490%	Breakthrough Improvement
Southcor	4,23	22,70	18,47	43%	437%	Breakthrough Improvement
Eastcor	3,76	20,30	16,54	47%	440%	Breakthrough Improvement
Capecor	4,40	16,80	12,40	54%	282%	Breakthrough Improvement
Northcor	1,17	9,90	8,73	73%	746%	Breakthrough Improvement
Westcor	0,28	5,10	4,82	96%	1721%	Breakthrough Improvement
North Eastcor	9,36	19,20	9,84	49%	105%	Continuous Improvement
Sishen - Saldanha (General Freight)	5,07	12,20	7,13	65%	141%	Continuous Improvement
South Eastcor	2,89	3,10	0,21	114%	7%	Continuous Improvement
Northern Cape - Namibia	0,77	0,80	0,03	162%	4%	Continuous Improvement
R Baycor (Heavy Haul)	41,65					Continuous Improvement
Sishen - Saldanha (Heavy Haul)	58,99					Continuous Improvement

Suitable Modernization Strategy Legend
New Idealized Design
Breakthrough Improvement
Continous Improvement

Source: author's synthesis.

Figure 4: Geographic breakdown of the recommended freight rail modernization strategy for South Africa



Source: author's synthesis with permission from GAIN Group to use their Freight Demand Model for 2050 map.

E Conclusions

1) Rail market spaces can be characterized in terms of rail genetic technologies.

    a. Whereas cape gauge rail can fully exploit the coupling RGT, full exploitation of the bearing and coupling RGTs require standard gauge rail.

    b. In both cases the 34 per cent extra width of the rail gauge offers a lower centre of gravity which allow for more product in higher wagons, double stacking of containers (in well wagons), and faster trains with more stability and improved rider comfort.

2) Save for the current preference of business rapid transit (BRT) over light rail, all of the other rail market spaces have been assessed for viability in the modernization strategy.

    a. The natural 'cut-over' threshold from cape gauge to standard gauge is reached at a bearing of 32,4 tonnes per axle, and / or a train speed of 160 km/h.

    b. Below these two thresholds, cape gauge functions adequately.

3) The proposed standard gauge modernization programme in the draft national rail policy (NRP) (Department of Transport 2017) will require a CAPEX of approximately ZAR792,73 billion (U$55,63 billion at ZAR: US$ = 14,25 as at 28 June 2021).

    a. An average ZAR147,92 million (U$10,38 million) per route-km, of which 29 per cent will be spent on a new 720km high speed railway between Johannesburg in Gauteng and Durban in eThekwini.

    b. Given the current underutilized and vandalized status of the South African rail system; and the new post COVID-19 economic realities that followed the publication of NRP 2017, this programme is ambitious.

    c. This programme will require efficient spending of ZAR26,424 billion per annum for 30 years, which comes down to ZAR112,4 million per working day for 235 business days (out of 365 calendar) or ZAR14 million per hour. Unless the procurement and project management capabilities can reliably scale to this spending rate, the programme will not complete on-time, on-budget and on-specification.

4) Basing the modernization strategy on a gauge conversion is costly endeavour.

    a. Conversion or upgrading of the existing national cape gauge network to standard gauge offers little more than a 20 per cent advantage over cape gauge in the long-term.

    b. Excluding the direct and consequential costs associated with service disruptions during construction, conversion of up to 15,000 km of cape gauge national 'core network' to dual cape- and standard gauge arrangement will require a CAPEX in excess of ZAR172 billion (or US$12 billion based on a ZAR100 billion estimate at a 2009 exchange rate of ZAR: US$ = 8.28).

    c. Given the existing underutilized network capacity and the relative low cost of a number of lower-cost untapped available breakthrough innovations, scarce capital must be directed accordingly. Only once these next S-curves are well established should a wholesale gauge conversion become imperative.

d. The standard gauge modernization programme required by NRP 2017 would require a 30-year CAPEX programme of some ZAR792,43 billion (or U$55,64 billion at 28 June 2021 exchange rate of ZAR: US$ = 14,25).

5) Unlocking latent capacity can reduce capital intensity.

Corollary 1: The long-established assumptions of a 'standard capacity model' results in a high levels of capital intensity.

Corollary 2: The standard capacity model comes at a significant premium of Rands invested per tonne moved.

Corollary 3: Save for new projects along new routes, the decision to build new (standard gauge) track to increase capacity must follow unlocking of existing latent capacity.

a. The standard capacity model allows for 35 per cent loss of theoretical capacity in favour of an operating allowance (the amount of time a train can run behind schedule without interfering with the following trains), schedule recovery allowance (the amount of time added to the terminal turn-around time to allow for recovery from accumulated delays on the preceding trip), and time allowed for track maintenance.

b. This 65 per cent operational capacity is further reduced by externalities such a theft and vandalism that leaves about 50 per cent practical capacity to trade in the market.

c. After allowing for train cancellations and unsold train slot, the used capacity is in the order of 30 to 40 per cent of theoretical capacity.

6) The proposed modernization strategy is compliant with the African Union (AU) policy on standard gauge.

F Recommendations

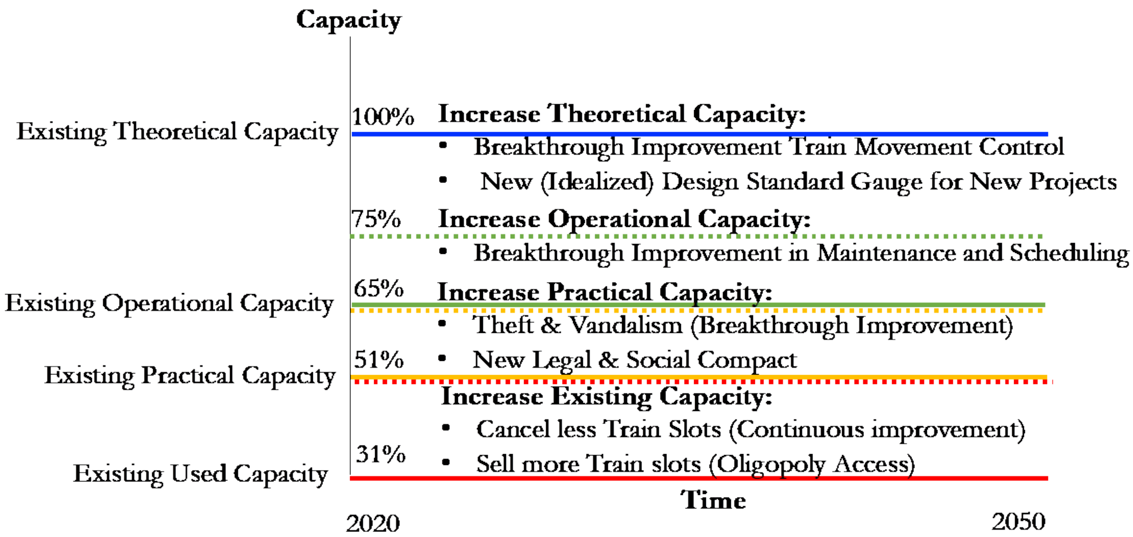
The following recommendations are proposed as a modernization strategy:

Technical

1) Unlock latent freight and passenger rail capacity through continuous improvement of the current system's S-curve, breakthrough improvement to deliver the next S-curve and idealized design for new S-curves.

   a. For both passenger and freight rail (Figure 5 – illustrative), exploit the existing capacity model through a combination of continuous improvement (completing puzzles), breakthrough improvement (addressing problems), and selective idealized design (dealing with messes) (Table 4), with due cognizance of Pidd's (2009) *caveat* that 'one of the greatest mistakes that can be made when dealing with a mess is to carve off part of the mess, treat it as a problem and then solve it as a puzzle – ignoring its links with other aspects of the mess'.

Figure 5: Proposed freight rail capacity modernization strategy



Source: author's conclusion.

Table 4: Approach to Messes, Problems and Puzzles

Complexity	Solution Methodology	Horizon	Business Model	Approach
Messes	Idealized Design	3 to 5 years	New S-curve	Strategic
Problems	Breakthrough Improvement	1 to 3 years	Next S-curve	Innovative
Puzzles	Continuous Improvement	< 1 year	Current S-curve	Deterministic

Source: author's elaboration.

Organize modernization teams first according to market spaces (Figure 3), and then according to impact (Table 4).

a. Aggressively deploy Transnet's more than 800 Six Sigma Black Belt certified continuous improvement process expert employees with a strong mandate to question every capacity constraining assumption or process.

b. A large portion of this team should be redeployed into a project structure and also made available to PRASA on a non-partisan basis.

2) Arrest the destructive effects of vandalism.

a. A specific 'Marshall Plan' recovery programme must be launched urgently to recover the urban passenger network of PRASA to restore the Metrorail patronage from 10 million passenger trips per annum (2019/20) back to the 2014/15 business case of 270 million.

b. Similarly, a specific 'Marshall Plan' recovery programme must be launched urgently to recover the lost train minutes on the Transnet freight rail network due to vandalism.

c. This will require ministerial determinations provided for in both the Preferential Procurement Policy Framework Act 5 of 2000 (PPPFA) and the Public Finance Management Act (PFMA) allow for the respective ministers to approve exemptions to the provisions of the acts, respectively:

   i. PPPFA section 3: 'The Minister may, on request, exempt an organ of state from any or all the provisions of this Act if (a) it is in the interests of national security; (b) the likely tenderers are international suppliers; or (c) is in the public interest.'

   ii. PFMA section 92: 'The Minister, by notice in the national Government Gazette, may exempt any institution to which this Act applies, or any category of those institutions, from any specific provisions of this Act for a period determined in the notice.'

d. The 'Marshall Plan' requires establishment a special programme office, that operates independently and is protected from operational, political interference, or other forms of interference. It must be staffed with its own dedicated team of experienced (large-scale) project management, procurement, contract management, engineering, operational, safety and security, and continuous improvement specialists.

3) Exploit the natural advantages of rail genetic technologies.

   a. Existing network:

      i. Fix & continuously improve:

         1. National new social and legal compact ('It's your railway, cherish it').

         2. Metrorail: complete the 120kph programme.

         3. Transnet freight rail:

            a. Implement a predictable service,

            b. Integrated peri-urban terminals,

            c. Redirect best resources to heavy domestic intermodal,

            d. Dynamic (re)planning system to respond to market dynamics.

      ii. Implement breakthrough improvement to increase operational and theoretical capacity, for example: densify corridors with moving block and automatic train protection.

   b. New projects on SG:

      i. Expand Gautrain as planned on standard gauge,

      ii. UAR Corridor 4,

iii. Develop the Boegoebaai port and rail infrastructure – SIP21(o) Northern Cape Govt,

iv. Develop the Energy and Metals Special Economic Zone (EMSEZ) – Mokopane heavy haul line on standard gauge,

v. Regional 160kph is less than price of High Speed Rail (HSR).

c. Radically re-engineer processes and timelines for: procurement, project management, project development.

Institutional

4) Urgently establish a central rail modernization programme office that can develop and provide the requisite procurement and project, contract and asset management skills, and provide non-partisan assistance to incumbent rail operators.

5) Apart for its other regulatory functions, the single transport economic regulator (STER) must insist on network statements based on auditable asset management standards, such as ISO 55000, as a perquisite for tariff determination. Ultimately the reliability, availability, safety, and sustainability ($RAMS^2$) of a network train slot is embedded in the access charge. STER should use its regulatory power to incentivize innovation and foster $RAMS^2$.

6) Offer the Sishen-Saldanha heavy haul line, inclusive of the Saldanha iron ore export terminal on a vertically-integrated basis to the mining industry to operate as a horizontally-separated concession.

   a. Engineering criticality and maintenance cost of maintaining the wheel-rail interface under heavy axle load and large throughput heavy-haul conditions prefer vertically integrated ownership and operations.

   b. Globally the competitors of South African iron ore exports in Brazil (Vale) and Western Australia (BHP Billion, Fortesque Metals Group, Rio Tinto, and Roy Hill) all own and operate their respective mines, rail links, and port terminals on an integrated basis.

7) Separate the rest of the network between a state-owned infrastructure manager and an oligopoly of public and private sector train operators.

8) Devise a special dispensation for the ~70Mtpa coal export industry between Ermelo and Richards Bay by providing open access to an oligopoly of public- and private sector train operators growing with the Richards Bay port master plan.

   a. Presently approximately 30 per cent of the traffic is classified as general freight and 70 per cent is dedicated to coal exports using a world-class heavy haul operation to the largest privately-owned coal terminal in the world. All indications are that coal exports will decline towards 2050 as the so-called 'coal cliff' for pulverized coal-fired power stations loom.

   b. Implementation of the 2045 Richards Bay port master plan as espoused in the Transnet Long Term Planning Framework (LTPF 2017) will drastically broaden the 'coal port' to the premier 'industrial port'.

9) Initiate devolution of the urban passenger market in Gauteng, KwaZulu Natal and the Western Cape from the national to the provincial sphere only once the recovery 'Marshall Plan' shows signs of stability. In the long term the devolution of the urban passenger market space to local government is a foregone conclusion globally.

10) Develop a comprehensive surface passenger flow model (PFM) and a passenger demand model (PDM) for South Africa. Whereas South Africa has access to a mature integrated freight flow model (FFM) and freight demand model (FDM) for both road and rail freight, the paucity of a PFM and a PDM covering the spectrum of car, minibus, bus, BRT, urban rail, regional rail, conventional rail, high-speed inter-city, and HSR is a serious shortcoming in our macro-economic planning toolset.

1 Introduction

In his address to a joint sitting of Parliament on 15 October 2020, President Ramaphosa announced that 'to fast-track the delivery of economic reforms, Operation Vulindlela will be implemented as a joint initiative of The Presidency and National Treasury.' Nineteen priority policy reforms have been identified across four network industries, i.e. electricity, water, digital communication, and transport to positively impact economic growth. The four policy reforms for transport sector are: 'i) Corporatize the Transnet National Ports Authority in terms of section 3(2) of the National Ports Act of 2005); ii) Improve competitiveness and efficiency of ports (in terms of the Economic Reconstruction and Recovery Plan); iii) Establish a Transport Economic Regulator through the Economic Regulation of Transport Bill (in terms of the Treasury growth document); iv) Implement third party access policy and concession branch freight rail lines (in terms of the Treasury growth document); and iv) Finalize and implement White Paper on National Rail Policy (a DOT initiative)' (The Presidency and National Treasury 2020).

Section 11 of the National Land Transport (Act 5 of 2009) places the responsibility to formulate transport policy and strategy with the national sphere of government. In February 2021 the Cabinet of Ministers approved the White Paper on National Transport Policy (Department of Transport 2021), which frames the National Rail Policy - Draft White Paper (Department of Transport 2017).

This research paper, informed by the National Rail Policy - Draft White Paper (Department of Transport 2017), presents a high-level long-term plan for the sequenced, phased and feasibility-based development of a modern standard gauge South African national rail backbone based on: i) the principles of open access, multiple concessions, private sector investment, and connectivity to passenger and freight terminals; ii) the UNDP's Sustainable Development Goals; iii) the World Bank- led Sustainable Mobility for All initiative; iv) the Paris Agreement on climate change; and v) 'future-proofing' against the emerging Physical Internet initiative.

2 Situational Analysis

2.1 Status quo of track access in South Africa

Presently in 1H2021, track access arrangements in South Africa differ between the existing dominant 'narrow' Cape Gauge (CG) and Standard Gauge (SG) networks.

Existing Cape Gauge network in South Africa

Since 1990 the ownership of South Africa's passenger and freight rail network has been separated between two new entities, the South African Rail Commuter Corporation (SARCC) and Transnet SOC Ltd (Transnet). Transnet retained large portions of the network leaving SARCC owning only portions of the rail network in the metropolitan areas. In the Eastern Cape, Transnet owns the entire network. When the Department of Transport (DOT) established the Passenger Rail Agency of South Africa (PRASA) in 2008, SARCC was included into PRASA. Each of TFR and PRASA is the respective Infrastructure Manager (IM) of its own network.

Transnet Freight Rail (TFR) (an operating division Transnet SOC Ltd) presently operates freight rail services, as well as the long-distance luxury Blue Train. PRASA operates the Metrorail and the Shosholoza Meyl main line passenger service (MPLS) across both its own urban and Transnet Freight Rail Cape Gauge (CG) networks.

Future devolution of the metropolitan rail system to the spheres of provincial and /or local government should therefore consider network ownership, infrastructure management and train operations individually.

Whereas full track access is provided by TFR to luxury passenger rail operator Rovos Rail, TFR provides international rail transit services on its network to Southern African Development Community (SADC) countries on a 'hook-and-haul' basis.

Existing Standard Gauge network in South Africa

The Gautrain Rapid Rail Link (GRRL) is presently the only operational Standard Gauge network in South Africa. It belongs to the Gauteng Provincial Government (GPG), one of three spheres of government in South Africa. The GPG established a 'Gautrain Management Agency as a provincial public entity to manage and oversee concession agreements for the Gautrain Rapid Rail Link Project' (Gautrain Management Agency Act, 2006).

The sole operator of the 80km GMA-owned Gautrain rapid rail system is the Bombela Concession Company (BCC) who won the Gauteng Provincial Government tender in 2006 to build, maintain, operate and partially finance the current Gautrain rapid rail system, thus connecting three metropolitans in Gauteng, namely, Tshwane, Johannesburg and Ekurhuleni. Gautrain is deployed as a Public Private Partnership (PPP) in terms of Treasury Regulation 16 of the Public Finance Management Act (PMFA).

GMA is presently preparing for the 150km Phase 2 expansion of the Gautrain rapid rail system, which will be floated separately as a standalone concession. Until such time that Gautrain Phase 2 becomes operational, there is no requirement for other train operators to access the Gautrain network.

2.2 National Development Plan—NDP 2030

The National Development Plan 2030 contends that 'South Africa has missed a generation of capital investment in roads, rail, ports, electricity, water, sanitation, public transport and housing' (NPC 2012). It prioritizes investment in commuter rail vehicles, as subsequently evidenced by the R51bn Gibela Rail Transport Consortium contract to provide up to 600 new Alstom-designed CG trainsets[3] to PRASA. Without explicitly selecting CG, NDP 2030 also calls for a new heavy-haul Waterberg coal export railway (predating the 2015 Paris Agreement on climate change), improvement of other mineral rail lines as well as regional integration, which will be CG-based unless affordable transshipment infrastructure is developed to deal with the break-of-gauge problem between CG and SG.

NDP 2030 also calls for economic regulation of South Africa's network industries, including rail. It recognizes that a new funding model for rail expansion is required, other than offtake guarantees by companies to Transnet, who in turns must use those to secure funding for infrastructure development and expansion of the rail network.

NDP 2030 identifies the following rail and transported related policy issues to be addressed: i) 'Create workable urban transit solutions, specifically: increase investment in public transport and resolve existing public-transport policy issues; devolve transport management to local government; provide incentives for public-transport use; improve road infrastructure, renew the commuter train

[3] https://www.gibela-rail.com/about-us (accessed on 14 April 2021).

fleet'; ii) achieving by 2030 intermodal flexibility between road and rail on the Durban-Gauteng corridor where most of the country's high-value freight flows; iii) linking the Botswana coal fields via a new Waterberg coal railway line to Richards Bay; iv) effectively linking the ports of Durban to Dar-es-Salaam (Tanzania) via Zimbabwe and Zambia along existing the (undercapitalized) CG North-South Corridor; v) 'providing long-distance transport alternatives include travel by intercity bus, taxi, private transport, air travel and limited intercity passenger trains' with the caveat to carefully assess the long-term viability of inter-city passenger rail services; and vi) using the rural rail network, classified by Transnet as 'branch lines' to connect small-scale farmers to markets.

Rail is also mentioned by NDP 2030 as a Greenhouse Gas (GHG) friendly transport mode.

2.3 National Infrastructure Plan 2012

The Cabinet established the Presidential Infrastructure Coordinating Committee (PICC) in 2012 to 'ensure systematic selection, planning and monitoring of large projects' (PICC 2012). The resulted in the compilation of an infrastructure book listing 645 projects and a National Infrastructure Plan containing 18 Strategic Integrated Projects (SIPs), which were extend to36 SIPs in 2020. Rail-related SIPs are detailed below.

Rail-related SIPs

Herewith the list of Strategic Integrated Projects (SIPs) detailed where *rail*, *trains*, *logistics*, or *transport* is explicitly mentioned, (PICC 2012) *verbatim*:

SIP 1: Unlocking the northern mineral belt with Waterberg as the catalyst. 'Unlock mineral resources; *Rail*, water pipelines, energy generation and transmission infrastructure; Thousands of direct jobs across the areas unlocked; Urban development in Waterberg - first major post-apartheid new urban centre will be a "green" development project; Rail capacity to Mpumalanga and Richards Bay; Shift from road to rail in Mpumalanga; Logistics corridor to connect Mpumalanga and Gauteng.'

SIP 2: Durban-Free State-Gauteng *logistics* and industrial corridor. 'Strengthen the *logistics* and *transport* corridor between SA's main industrial hubs; Improve access to Durban's export and import facilities; Integrate Free State Industrial Strategy activities into the corridor; New port in Durban; Aerotropolis around OR Tambo International Airport.'

SIP 3: South-Eastern node & corridor development. 'New dam at Mzimvubu with irrigation systems; N2-Wild Coast Highway which improves access into KwaZulu- Natal and national supply chains; Strengthen economic development in Port Elizabeth through a manganese *rail* capacity from Northern Cape; A manganese sinter (Northern Cape) and smelter (Eastern Cape); Possible Mthombo refinery (Coega) and transshipment hub at Ngqura and port and *rail* upgrades to improve industrial capacity and performance of the automotive sector.'

SIP 4: Unlocking the economic opportunities in North West Province. 'Acceleration of investments in road, *rail*, bulk water, water treatment and transmission infrastructure; Enabling reliable supply and basic service delivery; Facilitate development of mining, agricultural activities and tourism opportunities; Open up beneficiation opportunities in North West Province.'

SIP 5: Saldanha-Northern Cape development corridor. 'Integrated *rail* and port expansion; Back-of-port industrial capacity (including an IDZ); Strengthening maritime support capacity for oil and gas along African West Coast; Expansion of iron ore mining production and beneficiation.'

SIP 11: Agri-logistics and rural Infrastructure. 'Improve investment in agricultural and rural infrastructure that supports expansion of production and employment, small-scale farming and rural development, including facilities for storage (silos, fresh-produce facilities, packing houses); transport links to main networks (rural roads, *branch train-line*, ports), fencing of farms, irrigation schemes to poor areas, improved R&D on rural issues (including expansion of agricultural colleges), processing facilities (abattoirs, dairy infrastructure), aquaculture incubation schemes and rural tourism infrastructure.'

SIP 17: Regional integration for African cooperation and development. 'Participate in mutually beneficial infrastructure projects to unlock long-term socio-economic benefits by partnering with fast- growing African economies with projected growth ranging between 3% and 10%. The projects involving *transport*, water and energy also provide competitively-priced, diversified, short and medium to long-term options for the South African economy where, for example, electricity transmission in Mozambique (Cesul) could assist in providing cheap, clean power in the short-term whilst Grand Inga in the DRC is long-term. All these projects complement the Free Trade Area (FTA) discussions to create a market of 600 million people in South, Central and East Africa.'

On 24 July 2020 another rail-related SIP was added (Government Gazette 43547, see Government of South Africa 2020):

SIP 21: Transport. N1 Winburg Interchange to Winburg Station: Free State; N1 Musina Ring Road: Limpopo; N1 Polokwane Eastern Ring Rd Phase 2: Limpopo; N1 Ventersburg to Kroonstad: Free State (2 projects in One); N2 Mtunzini Toll Plaza to Empangeni T-Junction: KwaZulu Natal; N3 Cato Ridge to Dardanelles: KwaZulu Natal; N3 Dardenelles to Lynnfield Park: KwaZulu Natal; N3 Paradise Valley to Mariannhill Toll Plaza: KwaZulu Natal; N2 Edwin Swales to South of EB Cloete Interchange: KwaZulu Natal; N3 Ashburton Interchange to Murray Road: KwaZulu Natal; N3 Mariannhill Toll Plaza to Key Ridge: KwaZulu Natal; N2 EB Cloete Interchange: KwaZulu Natal; Small Harbours Development: National; N3 New alignment via De Beers Pass: Free State; Boegoebaai Port and *Rail* Infrastructure Project: Northern Cape.

Other SIPs

SIP 8: Green energy in support of the South African economy. SIP 9: Electricity generation to support socio- economic development. SIP 10: Electricity transmission and distribution for all' SIP 6: Integrated municipal infrastructure project. SIP 7: Integrated urban space and public transport programme. SIP 12: Revitalization of public hospitals and other health facilities. SIP 13: National school build programme. SIP 14: Higher education infrastructure. SIP 15: Expanding access to communication. SIP 16: SKA & Meerkat technology. SIP 18: Water and sanitation infrastructure.

Since 25 July 2020 the following SIPs were added (Government Gazette 43547, see Government of South Africa 2020):

SIP 19: Water and Sanitation (since 2020). SIP 20: Energy (since 2020). SIP 22: Digital Infrastructure. SIP 23: Agriculture and Agro-processing. SIP 24: Human Settlements. SIP 25: Rural Bridges 'Welisizwe' Programme; SIP 26: Rural Roads Upgrade Programme. SIP 27: Upgrading and Repair of Township Roads in Municipalities Programme. SIP 28: PV and Water Savings on Government Buildings Programme. SIP 29: Comprehensive Urban Management Programme. SIP 30: Digitising of Government Information Programme. SIP 31: Removal of Alien Vegetation and Innovative Building Materials Programme. SIP 32: National Upgrading Support Programme

(NUSP). SIP 33: Solar Water Initiatives Programme. SIP 34: Student Accommodation. SIP 35: SA Connect Phase 1B Programme. SIP 36: Salvokop Precinct.

2.4 Analysis of the contribution of Transnet and PRASA to Vision 2030

The National Planning Commission (NPC) published its analysis of the contribution of inter alia Transnet and PRASA to Vision 2030 (NPC 2020). The NPC contracted Genesis Analytics to assess each of the SOEs (Genesis Analytics 2019).

Analysis of Transnet Freight Rail: i) 'Transnet is meeting its core mandate in respect of heavy commodity export lines'; ii) 'Transnet is not meeting its core mandate in relation to general freight'; iii) 'operational service has proven skewed towards the extractive economy, perpetuating South Africa's minerals-dependency in the economy'; iv) 'Transnet does not sufficiently promote effective intermodal linkages to support an integrated logistics network'; v) 'rural economies are not sufficiently serviced by Transnet'; vi) 'Transnet is currently financially sustainable, but there are material concerns on the horizon'; vii) 'Transnet is failing to promote the transition to a low-carbon economy by providing legitimate alternatives to transport by road'; viii) 'the ratio of resourced to theoretical capacity, aged locomotives and signalling systems indicate a serious underinvestment in maintenance'; and ix) whereas private sector partnerships were intended to reach 5% of market share in (port) and rail, tangible progress has been slow (NPC 2020, excerpts from pages 12–14)

Analysis of PRASA: i) 'Overall, the performance report indicates that PRASA has replicated previous patterns of inequality and exclusion of low-income households'; ii) 'there have been significant governance and organizational culture concerns'; iii)'there has been a dramatic loss in customers'; iv) 'the low scores in the safety of commuters and reliability of trains are a deterrent to many customers'; v) 'PRASA is unable to generate enough investment to fund its current operations'; vi) 'there is significant divergence between what would be required by the NDP, what is in the shareholder compact and actual performance'; and vi) 'market structure issues must be addressed [since] [a]bout 2/3 of public spending on urban transport goes to PRASA, accounting for only 17% of trips' (NPC 2020, excerpts from pages 15 and 16).

The NPC (2020) study recommends far-reaching and detailed governance, financial, structural, policy and process reforms to arrest the underperformance of these SOEs to deliver on their nominated SIP mandates and the broader aspirations of the NDP.

The next section reviews the rail gauge study report published in 2009 (see NATMAP RWP 2009) as part of the NDOT's 2005 National Transport Master Plan (in short: NATMAP 2050).

2.5 National Transport Master Plan NATMAP 2050

The NATMAP 2050 study votes against a dual gauge conversion of the existing Narrow Cape Gauge network in South Africa. Conversion of the 15,000 km core network from Cape Gauge to dual gauge (Cape Gauge and Standard Gauge) will cost approximately R100 billion in 2009 Rands.

Furthermore, the report considers the advantages of Standard Gauge (SG) over Narrow Gauge (NG) for freight volumes for various CAPEX premiums in 2009 Rands. Whereas SG is advantageous to NG for all traffic volumes if the CAPEX cost is the same, an SG CAPEX premium of R700,000 per km over NG requires a minimum of 10 Mtpa to provide the same benefit. Realistically the SG advantages over NG will seldom exceed 20% irrespective of the CAPEX premium to NG.

NATMAP 2050 also calculated the cost implications of High-Speed Rail (HSR). At R1000 per seat-trip (2009 Rands), the service must carry 10,800 passengers per day, or 3,7 million passengers per 350-operating day annum (NATMAP RWP 2009).

2.6 Break of Gauge

Globally, there are quite a few examples where operations take place across two different gauges, notably between Standard Gauge in China and Broad Gauge in Mongolia, Russia, and Kazakhstan. The dual gauge intermodal terminal at Erenhot on the Mongolia–China border has extensive investment in transshipment technology.

Notwithstanding this investment, there are major freight delays in the terminal due to the unprecise railroading and train scheduling conflict between Chinese and Mongolian train operators (World Bank 2020b). Operations across a gauge break requires precision railroading to ensure a predictable service with minimal buffer storage.

2.7 African Union Rail Policy

In January 2015 the Heads of State and Government of the African Union assembled for the 24th Ordinary Session of the Assembly of the Union, Addis Ababa, Ethiopia reaffirmed their support for Agenda 2063 'as a collective vision and roadmap for the next fifty years (from the initial 2013 planning process – ed.) and therefore commit to speed-up actions' to deliver on the sixteen Agenda 2063 Aspirations. Although none of them address transport or rail explicitly, the heads aspire that by 2063, 'Africa shall have world class, integrative infrastructure that criss-crosses the continent' (AU 2015).

According to Parida (2014) the rail gauge distribution of Africa's 80,781km rail network is as follows: i) 15.5% (12 514 km) built to 1 435mm 'standard' gauge (SG); ii) 17.8% (14 355 km) built to 1 000mm narrow 'metre' gauge (MG); and iii) 66.7% (53 912 km) built to 1 067mm narrow 'Cape' gauge (CG). South Africa has 22 300km of CG track that makes up 41.4% of the continent's CG track and 27.6% of the overall installed track. Note that Parida's analysis for South Africa excludes 80km of SG track in use for phase 1 of the Gautrain Rapid Rail Link, as well as a small portion of lesser-width narrow gauge track associated with occasional day-tourism, or largely in disuse.

During its November 2007 Johannesburg conference on 'African Railways Systems Interconnection, Inter-operability and Complementarity', the African Union (AU) resolved to build new railway lines to SG:

'*To this end and to facilitate interoperability of rail transport networks in Africa, standard 1 435 mm gauges should be adopted and retained for construction of new rail lines in the Continent*' and concluded that: '*The conversion to standard gauge (1 435 mm) for new railway lines should enable African railways to benefit further from the wide range of material and equipment at global level, and will contribute significantly to resolving the problem of interoperability in the future Pan-African railway network*.' (AU 2007).

In April 2014 the African Ministers responsible for transport adopted 'Vision 2040 for Railway Revitalization in Africa' during their conference held in Malabo, Equatorial Guinea. This followed work by the International union of railways (UIC) (UIC 2014) that identified eight main capabilities (infrastructure, signalling, interoperability, planning, standards, costs, data, and safety) to achieve a future goal of interoperable and efficient rail networks. Determining the 2040 45-year outlook from a low 2018 base: i) the infrastructure should be renewed; ii) signalling should be automated; iii) cross border interoperability should be the order of the day; iv) international standards should apply; v) costs should be competitive throughout the network; vi) safety levels should be to international standards; vii) digital twin models should be in use; viii) and continental planning towards 2063 should be in place. (Blumenfeld et al. 2019).

Ten Corridors and three Radials feature in the vision of the Union of African Railways. Member states are encouraged to keep these in mind for future integration whenever new lines are considered. One of these corridors, the North-South corridor reaches into South Africa.

2.8 White Paper on National Transport Policy - Revised 2020, to be gazetted

According to the National Transport Policy (in short: NTP 2021) (Department of Transport 2021), the mission of rail is: '*To develop an integrated railway transport system and sustainable, competitive rail transport industry that enables the safe, reliable, efficient and effective movement of passengers and freight, and stimulates the economic growth and social development of South Africa*.' However, the rail sector suffers from underinvestment in infrastructure, low network utilization and inefficient operations. NTP 2021 (Department of Transport 2021) proclaims the following policy statements for rail, *verbatim*:

Rail Infrastructure Policy Statement

'The Government will prioritize investment in track, rolling stock and appropriate technologies in rail. A comprehensive upgrade and renewal of infrastructure and investment in world-class high-performance network and appropriate competitive technologies is required to enable the shift of freight and passenger traffic from road to rail.

The State will retain ownership of state-owned rail infrastructure and land associated with rail reserves. Any further provision of rail infrastructure for commuter transport will be determined by a combination of market needs and social considerations.

The provision and maintenance of rail infrastructure for bulk and general cargo freight transport, and for inter-city passenger transport, will be determined by market needs and commercial viability.

The above policy objectives seek to address investment, infrastructure provision and maintenance of rail infrastructure. As a further implementation programme, issues relating to effective competition may necessitate free market principles and an active role by rail operators to advance increased utilization of rail transport.'

Rail Network Policy Statement

'Planning for new or existing passenger rail services will be carried out at a local level as included in the National Land Transport Act, 2009 (NLTA) and provision should be made for coordinating bodies. However, rail infrastructure planning and strategic decisions remain a national competency.

The DOT must support the revitalization of branch lines. The implications of a sustainable strategy where closures of branch lines are objectively justified must be investigated. Branch lines should be categorized as strategic and non-strategic to guide interventions and investment decisions, as branch lines that are not economically viable may still have developmental or strategic importance. A branch-line strategy is required to outline appropriate interventions and support for branch lines. The investigation should further develop a strategy considering both commercial and public service obligations on how to maximize the potential use of branch lines in rural areas to facilitate both passenger and freight transport.

The implementation of new railway lines will be considered where it is possible to serve both freight and passenger demand. Investments in high-speed intercity, heavy-haul, double-stacking, heavy intermodal and contemporary urban rail networks will be considered where viable. The development of such new railways should be actively encouraged.

New long-distance transportation infrastructure (e.g., long-distance trains) must be planned with lower energy intensity than road transport, provided that the proposed interventions meet the minimum distance threshold for the transport infrastructure to be cost-effective and to compete with other forms of transport.

Standard gauge will be considered as the first option in high-density corridors, however, the appropriate gauge for each corridor should be assessed and confirmed through feasibility studies. South Africa will therefore have to coordinate carefully with the SADC region in its consideration and implementation of a wider track gauge, if required and feasible.

Categories will be introduced for passenger rail services. These passenger rail categories will be classified in terms of service distance, speed, station spacing, and target markets and range from metropolitan, suburban low-speed commuter and inter-city medium and low-speed systems, to inter-city high speed systems.'

Rail Funding Policy Statement

'The Government will promote the participation of the private sector in investment projects, and limit its role to strategic investment that cannot or is undesirable to be undertaken by the private sector. The Government will provide for third-party access to the national railway network, where appropriate, subject to regulation by the Single Transport Economic Regulator (STER).

Private sector participation should be encouraged in building and operating freight trans-shipment/inter-modal interchange facilities, to facilitate the shifting of freight from road to rail.

An investment-friendly environment must be created, and regulatory uncertainty must be removed through the establishment of the STER. Rail economic regulation under the STER must establish a legal framework between public and private operators that is clear, objective, and neutral. Tariff regulation must be fair and reasonable, provide efficiency incentives, and give effect to the principle of reasonable return on investment.

Investment in rail infrastructure is critical for the revitalization of the rail sector. *Funding for railway investment in new long-distance network infrastructure will be managed by Transnet under direction from the Government. Funding for railway investment in* narrow gauge urban networks and *wider gauge passenger lines such as high-speed lines will be managed by the Passenger Rail Association of South Africa (PRASA).* Both PRASA and Transnet Freight Rail (TFR) must invest in passenger and freight infrastructure and rolling stock, respectively, in order to meet customer demand. Private sector participation in passenger and freight infrastructure and rolling stock will also be enabled and encouraged where PRASA and TFR are unable to invest.'

2.9 National Rail Policy Draft White Paper 2017

The DOT-published the National Rail Policy (NRP) in 2017 (Department of Transport 2017), which *inter alia* describes the issues pertaining to Cape Gauge (CG), the merits of Standard Gauge (SG), and then makes the following policy statements on SG, *verbatim*:

Liberate Rail's Inherent Competitiveness SG Policy Statement:

'The DOT shall therefore develop, as part of the National Rail Master Plan, a standard-gauging plan to guide relevant rail infrastructure investment.

The standard-gauging plan must balance a brownfields approach, to minimize costs by retaining as much as economically possible of the existing infrastructure, against a green fields approach, to extend the standard gauge network at every economically justifiable opportunity to turn the tide of road domination.

The country's Cape gauge national rail network shall be re-gauged to develop the standard-gauge high-performance national rail network, with due regard for necessary route rationalization.

The standard-gauge high-performance national rail network must be designed to maximize the economic stimulation that follows agglomeration of spatial developments by a competent railway network and optimize rural cohesion and inclusion.'

Affected Corridors and their Timing SG Policy Statement

'DOT's Rail Planning Component shall prioritize and accelerate standard gauge implementation on major rail corridors that will constitute the standard-gauge high- performance national rail network, to ensure that new commercial, industrial, mining and or residential spatial developments are afforded maximum opportunity to align and integrate their plans with freight and passenger rail transport opportunities.

To the extent that increasing urbanization extends beyond the natural reach of Cape gauge urban rapid transit, standard gauge regional rapid transit must be provided. Where such routes are conveniently close to portions of the standard-gauge high- performance national rail network, sharing the same infrastructure or right of way must be considered, together with provision of incremental line capacity for passenger services, so that they do not adversely affect freight services.

The minimum standard gauge high performance network will include the important Gauteng to Cape Town, eThekwini and Nelson Mandela corridors, which will be cleared for double stacked containers and, depending on the outcome of feasibility studies, may also provide capacity for 160-200km/h passenger trains on some sectors.

Heavy haul lines must be treated separately. The remaining life of existing mines and the life expectations for new mines are germane to contemplating retention of Cape gauge or standard-gauging them. The mining sector is best informed and equipped to make the correct call to align rail transportation investment with mining investment. DOT's Rail Planning Component shall engage the mining sector to create effective, funded, integrated and responsive rail logistics solutions to support the country's mineral extraction, beneficiation and export objectives.

High level achievements will generally follow the timing below:

2019 National Rail Policy enacted.

2021 Accounting separation of TFR Infrastructure Manager and TFR Train Operator complete and regulated third party access commences.

2022 National Rail Master Plan completed.

2022 Local authorities complete planning for additional urban guided transit corridors.

2024 Construction of short lead time projects commences, followed in later years by longer lead time projects.

2025 Devolution and assignment of urban guided transit to local authorities completed.

2032 Earliest operating commencement date for Gauteng–eThekwini high speed trains.

2032 Earliest operating commencement date for regional rapid transit trains.

2032 Earliest operating commencement date for additional urban guided transit corridors.

2037 Gauteng to Cape Town, Nelson Mandela and eThekwini sectors of the high-performance standard gauge national network completed.

2049 Latest operating commencement date for Gauteng–eThekwini high speed trains.

2050 All other rail revitalization projects completed.'

Standard-gauge Specifications SG Policy Statement

'Trains must go where business and passengers want them to go: The standard-gauge high-performance national rail network shall therefore support unrestricted interoperation over its entire extent. As exception dedicated passenger lines should not require vertical clearance for double stacked containers.

This Policy proposes a meta-specification, i.e. a specification for a suite of specifications, not the specifications themselves. To avoid casting presently imprecise requirements in legislative concrete, DoT must facilitate and lead, in consultation with the rail sector and its suppliers, a forum within which stakeholders can negotiate and agree a suite of specifications for the standard-gauge high- performance national rail network.

DoT and the stakeholder forum must therefore maximize use of specifications created by others to acquire suitable and compliant equipment at minimal or no price premium. They must also envision a liberal development trajectory that will not lock in constraints, such as those that determined its narrow-gauge heritage, but will maximize its strategic freedom in the decades ahead.

DoT and the stakeholder forum shall develop specifications for maximum axle loads, speeds and train lengths; vehicle profile; train authorization and protection systems, and electrification where that is indicated. In the proposed regulated third-party access dispensation, where penalties for in-service and in-section failures will exist, passenger trains tend to be sufficiently reliable to exclude coupling and braking as interoperability constituents.

Standard gauge specifications should maximize rail's competitive advantage by maximising the contributions of its genetic technologies. Regarding Supporting, vehicles on public roads cannot emulate rail's heavy axle load, so revitalization investment must aim high, e.g. 32.5 tonnes, for general freight. Regarding Coupling, the country already occupies a leading position in freight so Association of American Railroads' specifications remain a good choice while and distributed power can increase train length even after coupler strength maxes out: This is a non-issue for passenger trains. Regarding Guiding, new high-speed lines should also aim high e.g. 400km/h, to provide headroom for future increases.'

Route Rationalization and Expansion SG Policy Statement

'The heritage network attributes will best serve as foundation for a freight national rail network, although requirements also exist to accommodate passenger services that use or will use the national rail network.

DoT shall therefore specify the new standard-gauge high-performance national rail network, which will replace the existing Cape gauge national rail network, to meet essential freight rail requirements: It will serve only high-density corridors that can support the investment required to reposition rail in market spaces where it can exploit its inherent strengths to attract sufficient traffic. Noting that single track standard gauge freight railway capacity maxes out at around 150 million tonnes per year, some currently double tracked routes may be reduced to single track, to minimize the overall cost of developing the standard gauge high performance national rail network.

DoT shall consider all branch lines in the light of their traffic volume and economic interoperability, to determine whether they qualify for connection to the standard- gauge high-performance national rail network or for service by gauge-changing rolling stock.

DoT will also promote the expansion of the existing urban network to relieve road congestion where necessary.'

Neighbouring Countries and Africa SG Policy Statement

'South Africa will use technical solutions to maintain rail connectivity with the SADC Region, whilst facilitating a dialogue with the Region on migration to standard gauge.

In line with the AU resolution, all future green fields rail projects will be on standard gauge, with the exception of extensions to the Cape gauge urban networks.'

Rolling stock SG Policy Statement

'Train operators, including third party operators, on the existing Gape gauge national rail network and on the future standard-gauge high-performance national rail network shall therefore fund, procure and maintain their own rolling stock. During Cape gauge to standard gauge transition, state owned entities may dispose of rolling stock, even that of entire business units, in terms of applicable public procurement legislation to raise funds for infrastructure investment.

Government regards provision of own rolling stock by freight and passenger train operators as an additional funding source to be exploited to close the gap between existing funding sources and overall funding requirements.

After responsibility for urban rail has been assigned to local authorities, they shall procure their own rolling stock requirements.

Government recognizes the importance of standard gauge in mitigating the risk of rolling stock investment failure by ensuring that alternative deployment, if need be in the large global standard gauge market, is possible.

To the extent economically feasible, new rolling stock must be future-proofed against obsolescence due to changing track gauge. Traction bogies for Cape gauge locomotives in particular should provide for changing wheel sets to standard gauge.

Rolling stock planning is excluded from the DoT's responsibilities. Nevertheless, it must be conversant with key attributes of railway rolling stock and trains.'

3 Literature Review

3.1 Economies of Density

According to Graham et al. (2003), who researched seventeen passenger rail operators on the UK rail network, 'railways reveal constant returns to scale but increasing returns to density'. This insight corroborates the seminal 1977 findings by Robert Harris for the USA freight rail system.

Passenger rail

Graham et al. (2003) suggest that whereas passenger rail car kilometres, a measure of scale, is insensitive to total cost or labour hours, passenger journeys, a measure of traffic density, respond positively to the same. They also found that for urban rail: i) the Returns to Density is 1.432; ii) the Returns to Network Size is – 0,342; and iii) the Return to Scale is 1.

'We find on average, that if the use of factors associated with density increases by 10%, the average output of urban rail operations increases by 13.4%. This of course implies that systems with higher density have lower unit costs' (Graham et al. 2003).

Freight Rail

In 1977 Harris (1977) published similar insights for freight rail based on his research in the railway economics of the USA freight rail system. He concluded: 'To the extent that our empirical results offer a fair representation of the relationship between traffic density and the cost of rail freight service, we can draw from them the following policy implications. First, the cost of rail service on light density lines is much higher than earlier studies have claimed. Second, the costs of rail service on high density lines are much lower than at average density levels. Finally, the Interstate Commerce Commission should move toward a rate system which reflects the widely differing costs in the provision of rail services among ship- pers. Railroads should be allowed to raise rates on light density lines (which would in turn lessen opposition to abandonment of redundant lines), and to lower rates on long-haul freight moving over the high-density mainline rail network. Such policies would greatly enhance the financial viability of the rail freight industry, and significantly reduce the need for massive public investment.'

Simply put, Harris' insights mean that economically sustainable freight rail corridors achieve the lowest practical operating cost when the corridor traffic density exceeds 8.8 million tonne-km per route-km. In 2016 the Author and Roland Berger verified this insight with a global survey based on a number of data sources. South Africa is borderline self-funded. Arguably to the positive impact of the low-cost high-density heavy-haul ore and coal export lines offsets the loss-making low-density corridors (Van der Merwe 2017).

Taken together, it is fair to claim then that a corridor with an Operating Ratio (O/R) of 100% typically costs US$0.001 per net tonne-km to operate, which operating cost requires in the order of 8 million tonne-km per available route-km. Once any corridor O/R approaches 75% there should be enough profit to secure capital funding for the corridor. The implication therefore is that we need to densify freight corridors to exceed 10 million tonne-km per route-km to attract (private sector) capital.

Globally, the Canadian National Railway (CN) is a leader in Operating Ratio performance (Statista 2021). Modernization of the South African freight rail system should at least aspire to the demonstrated case history of a market leader such as CN.

The next section addresses railway capacity.

3.2 Railway Capacity

A sound understanding of the existing and required future railway capacity in South Africa is central to the development of a 'high-level long-term plan for the sequenced, phased and feasibility-based development of a modern standard gauge national rail backbone in South Africa with connectivity to passenger and freight terminals'.

The UIC (2004) concluded that 'A unique, true definition of capacity is impossible.' Herewith a number of published definitions for capacity:

- 'Capacity is the level of traffic (i.e. number of trains per day) that a rail line can accept without exceeding a specified limit of queuing time' (Peat Marwich and Partners 1977).
- 'The ability of the carrier to supply as required the necessary services within acceptable service levels and costs to meet the present and projected demand' (Kahan 1979).
- 'Capacity is the highest volume (trains per day) that can be moved over a subdivision under a specified schedule and operating plan while not exceeding a defined threshold' (Krueger 1999).
- 'Line capacity is the maximum number of trains that can be operated over a section of track in a given period of time, typically 1 hour' (Transportation Research Board 2003).
- 'Capacity is measured as the count of valid train paths over a fixed time horizon within an optimal master schedule' (Harrod 2009).
- 'The maximum number of trains that may be operated using a defined part of the infrastructure at the same time as a theoretical limiting value is not reached in practice' (Hansen and Pächl 2008).

The UIC (2004) states that railway infrastructure capacity is a trade-off between the number of trains, heterogeneity, average speed, and quality of service (stability). This is due to discrete nature of capacity utilization which is discussed is the following section. The UIC concludes that, since capacity is used indirectly by passengers and freight being batched into discrete trains, capacity as such does not exist and '*railway infrastructure capacity depends on the way it is utilised*'.

According to UIC (2004), rail capacity can be viewed from at least four major perspectives (Table 5).

Table 5: Different views of capacity—summary of UIC Code 406

Market (customer needs)	Infrastructure planning	Timetable planning	Operations
expected number of train paths (peak)	expected number of train paths (average)	requested number of train paths	actual number of trains
expected mix of traffic and speed (peak)	expected mix of traffic and speed (average)	requested mix of traffic and speed	actual mix of traffic and speed
infrastructure quality need	expected conditions of infrastructure	existing conditions of infrastructure	actual conditions of infrastructure
journey times as short as possible	time supplements for expected disruptions	time supplements for expected disruptions	delays caused by operational disruptions
translation of all short and long-term market-induced demands to reach optimised load	maintenance strategies	time supplements for maintenance	delays caused by track works
		connecting services in stations	delays caused by missed connections
		requests out of regular interval timetables (system times, train stops, ...)	additional capacity by time supplements not needed

Source: content reproduced from Figure 2 in UIC (2004: 3), for analysis purposes.

According to Abril et al. (2008), there are various types of capacity associated with a railway system: i) *Theoretical Capacity*, a purely mathematical calculation, is greatly affected by infrastructure (number of tracks, signals, etc.), track features (speed of trains, heterogeneity, etc.), and operating requirements (commercial stops, maximum trip time, etc.); ii) *Practical Capacity*, which represents the practical limit of running trains reliably, usually between 60% and 75% according to Kraft (1982); iii) *Used Capacity*, which is the actual level of traffic on a network that is normally less than the Practical Capacity; and iv) *Available Capacity*, which is the difference between the Practical and Used Capacities.

Abril et al. (2007: 776–77) define the various capacities as follows, *verbatim*:

Theoretical Capacity. 'It is the number of trains that could run over a route, during a specific time interval, in a strictly perfect, mathematically generated environment, with the trains running permanently and ideally at minimum headway (i.e., temporal interval between two consecutive trains). It is an upper limit for line capacity. Frequently, it assumes that traffic is homogeneous, that all trains are identical, and that trains are evenly spaced throughout the day with no disruptions. It ignores the effects of variations in traffic and operations that occur in reality. Theoretical Capacity is calculated using an empirical formula. This number is relatively easy to generate (it depends on the longest distance between crossing stations for single-track lines or the minimum headway for double-track lines). It is not possible to actually run the number of trains that can be worked out mathematically.'

Practical Capacity. 'It is the practical limit of "*representative*" traffic volume that can be moved on a line at a reasonable level of reliability. The "*representative*" traffic reflects the actual train mix, priorities, traffic bunching, etc. If the theoretical capacity represents the upper *theoretical* bound, the practical capacity represents a more realistic measure. Thus, practical capacity is calculated under more realistic assumptions, which are related to the level of expected operating quality and system reliability. It is the capacity that can permanently be provided under normal operating conditions. It is usually around 60%-75% of the theoretical capacity, which has already been concluded by Kraft (1982). Practical Capacity is the most significant measure of track capacity since it relates the ability of a specific combination of infrastructure, traffic, and operations to move the most volume within an expected service level.'

Used Capacity. 'It is the actual traffic volume occurring over the network. It reflects actual traffic and operations that occur on the line. It is usually lower than the practical capacity.'

Available Capacity. 'It is the difference between the Used Capacity and the Practical Capacity. It is an indication of the additional traffic volume that could be handled in the route. If it allows new trains to be added, it is a useful capacity; otherwise, it is lost capacity.'

Abril et al. (2008) identified the following factors that determine capacity: i) *infrastructure* (the block and signalling system, single or double tracks, the definition of lines and routes, network effects, track structure and speed limits, length of the subdivision between stations); ii) *traffic parameters* (new or existing lines, train or traffic mix and associated train speeds, regular timetables, traffic peaking factor, priority trains); and iii) *operating parameters* (planned or unplanned track access interruptions, train stop time on the line, maximum trip time threshold, time window for capacity solution, quality of service, reliability, or robustness).

Rail capacity is made up from the number of train paths, or 'train slots', that safely allow trains to follow each other in occupied 'block sections' (UIC 2013). These blocks can be: i) maximum train length 'fixed blocks', where the track is permanently delineated by track circuits or axle counters, allowing a train to either solely occupy a single block or solely straddle two blocks for a brief period; ii) 'fixed-length moving block', where trains safely occupy a virtual maximum train length portion of the track as it traverses along a route; or iii) 'flexible-length moving block', where trains safely occupy a virtual individual train length portion of the track as it traverses along a route. On single lines, opposing trains cross at stations or passing loops. Lastly, Abril et al. (2008: 775) state that 'the goal of capacity analysis is to determine the maximum number of trains that would be able to operate on a given railway infrastructure, during a specific time interval, given the operational conditions'.

3.3 Network Statements

A modern standard gauge national rail backbone in South Africa with connectivity to passenger and freight terminals should be described by a Network Statement, once operational.

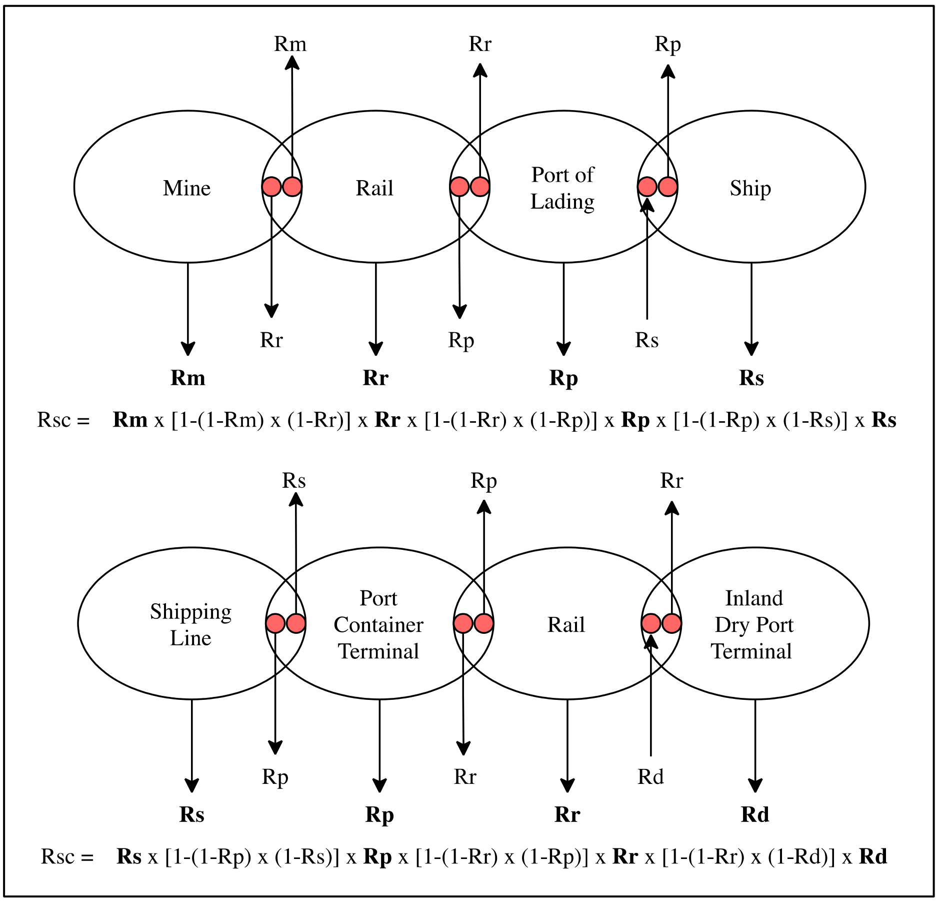
A good example of a Network Statement is published by Network Rail in the UK, which is structured under seven headings, *verbatim*: "i) **Access Conditions**: Conditions for Applying for Capacity; Conditions for Access to the Railway Infrastructure; Licences; Safety Certificate; Insurance; Contractual Arrangements (Framework Agreement, Contracts with Railway Units "RU"s, Contracts with non-RU applicants, General Terms and Conditions), Specific Access Requirements (Rolling Stock Acceptance, Staff Acceptance, Exceptional Consignments, Dangerous Goods, Test Trains and Other Special Trains); ii) **Infrastructure**: Extent of network (Limits, Connecting Railway Networks), Network Description (Track typologies, Track gauges, Stations and nodes, Loading Gauge, Weight Limits, Line Gradients, Maximum Line Speed, Maximum Train Lengths, Power Supply, Signalling Systems, Traffic Control Systems, Communication Systems, Train Control Systems), Traffic restrictions (Specialised Infrastructure, Environmental restrictions, Dangerous Goods, Tunnel restrictions, Bridge restrictions), Availability of the infrastructure 34 2.6 Infrastructure development; iii) **Capacity Allocation**: General Description of the Process, Reserving Capacity for Temporary Capacity Restrictions (General Principles, Deadlines and Information Provided to Applicants), Impacts of Framework Agreements, Path Allocation Process (Annual Timetable Path Requests, Late Annual Timetable Path Requests, Ad-Hoc Path Requests, Coordination Process), Dispute Resolution Process, Congested Infrastructure, Exceptional Transports and Dangerous Goods, Rules After Path Allocation (Rules for Path Modification, Rules for Path Alteration, Non-Usage Rules); iv) **Services and charges**: Charging Principles, Minimum Access Package and Charges, Additional Services and Charges, Ancillary Services and Charges, Financial Penalties and Incentives (Penalties for Path Modification, Penalties for Path Alteration, Penalties for Non-Usage, Penalties for Path Cancellation, Incentives/Discounts), Performance Scheme, Changes to Charges, Billing Arrangements; v) **Operations**: Introduction, Operational Rules, Operational Measures (Principles, Operational Regulation, Disturbances), Tools for Train Information and Monitoring; vi) **Service Facilities**: Introduction, Service Facility Overview, Service Facilities Managed by the Infrastructure Manager (Common provisions, General Information/ Services/ Service Facility Description/ Charges/ Access Conditions/ Capacity Allocation for Passenger Stations and Freight Terminals, Marshalling Yards and Train Formation Facilities, including Shunting Facilities, Storage Sidings, Maintenance Facilities, Other Technical Facilities, including Cleaning and Washing Facilities, Maritime and Inland Port Facilities, Relief Facilities, Refuelling Facilities); and vii) **Other information**: Route Capability Gradients, Schedule of timetabling process, and Extent of electrification across the network' (Network Rail 2022s).

Transnet uses its Long Term Rail Planning Framework to publish its network statement (LTPF 2016).

3.4 Reliability

Typically, a freight railway links ports to industry as part of a larger supply chain. The overall reliability depends on each element's intrinsic reliability as well as how reliable each element interfaces with the adjacent upstream or downstream element (Figure 6) (Bueno-Solano et al. 2016; Taghizadeh et al. 2012).

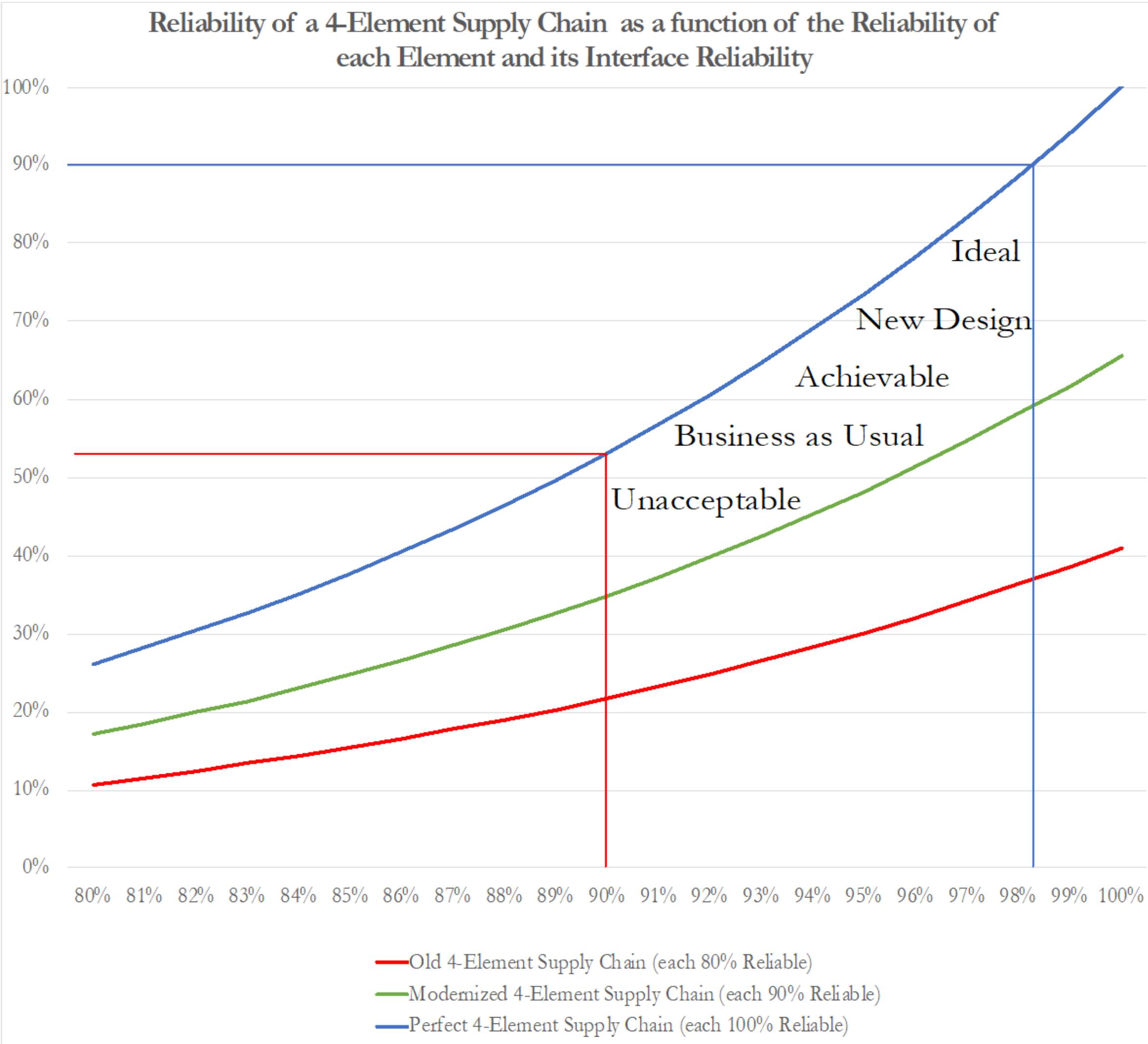
Figure 6: Reliability of a Supply Chain depends on the reliability of each Supply Chain Element and its respective Interfaces



Source: author's elaboration.

Figure 7 shows how sensitive a 4-element supply chain is to interface management reliability. If we assume each element of such an 'old' supply chain is 80% reliable, the overall supply chain reliability will not easily exceed 35%. If we were to modernize each element to 90% reliability, the overall supply chain reliability will not easily exceed 60%. Realistically we can modernize and manage an existing design to approximately 60-65% reliability in the 'Achievable' zone. To outperform that to 75% will require a New Design.

Figure 7: Impact of interface management reliability on Supply Chain Reliability



Source: author's elaboration.

Next we will consider the modernization of a (rail) system as a concatenated sequence of: i) *Continuous Improvement* of the existing design; ii) follow by *Breakthrough Improvement* through reengineering of the existing design, which in itself can then be subjected to continuous improvement; and finally iii) a totally new *Idealized Design*.

3.5 Modernization

Theodore Levitt first described the product life cycle of an entire industry as an 'S' shape curve in 1965 with four distinct stages: i) Market Development; ii) Market Growth; iii) Market Maturity; and iv) Market Decline. Nunes et al. (2020) showed that high performing businesses continuously seek breakthrough innovations to remain industry leaders, thus creating an upward-trending business performance wave. Tidd et al. (2011) present a four-stage innovation process that pre-empts the end of their S-Curves before it is too late: i) Search (How can we find innovation opportunities?); ii) Select (What we will do, and Why?); iii) Implement (How to make it happen?); and iv) Capture (How will we get benefits from it?).

Typically, each S-curve derives from a specific technology that can be extended through continuous improvement. The next S-curve arises from breakthrough engineering and science undertaken during the maturity phase of the existing S-curve, but ideally commencing during the growth phase. For example, whilst Blockbuster dominated the home video rental market using branded stores, Netflix initiated its entry into the same market using surface mail. Not only did this lead to the demise of Blockbuster, but Netflix almost immediately started developing is streaming service during the growth phase of its mailing service business model. A new design is typically required once the current S-curve has completely declined.

Continuous Improvement (CI)

Continuous Improvement (also known in Japan as Kaizen) was conceived by Edward W. Deming as a continuous quality improvement approach to achieve lasting improvements in small incremental improvements. CI can be depicted as a series of small steps. The so-called Deming cycle is a four-stage approach to CI: i) **Plan** ahead and understand what you intend to achieve; ii) **Do**—execute you plan with scientific precision and rigour; iii) **Check** if you have achieved your outcomes and **Study** the reasons for any variances—Deming preferred the latter as he emphasized that its more important to known why the plan worked or failed, than that it worked or failed; and iv) **Act** to embed the learnings of the cycle and then lead into the next CI cycle's planning (Deming 1950).

Note that it is very important to have good 'fit willing and able' execution capabilities to make the most of a Breakthrough Improvement opportunity. Once the execution takes too long, project fatigue sets in and the performance improvement becomes a long and tedious continuous process. A strong project management unit, often outside the line of business, can ensure the rapid deployment of a breakthrough opportunity.

The Japanese implementation of the Deming cycle for Continuous Improvement is known in Japan as *Kaizen*—literally 'improve good'—consisting of six steps, *viz.*: i) identify a problem or opportunity; ii) analyze the process; iii) develop an optimal solution; iv) implemet the solution; v) study the results and adjust; and vi) standardize the solution (Do 2017).

Similarly, legendary American fighter pilot Col. Johan Boyd developed the so-called 'OODA loop', a Command and Control approach to train pilots to outsmart their opponents in aerial combat. Over the years the OODA loop has found its way into business management and is now also considered a valid and useful form of Continuous Improvement. Boyd wrote:

'Without our genetic heritage, cultural traditions, and previous experiences, we do not possess an implicit repertoire of psycho-physical skills shaped by environments and changes that we have previously experienced.

Without analysis and synthesis across a variety of domains or across a variety of competing independent channels of information, we cannot evolve a new repertoire to deal with unfamiliar phenomena or unforeseen change.

Without a many-sided implicit cross-referencing process of projection, empathy, correlation, and rejection (across many different domains or channels of information), we cannot even do analysis and synthesis.

Without OODA Loops, we can neither sense, hence observe, thereby collect a variety of information for the above process, nor decide as well as implement actions in accord with these processes.

Or, put another way, without OODA Loops embracing all the above and without the Ability to get inside other OODA Loops (or other environments), we will find it impossible to comprehend, shape, adapt to, and in turn be shaped by an unfolding, evolving reality that is un- certain, ever changing, and unpredictable' (Boyd et al. 2018).

Eventually CI efforts reach diminishing returns, which leaves us with the option to either accept the system is 'as good as it gets', or we need a *Breakthrough Improvement* that often results in a redesign using a new breakthrough technology, or we need to design a totally new system. In the case of traditional railways, the Breakthrough Improvement stems from exploiting Rail Genetic Technologies (RGT).

Breakthrough Improvement

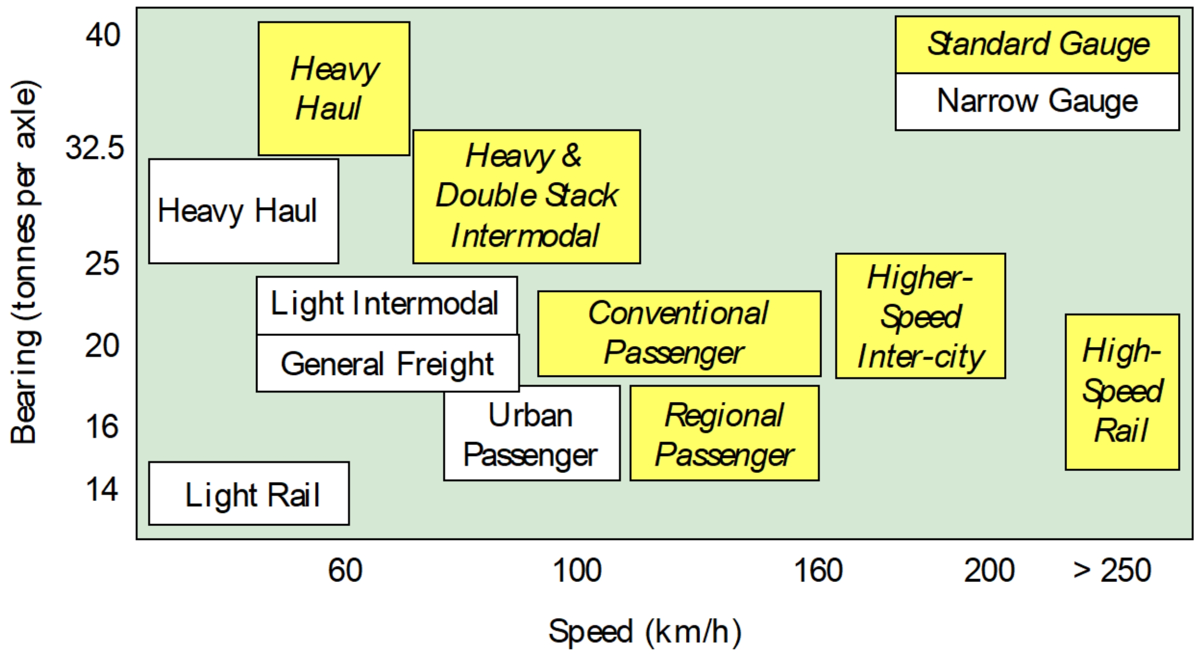
The successful exploitation of Rail Genetic Technologies (RGT) (Figure 8) lies at the heart of a Breakthrough Improvement in the performance of traditional railway systems. Competitive and sustainable rail market spaces are identified that exploits rail's ability to run long, heavy and fast trains each based on a rail genetic technology: i) '**Bearing** (the ability to carry heavy axle load); ii) **Guiding** (the ability to run at high speed); and iii) **Coupling** (the ability to couple vehicles together to achieve capacity)' (Van der Meulen 2007).

Bearing presently (in 2021) supports Heavy Haul operations up to 40 metric tonnes per axle, and evaluation of 42.5 tonnes per axle operations for Western Australia's Pilbara iron ore exports are under consideration. Guiding supports High-speed Intercity and High-Speed Rail (HSR) operations, and provides controlled access to a grade, curvature and energy optimized route. Together, bearing and guiding support the Heavy Intermodal market space for transportation of domestic Bulk Mineral Containers (BMCs) and Double Stack ISO-compliant shipping containers. Coupling leverages all three market spaces to provide requisite capacity at very low energy consumption and endows Urban Rail with its strength of high capacity for mass transit. Sustainability is the ability to generate funds for new investment. 'Research has shown that sustainability associates with competitiveness. This outcome is consistent with business in general, namely that competition improves the offering, and the fittest businesses are sustainable' (Van der Meulen 2007).

Given the overwhelming evidence, all in the common cause, of the successful exploitation of Rail Genetic Technologies in the freight rail sector (Heavy Haul, Heavy Haul in Australia, Brazil, China, India, North America, Russia, South Africa, and Sweden) and in the passenger rail sector (HSR in China, France, Germany, Japan, Korea; and Urban Mass Transit across Asia Pacific, China, Central Asia, Europe, India and Japan), RGT must be seen a hygiene factor for the design of any new railway system.

It is important to note that irrespective of traffic density, the conversion of Cape Gauge to Standard Gauge will not improve the total operating cost (including capital repayment) by more than 20% (NATMAP RWP 2009). Standard Gauge rail track is operationally required to access specific rail-competitive Market Spaces, viz.: i) higher-speed heavy-haul useful in large-scale iron ore export operations, typically more than 100 million tonnes per annum; ii) heavy intermodal allowing for road-truck 'piggy backing' on rail and double stacking of shipping containers, both also requiring sufficient vertical clearance under overhead electrification and in tunnels; iii) all non-urban passenger rail competing with road trips that take at least 1 hour; iv) high speed passenger rail competing with commercial air travel, typically taking 3 to 4 hours door-to-door including up to 2 hours of flying time; v) all non-urban passenger rail competing with road trips that take at least 1 hour.

Figure 8: Competitive rail market spaces based on rail's genetic technologies



Source: author's elaboration.

Whereas the Shinkansen in Japan led in CI on *guiding* for HSR since the 1960s, and Fortesque Metals Group (FMG) in Western Australia leads the world in *bearing* with 40 tonne axle load operations (and now testing 42.5 tonne axle loads), Transnet Freight Rail leads the world on coupling with the longest iron ore trains (342-wagons) and the longest mixed commodity trains 374-wagons of iron ore and manganese. In recent times China has overtaken the HSR market in many respects, notably by implementing a 450km/h magnetically levitated 'maglev' train between Shanghai airport and the city.

Notable in the common cause, Breakthrough Improvements in train movement control of heavy-haul freight trains include: i) China's Haoji Railway transports up to 200Mtpa coal over 1 800km at a flow rate of some 24 000 metric tonnes per hour; ii) Rio Tinto Iron Ore has implemented driverless Autohaul® 'drone trains' between its mines and Port Hedland (Pilbara, Western Australia); iii) BHP Iron Ore and the Roy Hill Railway has implemented Communication-Based Train Control with moving block in-Cab signalling to increase train density.

All of the above CI initiatives follow in the wake of the RGT Breakthrough Improvement. As they will eventually reach diminishing returns, the rail sector will once again be faced with the option to either accept the system is 'as good as it gets', or we need a new Breakthrough Improvement that often results in a redesign using a new breakthrough technology, or we need to design a totally new system. Save from taking the best from RGT in diminishing returns, a new design looks into the future with a clean slate. Since there is no 'Ideal Design' we plan for an 'Idealized Design' that will be subjected to continuous improvement as its predecessor was.

Jacques (1996) and WHCA (1996) describes the *Idealized Design of a system* as 'the design its stakeholders would have right now if they could have any system they wanted. The design is subject to only two constraints: i) it must be *technologically feasible* (no science fiction); ii) and it must be *operationally viable* (capable of surviving in the current environment if it came into existence, with or without modification). The design has one requirement: it must be capable of rapid and effective *learning and adaptation*, and therefore be able to change. It is called *idealized* because it is the best ideal-seeking system its designers could imagine at the time, recognizing that they and others may be able to imagine a better one in the future.'

Idealized Design

Whereas implementation of Continuous and Breakthrough Improvements of the existing rail system capacity and performance could restore the South African rail system to its glory days and beyond, the generally accepted Freight Demand Model for 2050 determined through extensive research and modelling by Stellenbosch University Logistics Professor Jan Havenga and his team in the GAIN Group requires 'five new railways' (5NR) in South Africa. Careful selection of a planning methodology is required for the 5NR to align with this study outcome, *viz. the development of a high-level long-term plan for the sequenced, phased and feasibility-based development of a modern standard gauge national rail backbone in South Africa with connectivity to passenger and freight terminals*.

Russel Lincoln Ackoff, a protégé of Edward W. Deming and also a friend of Peter Drucker (who pioneered the discipline of professional management), is widely acknowledged as a leading management thinker in the field of systems thinking, operations research and planning. Ackoff (2006) classified three dominant planning paradigms: i) *reactive* planning; ii) *preactive* planning; and iii) *interactive* planning. Ackoff (2001) defines them as follows:

'**Reactive planning** is tactically oriented, bottom-up planning that consists of identifying deficiencies in an organization's performance and devising projects to remove or reduce them one by one.' It is deficient in two ways: i) reactive planning is dedicated to removing 'unwanted' deficiencies, but that does not necessarily result in the 'wanted', which often results in something worse; and ii) since it deals with the parts of the system separately, reactive planning tends to ignore the emergent properties caused by the 'sum or of the parts', and their interdependencies.

'**Pre-active planning** is strategically oriented, top-down planning that consists of two major activities; Prediction, and Preparation.' This fatalistic method assumes that since the future will happen uncontrollably to us, the best we can do is prepare for our controllable outcome of a number of probable futures. Since this is based on the quality of assumptions, the future often turns out differently. Hence pre-active plans are seldom fulfilled.

'**Interactive planning** is directed at creating the future.' At its very essence is the interaction between creating a 'desirable present', or the 'future now' and then responding through continuous improvement against the future that unfolds. Continuous planning means no phase of interactive planning is ever complete, hence the system must have the ability to learn and adapt.

Ackoff eventually settled on *Interactive Planning* embodied using his *Idealized Design* methodology that consists of two parts: *Idealization* and *Realization*, where: i) *Idealization* consists of Formulating the Mess and Ends Planning; and ii) *Realization* executes in four steps, *viz*; Means Planning, Resource Planning, Design of Implementation, and Design of Controls.

Expected outcomes of an Idealized Design process

According to Ackoff (2001):

Technological Feasibility means 'the design must not incorporate any technology not currently known to be feasible. This does not preclude new uses of available technology. It is intended to prevent the design from becoming a work of science fiction.'

Operational Viability means 'the system (or organization) should be designed so as to be capable of surviving in the current environment, but it need not be implementable in the current environment.'

Learning and Adaptation means 'the system (or organization) should be designed so as to be able rapidly to learn from and adapt to its own successes and failures, and those of relevant others. It should also be capable of adapting to internal and external changes that affect its performance, and of anticipating such changes and taking appropriate action before these changes occur. This requires, among other things, that the system (or organization) be susceptible to continual redesign by its internal and external stakeholders.'

Since it is impractical to design a perfectly utopian *ideal* system, an alternative is to design the best conceivable *idealized* system which, subject to continuous improvement, exhibits intrinsic *ideal-seeking properties* (Ackoff 2001).

Phased sequencing of interactive planning phases using Idealized Design

Idealization: Formulating the Mess

'Managers don't solve simple, isolated problems; they manage *messes*.'[4] In 1974 Russell Ackoff first used the term 'messes' in response to the eminent American philosophers, William James and John Dewey recognized that: i) problems are assumed by, not issued to, decision-makers; and ii) problems are derived from 'unstructured states of confusion'. According to Ackoff: 'What decision-makers deal with, I maintain, are *messes* not problems. This is hardly illuminating, however, unless I make more explicit what I mean by a *mess*. A *mess* is a set of external conditions that produces dissatisfaction. It can be conceptualized as a system of problems in the same sense in which a physical body can be conceptualized as a system of atoms.'[5]

Formulating the Mess aims to identify the 'seeds of self-destruction', or the 'Achilles heel' of the system. 'Every organization is faced with a set of interacting threats and opportunities, a system of problems that we call a *mess*. The aim of this phase of planning is to determine how the organization would eventually destroy itself if it were to continue behaving as it is currently; that is, if it were to fail to adapt to a changing environment, even one that is perfectly predicted.' (Ackoff 2001: 5).

From Ackoff (2001: 5–8), *verbatim* [layout modified]:

'Formulating the Mess involves preparation of: i) a systems analysis, a detailed description of how the system currently operates; ii) an obstruction analysis, identification of those characteristics and properties of the organization that obstruct its progress; iii) reference projections, projections of

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[4] https://sloanreview.mit.edu/article/the-messy-business-of-management/ (accessed on 24 April 2021).

[5] Ackoff, as quoted here: https://www.open.edu/openlearn/science-maths-technology/computing-and-ict/systems-computer/managing-complexity-systems-approach/content-section-6.2 (accessed on 24 April 2021).

aspects of the organization's future assuming: no change in its current plans, policies, programmes, etc.; and the future environment that it currently expects; iv) a reference scenario synthesized from the learnings (i), (ii), and (iii) above, describing how and why the organization would destroy itself if the assumptions made were true.

Idealization: Ends Planning

On an unconstrained basis, determine what the ideal system would like to be now. Determine the gaps between this ideal and the system projected in the reference scenario. The remainder of the planning process is directed at removing or reducing these gaps taken collectively and interactively.

Realization: Means Planning

Determination of what should be done to eliminate or narrow the gaps identified in ends planning, by selecting or inventing: the courses of action, practices, projects, programmes, and policies to be implemented in pursuing the system's idealized redesign.

Realization: Resource Planning

How much of each type of resource will be required, When and Where, in order to implement the means selected? i) facilities and equipment (materials, energy, services); ii) personnel; iii) money; Information (What), Knowledge (Intellectual How), Understanding (Empathetic How), and Wisdom (Why). How much of each type of resource will be available at the desired times and places if there are no planning interventions? What to do about the shortages or excesses that are identified?

Realization: Design of Implementation

Determine Who is to do What, When and Where.

Realization: Design of Controls

How to monitor these assignments and schedules and adjust for failures to meet the schedules; and How to monitor implemented planning decisions to determine whether they are producing expected results and, if not, determining what corrective action should be taken. […]

<u>[The Idealized Design outcome]</u>

The *idealized design* process has three parts: i) the formulation of a *mission* statement, ii) specification of the *properties* the designers want the designed organization to have, and iii) the *design* exhibiting these properties.'

Mission statement:

A mission statement is about thriving rather than surviving. It should be exciting, challenging, and inspiring and relevant to all of the system's stakeholders. It should state the *raison d'être* and its most general aspirations by identification of the way(s) the system 'will seek to be effective and unique, unifying all of its stakeholders in the pursuit of one or more common purposes. Once formulated, it should make a significant difference in what the system does, and make the progress toward the system's objectives, measurable' (Ackoff 2001: 8).

Specifications and Design:

'Specifications consist of a statement of the properties that the planners want the idealized organization to have. The design states how the properties specified are to be obtained' (Ackoff 2001: 10). The specifications are aspirational and the design is implementable. It is important to address the specifications for the whole system, i.e., the 'hardware, software, firmware, processes, people, organizations, governance structures, information, knowledge, techniques, facilities, services, other support elements, and (usually modified) natural elements' in the case of an engineered system INCOSE (2019). Considering the scope of work associated just with organizational design using a powerful tool such as the long-enduring 'McKinsey 7-S Framework' for (Waterman et al. 1980), detail specifications for the whole system can turn out to be a substantial undertaking.

Making Design Decisions

An *Idealized Design* is a collective consensus-based product. Agreement does not have to be in principle (what is required), but rather in practice (what is worth doing). For most design decisions, complete agreement is easily obtained, but some design decisions will only reach consensus through a test of the alternatives, a test to the results of which all agree to abide. In the latter case, to avoid design deadlock, an exhaustive process of postulation and defence is the best process for the group. If the design group then reaches consensus in opposition to the team leader, their design decision stands. Alternatively, if the group cannot reach consensus, then the team leader's design decision rules.

To give maximum effect to a new rail system design, one also has to carefully consider various options of rail reform to create policy certainty, secure public and private sector investment, enhance competitiveness, and ultimately reduce the cost of logistics.

Messes, Problems, and Puzzles

Ackoff (1974, 1979) created a simple hierarchy to describe complex problems, which he coined as Messes, Problems and Puzzles.

'A *puzzle* is a set of circumstances in which there is no ambiguity whatsoever once some thought has been given to what is happening or needs to be done. Although the nature of puzzles is simple, they are not always simple to solve. A *problem* is more complicated than a puzzle, but less complicated than a mess. This complication stems from the fact that a problem has no single answer that is definitely known to be correct. A *mess* is a set of circumstances in which there is extreme ambiguity and in which there may well be disagreement. In a puzzle, there is complete agreement about the nature of the puzzle (a single correct definition) and also a single correct solution. In a mess there is a whole range of possible definitions and descriptions of what is going on, and there may be no way of knowing whether a solution, as such, exists at all' (Jafarim et al. 2008).

Table 6 shows how complex problems can be practically approached using Ackoff's hierarchy.

Table 6: Approach to Messes, Problems and Puzzles

Complexity	Solution Methodology	Horizon	Business Model	Approach
Messes	Idealized Design	3 to 5 years	New S-curve	Strategic
Problems	Breakthrough Improvement	1 to 3 years	Next S-curve	Innovative
Puzzles	Continuous Improvement	< 1 year	Current S-curve	Deterministic

Source: author's elaboration.

Caveat emptor. Pidd (2009) warns that 'one of the greatest mistakes that can be made when dealing with a mess is to carve off part of the mess, treat it as a problem and then solve it as a puzzle – ignoring its links with other aspects of the mess'.

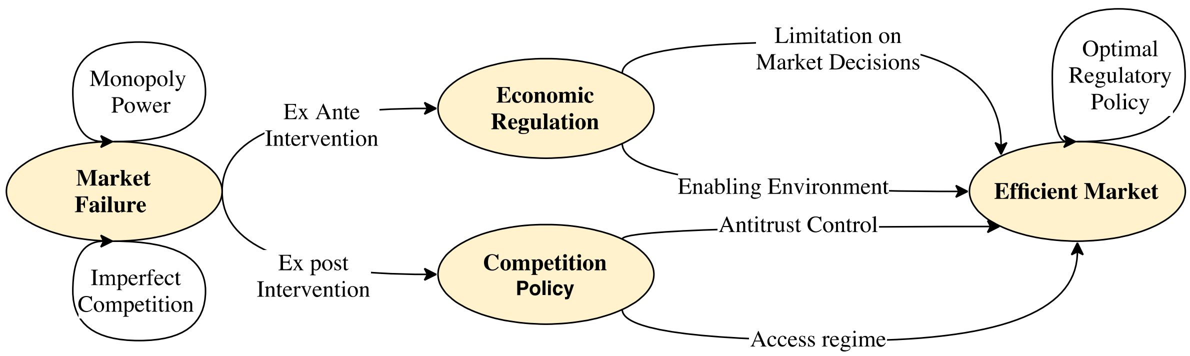
3.6 Rail reform

Systems models for rail reform

When an activity produces costs or benefits not fully borne by its actor, or some form of cognitive biases whereby human do not decide economically, classical economists consider these externalities to result in 'market failure' (Kahneman and Tversky 1979, cited by Logue 2016).

Regulation is used to avoid market failure, foster effective competition, protect consumer interest and increase access to services. Regulation is a typical response to abuse of market power that results in under-investment, lack of consumer choice and innovation, and high prices (FTI Consulting 2015). Since there is no scholarly consensus whether *ex-ante* or *ex-post* regulation has superior outcomes, Logue (2016) advocates the use of both *ex-ante* and *ex-post* regulatory interventions (Figure 9).

Figure 9: Systems model for market failure reform



Source: author's elaboration.

Salient features of *ex ante* Sector-specific Regulation and *ex post* Competition Authority are listed in a table on pages 8 and 9 of Gupta (2017).[6]

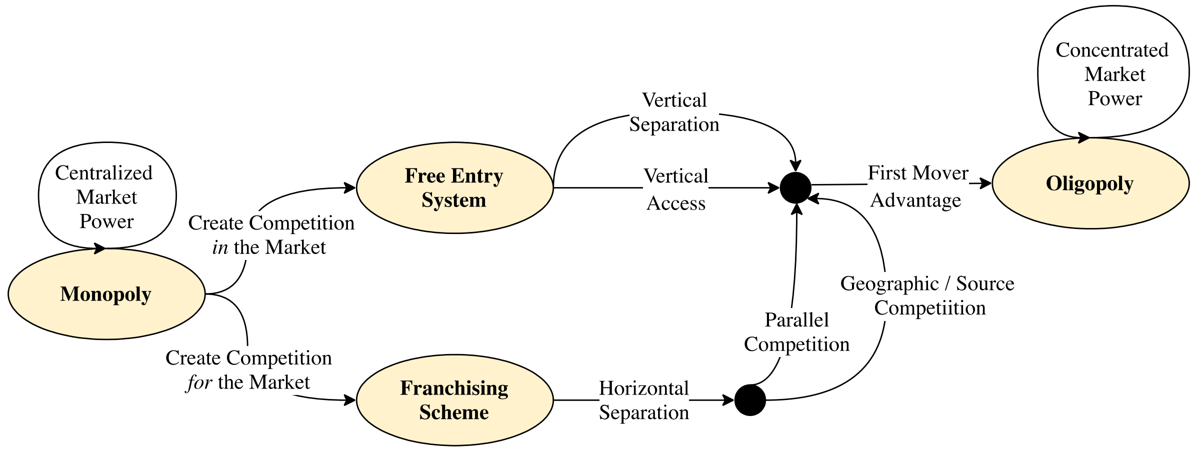
[6] The table is available here: https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/1_2%20Competition%20Issues%20-%20Experiences%20from%20India.pdf (accessed in March 2022).

Whereas perfect competition 'price-taker' markets typically have low barriers to entry and exit, homogenous products, and no dominant sellers or buyers; railways with its high barriers to entry and downward-sloping demand curves tend to be 'price-searcher' markets that often result in monopolies, or at best oligopolies.

Tjia (2020) identifies a number of reasons that railways manifest as natural monopolies: i) 'substantial fixed costs in rail infrastructure construction' (Carlos and Campos 1999); ii) 'integrated organizational structure' to deal with simultaneous management of different operations associated with passenger and freight services on common routes (Carlos and Campos 1999); iii) 'structural integration' to minimize transaction costs (Carlos and Campos 1999); iv) 'indivisibility of rail assets' under varying demand (Tjia 2020); v) inability of a railway to claim benefit from regulation for positive externalities such as a national (defence) strategic need for the rail footprint to extend to uneconomical regions (Tjia 2020); and vi) inability of a railway to claim benefit from regulation against negative externalities in the economy such as noise pollution, GHG emissions, and environmental hazards (Tjia 2020).

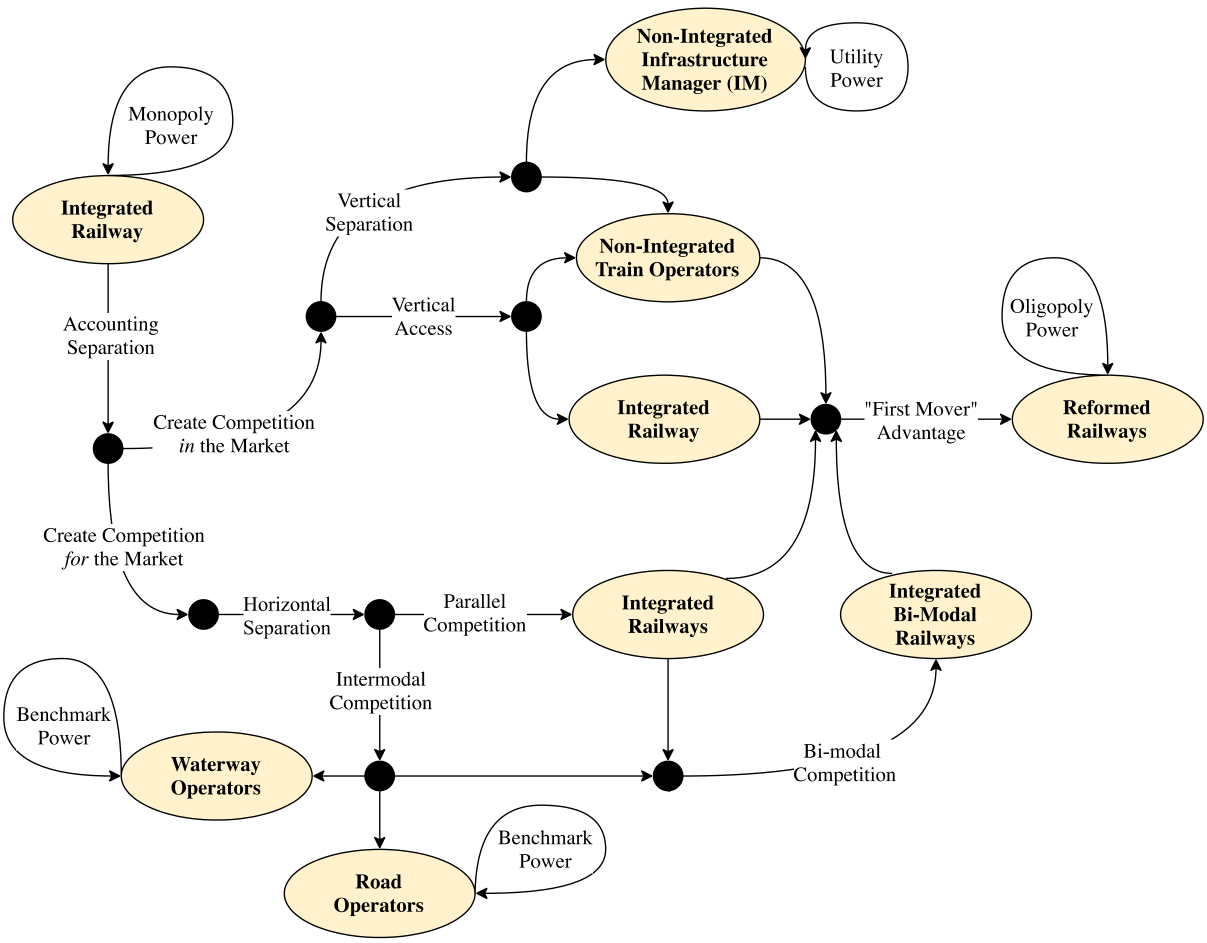
Figure 10 shows a systems model for monopoly reform of such integrated utilities. Note that despite reform, the dominance of non-vanishing economies of density in train operations tend to prevail due to the high barriers to entry. Figure 11 elaborates on possible reform outcomes.

Figure 10: Systems model for monopoly reform of integrated utilities



Source: author's elaboration.

Figure 11: Systems model of various forms of power emanating from integrated railway reform



Source: author's elaboration.

A state-owned railway, normally the subject of reform, enjoys the first mover advantage of the incumbent monopoly being embedded in large customer supply chains. At best, once can expect a resultant oligopoly, as evident in in Germany, where the *Deutsche Bahn* (DB) train operator still enjoys more than 60% market share on the German rail network (DB 2020). The discussion on liberal reform outcome in the European Union (EU) below, re-affirms this outcome (Figure 12).

Strong evidence exists that liberal reform of rail transportation results has a positive economic outcome, as detailed for the USA, the EU, and Australia below.

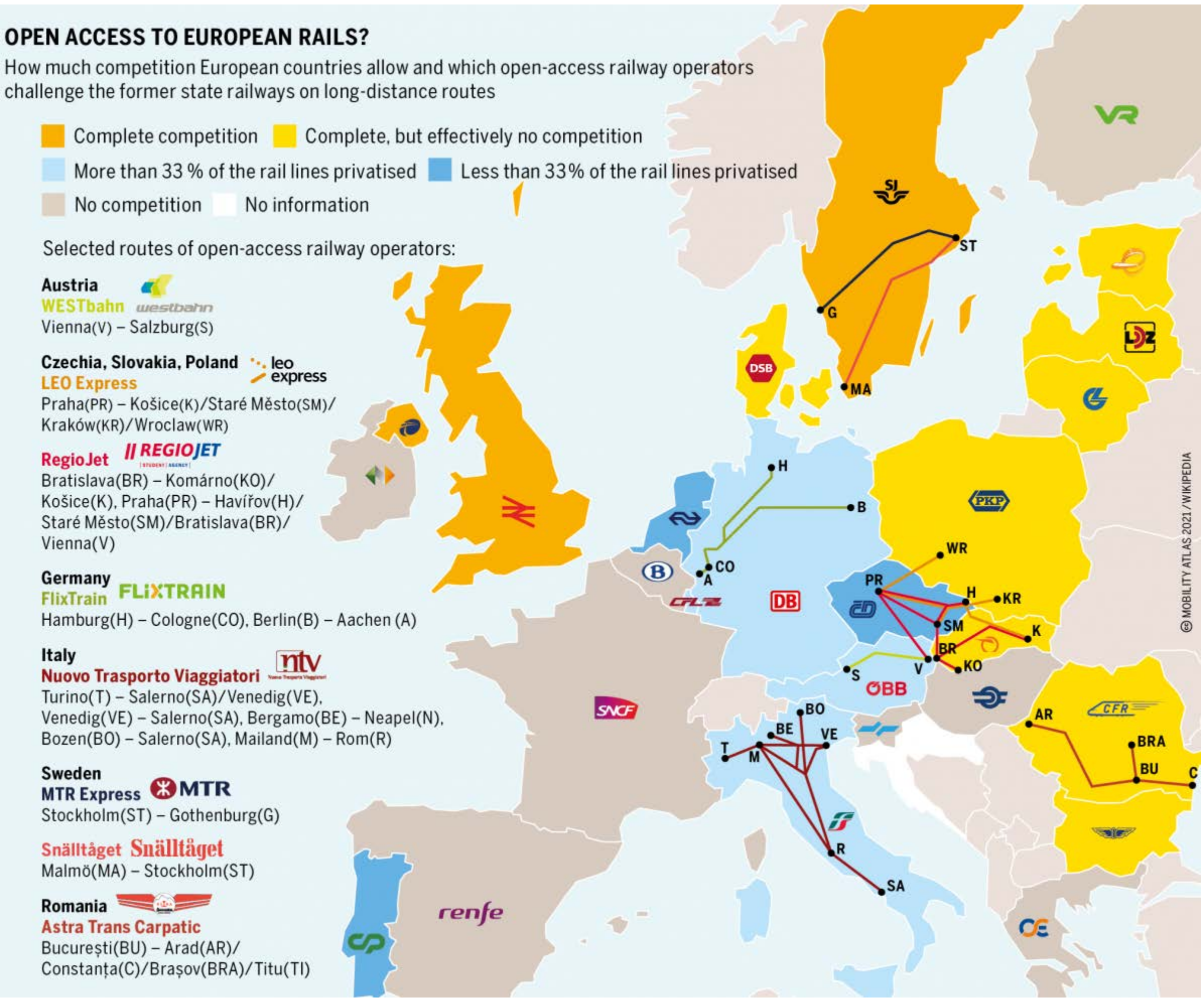
Rail transportation reform in the EU

The 1996 EU White Paper 'A Strategy for revitalising the Community's railways' envisaged the development of a single European railway area.

European Union *Directive 2012/34/EU* established a single European railway area (EU 2012). It consolidates four railway packages, respectively focused on: i) the infrastructure package that afforded rail operators non-discriminatory trans-European network access after 2001; ii) standardization of safety and interoperability arrangements after 2004; iii) open access rights for international passenger rail services from 2010; and iv) since 2013 the removal of all remaining institutional, legal and technical barriers to develop the single European railway.

Although much progress has been made, the infographic in Figure 12 affirms the project remains work-in-process.

Figure 12: The Challenges of a Single European Railway Area



Source: *European Mobility Atlas 2021*, page 19 (Heinrich Böll Stiftung 2021). Graphic: Böckmann, Duwe-Schrinner, Kurzhöfer, licensed under CC BY 4.0.

Some liberalization and harmonization results for the period show a modest increase in freight rail market share from 17.5% (2001) to 17.9% (2018), and 6.6% (2006) to 6.9% (2018) for passenger rail, both with some improvement in productivity resulting from the standardization focus of the Second Railway reform Package (Dehousse and Marsicola 2015; Back 2021).

Rail transportation reform in the USA

In the case of the USA, rail transportation lost 33% market share to road between 1950 and 1975 until policy makers implemented *total economic deregulation* through the Staggers Act of 1980 (Fagan 2008). The chart from Association of American Railroads (AAR) here[7] shows the resultant long-term positive effects on rail productivity, freight volume and revenue, whilst passing on a reduction in price to rail customers.

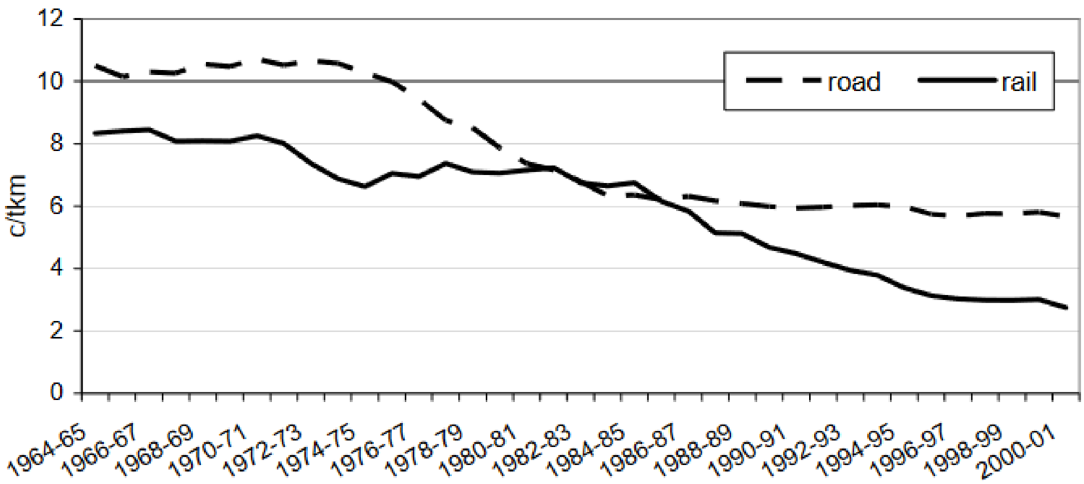
[7] Link to the chart: https://www.aar.org/data/u-s-freight-railroad-performance-since-staggers-act/ (accessed in March 2022).

The European Union and Australia opted for regulated *'open access'* to revitalize their respective rail transportation systems (Fagan 2008).

Rail transportation reform in Australia

In Australia, rail rates declined by more than 60% following passing of the Trade Practices Act in 1974. In 1995, the Part IIIA of the Trade Practices Act of 1974[8] was amended with the introduction of a National Access Regime to provide for *mandated access* onto *natural monopoly* railroads (Fels 2013). Interestingly, following this further liberalization, rail rates to customers declined slower (Figure 13).

Figure 13: Reduction in Australian rail rates ($2006) following the Trade Practices Act of 1974



Source: reproduced from Productivity Commission (2006: XXXVIII, Figure 6), with permission.

Rail transportation reform in China

Tjia (2020) documented the history of rail reform in China. A brief summary of her narrative follows below:

The first railway was built as a private initiative by Jardine, Matheson & Company in 1876 without the consent of the Qing government. By 1949 some 20,000 km of track was built to various standards, owned by foreign companies and the Nanking government (following a partial buy-out between 1904 and 1907), and largely concentrated in the north-east of China. In 1949, after the establishment of the Peoples Republic of China (PRC) the new government militarized the railway system as the Chinese People's Revolutionary Army Railway Bureau which later became the Chinese People's Liberation Army Corps of Railway Soldiers, and eventually placed under the new Ministry of Railways (MOR) of the Central People's Government reporting into the State Council. Along the way, the Chinese railway organization grew to 3.4 million people, and was then reduced down to 2.45 million people as smaller non-core functions were commercialized and spun off, or moved to more appropriate line ministries such as education (e.g. the colleges and universities) and health (e.g. the railway hospitals and clinics). The MOR was refocused into core services such as provision of freight and passenger transport. Notably, in 1983 the Guangzhou-Shenzhen

[8] Replaced by the Consumer and Competition Act 2010.

Railway Corporation was established and listed on the New York Stock Exchange in 1996. Many other sub-sectors were also corporatized under the MOR such as the Rolling Stock Corporation, the Communication and Signalling Corporation, the Railway Construction Corporation, and the Foreign Services Corporation.

On joining the World Trade Organization (WTO) in 2001, China came under pressure from the World Bank (since 2000) and the OECD (see OECD 2002) to reform its monolithic large-scale state-owned railway system for efficiency by allowing market competition and privatization. In 2000 the aforementioned corporations were moved from the MOR and placed under the State Assets Management Commission (SAMC) of the State Council. Re-regulation of these previously corporatized railway assets took place when they were placed under control of the 2003-established State-owned Assets Supervision and Administration Commission (SASAC) to give effect to the strategic agenda of the PRC.

In 2004 the prime minister Wen Jiabao approved the medium- to long-term plan for the rail network to be extended from 16,000 to 100,000 km by 2020. One of these positive outcomes was the establishment of a 10,000km high-speed rail (HSR) network capable of running trains at 200-350 km/h by 2012. Shortly thereafter a series of accidents led to the then minister of railways Liu Zhijun being charged with massive corruption and sentenced to death in 2011, later commuted to life imprisonment in 2015. In 2013 the MOR was transferred to the Ministry of Transport. Soon after the dissolution of the MOR, president Xi Jinping announced the Belt and Road Initiative (BRI) and the government elected to re-regulate the railway sector to ensure its control over the BRI rollout. There is no clear indication that China's rail sector will be deregulation any time soon.

Rail transportation reform in India

In the previous century the Indian economy expanded by 4.5% per annum between 1950 and 2000, but the rail network only grew by 0.5% per annum. By the turn of the century in 2000, passenger rail made up 57% of Indian Railways (IR) output, yet earning only 28% of revenues in contrast with the freight balance made up by the cost-plus freight system. Despite line speeds certified at 100km/h for passenger and 75km/h for freight, the effective speed for freight was reduced to 22km/h as crossing stoppages for the ever-growing passenger prioritized traffic on all mixed routes. (Mattoo 2000).

According to Indian Railways (IR), over 60% of rail routes are more than 100% utilized. Furthermore, 'In the last 64 years, while the freight loading has grown by 1344% and passenger kms by 1642%, the Route kms have grown by only 23%'. (IR 2017). By 2025, IR aims to enjoy a 37% modal share with to 2.4 billion tonnes of freight on rail. This requires an 8.5% CAGR from the 2017 base of 1.2 billion tonnes (IR 2017). Some of the salient reforms under way at IR include:

- In the freight sector, IR has now implemented a number of policy interventions: i) introduced multi-point loading, ii) time-tabled freight services, iii) automatic freight rebate scheme in traditional empty flow direction; iv) opened up goods terminals for handling containers, and v) the container sector for more commodities; vi) liberalized the siding policy; and vii) provided last mile connectivity through RoadRailers, Roll-on Roll-offs. (IR 2017).

- In terms of partnerships, IR has: i) formed joint ventures (JVs) with state governments to earn revenue from space rights; ii) established the Railways of India Development Fund to tap pension, insurance and sovereign wealth funds for rail sector infrastructure development; and iii) leveraged free reserves and equity within IR to raise debt. (IR 2017).

- Apart from network expansion, development of dedicated freight corridors, mass digital roll-out and refurbishing some 40,000 coaches, IR has also embarked on a number of organizational interventions such as: i) activity-based accounting reforms; ii) common vision building; iii) objective merit-based performance appraisal of staff; iv) and a fully functional railway university (IR 2017).

Rail reform tends to manifest as the migration away from large (relative to the economy) state-owned integrated common carrier monopoly / oligopoly utilities towards a liberated market that allows third party and private sector participation. Since the state usually built and still owns the existing rail network, fair and equitable access to the existing rail network is an important success factor for effective rail reform.

3.7 Rail Access Principles

Refer to Figure 14 below. State-owned railways enjoy either *de jure* or *de facto* monopoly status, typically characterized as a vertically and horizontally integrated monolithic entity, *viz.* South African Transport Services prior to the establishment of Transnet and the SARCC in 1990. Total liberalization of rail eventually results in vertical separation between rail-and-below Infrastructure Managers (IMs) and above rail Train Operating Companies (TOCs), or 'carriers', and specialized 'operators'. According to Pittman (2020), 'protecting captive shippers is the strength of the vertical separation model, because if anybody can run a train on the tracks, then if I'm a coal shipper and I don't like the rate that Deutsche Bahn offers me, I can buy some locomotives and run my own trains, or I can try to attract some other company to run trains on the common track and protect me'. Note that in the case of vertically integrated railways, such as in the USA and Canada, regulatory provision is made for Switching an Trackage rights to allow captive shippers access to nearby parallel railways. Since railway last a long time, vertically separated state-owned railway networks compete with, and often lose out, with other publicly-funded infrastructure programmes as evidenced in Europe.

Whereas competition *for* the market requires Horizontal Separation of the network, either into passengers and freight, and/or geographically; competition *in* the market requires competitive access by TOCs to the same network—best facilitated by Vertical Separation managed by specialized IMs.

Horizontal Separation tend to result in Networked Monopolies, typical of the private Class 1 freight railroads in the USA and Canada. These Horizontally Separated and Vertically Integrated railroads are profitable and attract investment (see chart by AAR here[9]).

These railroads also allow Vertical Access network traversing of competing Integrated freight railroads and the US government-owned Amtrak main line passenger service. Driver and locomotive management practices favour a Hook & Haul arrangement for international rail traffic in SADC, as well as along the two-gauge Trans-Asian Railway (Eurasian land bridge), also known as the Belt-and-Road's 'Silk Road' railway that connects China and Europe.

Once an Integrated railway has achieved Accounting Separation between infrastructure management and train operations, Vertical Access can be fairly priced, and Vertical Separation can take place institutionally.

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[9] Link to the chart: https://www.aar.org/data/freight-railroads-spent-635-billion-rail-network-since-1980/ (accessed in March 2022).

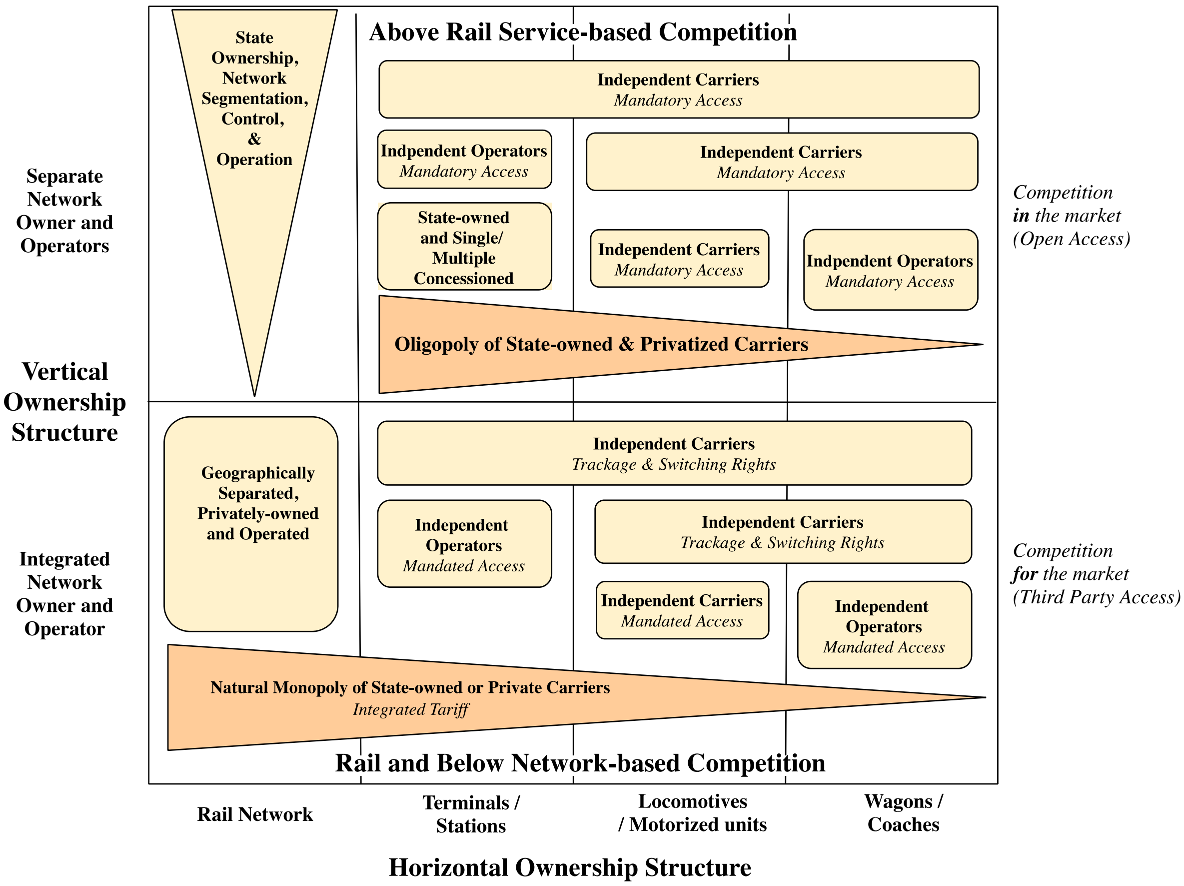
Whereas mainland Europe is typical of country-specific Oligopolies, the UK is arguably the best example of a Free-Market railway system with state-owned Network Rail providing access to 28 private operators[10].

Figure 14 illustrates the many models to establish competition *for*- and *in* markets through ownership, control and operations of all or parts of the network, terminals, locomotives, motorized passenger units, freight wagons and passenger coaches.

Casullo (2016) contends that network industries, such as high fixed-cost railways, respond to: - i) economies of scale that invariably leads to competition *for* the market; and ii) to economies of density, often resulting in competition *in* the market, also known as *open access* in a vertically separated market.

In railways, competition *for* the market typically results in *natural monopolies* or *networked monopolies*; and competition *in* the market typically results in *regulated oligopolies* or a *regulated free market* (EU 2012; Fels 2013). Market power tends to arise where vertically integrated 'rail-and-below' network providers are also involved with provisions of 'above-rail' train operating services. Ex ante regulated *Third Party Access* founded on the essential facilities doctrine of antitrust law (Knieps 2014) mitigates against such market power.

Figure 14: Restructuring options for railways



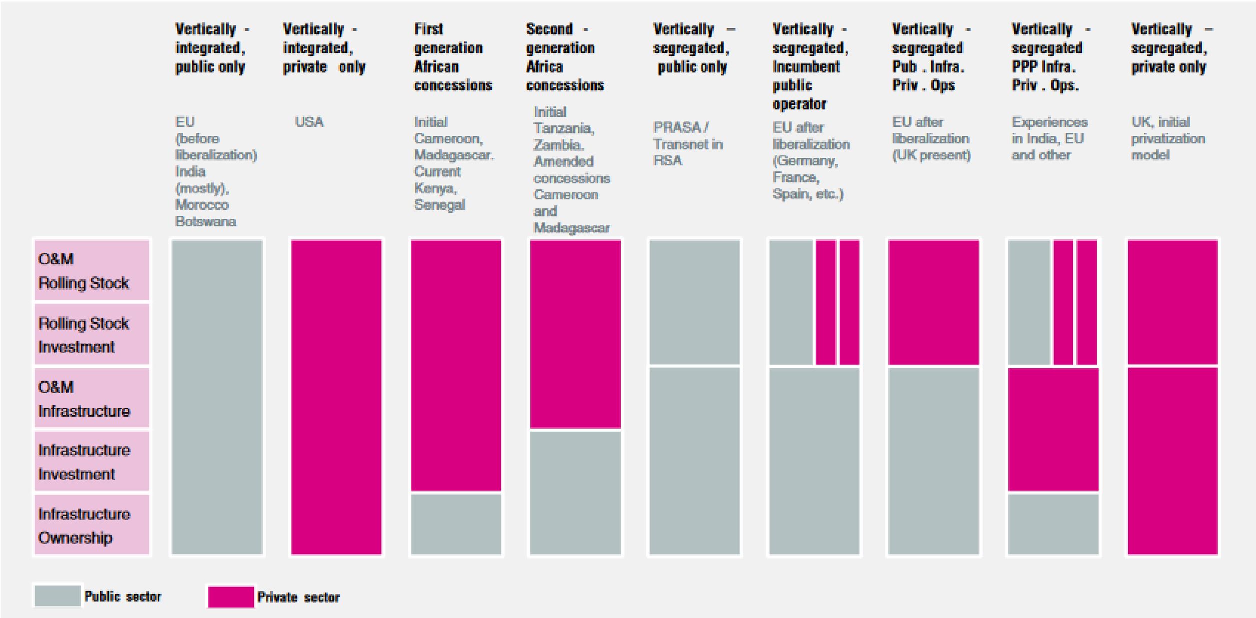
Source: author's own synthesis.

[10] http://www.rail.co.uk/our-partners/rail-operators/

Figure 15 tabulates a number of existing rail business models devised in response to specific environments.

Note that contrary to North America and Europe, where the largest railways are private, in South Africa both PRASA and Transnet remain public sector undertakings (1H2021).

Figure 15: Existing railways business models



Source : ALG

Note: ALG stands for Advanced Logistics Group, which conducted the study under the supervision of the Department of Transport and ITC of the African Development Bank

Source: reproduced from African Development Bank (AfDB 2015: 37, Figure 11).

Open Access

In the case of competition *in* the market the 'rail-and-below' the network provider, also known as an 'Infrastructure Manager' (IM), is not involved with provisions of 'above-rail' services provided by 'Train Operating Companies' (TOCs). Two type of competition stem from: i) either as 'rail-and-below' network-based competition—among alternative route lines, or different lines sharing common interconnecting terminal infrastructure; and ii) a natural monopoly where the railway forms a meshed network. In the first case there is little market power. However, network market power arise in the second case due to unavoidable monopolistic bottlenecks (Knieps 1997: 327–31; Knieps 2011). Monopolistic bottlenecks pervade throughout Europe (Knieps 2014). Ex ante regulated *Open Access* affords TOCs mandatory equitable access onto such rail network monopolies.

Multiple Concessions

Castelar and Azevedo (2016) show evidence that multiple vertically separated concessions fail to attract private investment. However, Sull et al. (2004) and da Rocha and Saes (2018) show evidence that multiple vertically integrated concessions succeed, even within a fragile institutional environment, but as long as property rights are respected and the case for logistics efficiency is compelling.

Brazil presents a good example of Multiple Concessions. In 1995 the Carodosa administration elected to split Brazil's 22,000km national railway system into seven concessions, which were auctioned off as integrated concessions between 1996 and 1998 in a competitive bidding process (Sull et al. 2004). According to National Land Transportation Agency (ANTT) regulations, access must be negotiated between Concessionaires and access if only mandatory if there is excess capacity on a concession network. ANTT's stated goal is to 'Ensure to users the adequate provision of services of land transport and the operation of highway and railway infrastructure' inclusive of highways, railways and pipelines.

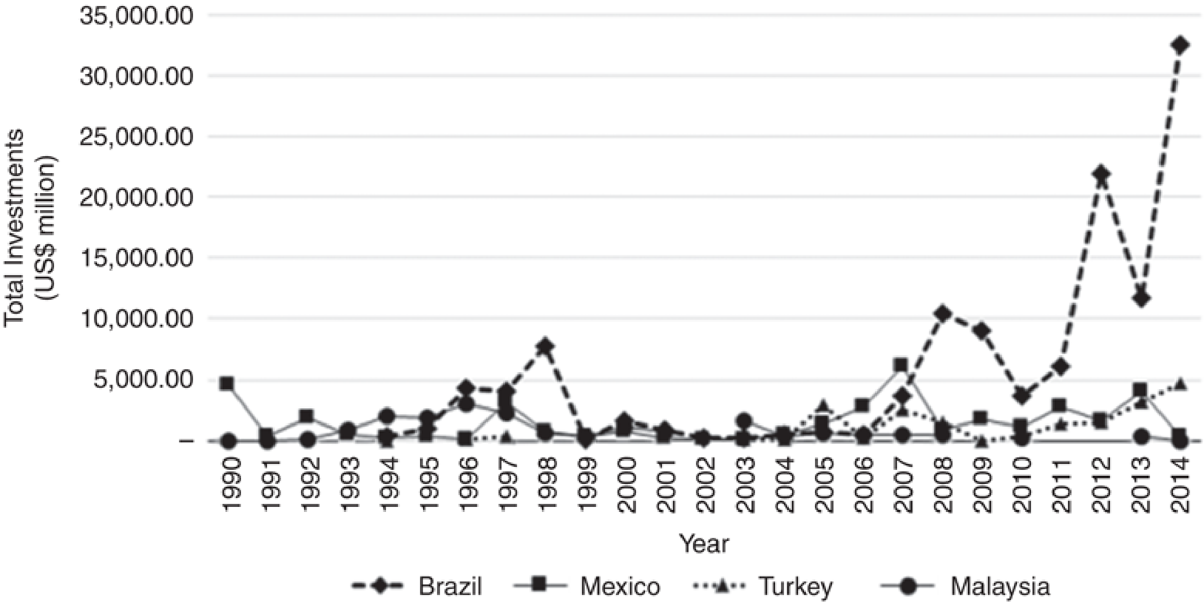
With only light regulation in place, between 1997 and 2012, the accident rate fell 83% and tonne-kilometres, grew at an annual average of 5.3% (Pinheiro 2014). However, train speeds remained slow and very little network expansion took place. To address these deficiencies ANTT elected to implement vertical separation across the board thereby disrupting the integrated concession business model. At the same time, under these new regulations. the government offered a number of greenfield concessions to the market as part of a Brazilian logistics expansion programme. By 2105 not a single concession was sold as investor shunned this 'over-regulated' concession model. Subsequently, to attract investment, the government elected to revert to vertically integrated concessions. (Castelar and Azevedo 2016).

Da Rocha and Saes (2018) clustered the TOP-10 countries with the largest private investments in transportation infrastructure between 1990 and 2014 based on salient institutional, logistics infrastructure, size, and economic growth variables, *viz*: Cluster 1 (Argentina and Russia – property rights, investment freedom); Cluster 2 (Brazil, Mexico, Turkey, Malaysia – property rights, logistics efficiency); Cluster 3 (China – GDP growth, population size); Cluster 4 (Columbia, Peru – investment freedom, logistics efficiency); and Cluster 5 (India – GDP per capita, population size).

Da Rocha and Saes (2018) conclude that:

'In Brazil as an example, the most important consideration is that the state plays an important role in directing investments and the interest of the public sector in less dynamic sectors of the economy, such as the infrastructure sector. The state is therefore not limited to correcting market failures or improvements in the institutional environment. The public administration has the power to act in the creation of incentives for private agents to make investments in logistics infrastructure. With the investment programmes created, regardless of their main purpose, there was a greater flow of investments in transportation infrastructure from the private sector in Brazil, whose institutional environment, among the countries of Cluster 2 (Figure 16 – ed.), was the most fragile. No crowding out effect was observed in the market, contrary to many theorists in the literature on investments and market failures expected.'

Figure 16: Private Sector Participation Investment in four countries with a weak institutional environment



Source: reproduced from Figure 1 in da Rocha and Saes (2018: 235). Licensed under CC-BY 4.0. Prepared with data from the World Bank.

Private Sector Investment (PSI) in railways

Latin America's concession experience shows Private Sector Participation (PSP) is useful for revival of the freight rail sector. However, PSI cannot substitute the sovereign obligation to invest in large infrastructure. The extent of private sector investment (participation) for various PPP business models ranges from: Full Public Sector, Service contracts, Management and Operating Contracts, Leases and affermage / Design Build ('DB'); Build Operate Transfer ('BOT') / Design Build Operate ('DBO'), Concession Build Own Operate ('BOO') Joint Venture / Partial Divestiture, to Full Divestiture (Ang and Marchal 2013).

Unless the role of the state increases (including the provision of guarantees) with evolving economic activity requiring reconfiguration of the railway system, PSP is not effective and hence PSI remains low. In the case of concessions, with the state retaining ownership of the network, PSI is not attracted to large investments in network reconfiguration (Sharp 2005).

The next section considers the customer experience during interaction with a railway.

3.8 Service Quality

Parasuraman, Zeithaml and Berry (1985, 1988) are well-known for their SERVQUAL model and research into the Determinants of Service Quality (DSQ), which are traded for a fair Tariff. Within most service industries, consumers use basically similar criteria in evaluating service quality:

1) RELIABILITY 'involves consistency of performance and dependability'.

2) RESPONSIVENESS 'concerns the willingness or readiness of employees to provide service. It also involves timeliness of service'.

3) COMPETENCE 'means possession of the required skills and knowledge to perform the service'.

4) ACCESS 'involves approachability and ease of contact'.

5) COURTESY 'involves politeness, respect, consideration, and friendliness of contact personnel'.

6) COMMUNICATION 'means keeping customers informed in language they can understand and listening to them. It may mean that the company has to adjust its language for different consumers — increasing the level of sophistication with a well- educated customer and speaking simply and plainly with a novice'.

7) CREDIBILITY 'involves trustworthiness, believability, and honesty. It involves having the customer's best interests at heart'.

8) SECURITY 'is the freedom from danger, risk, or doubt.'

9) UNDERSTANDING / KNOWING THE CUSTOMER 'Involves making the effort to understand the customer's needs'.

10) TANGIBLES 'include the physical environment and representations of the service.'

Selected DSQ analysis by Ribeiro (1993) of the Portuguese rail system showed that (7) Credibility (Trust) and (10) Tangibles (Comfort) are main customer perception drivers for hygiene DSQs (1) Reliability (Readiness), (8) Security, and (4) Access. Geetika and Nandan (2010) confirmed the following DSQs for Indian passenger railways on platforms as: (10) Tangibles (availability and quality of refreshments; (6) Communication (effectiveness of information systems); (2) Responsiveness (behaviour of railway staff); (10) Tangibles (basic amenities provided on platforms); and (8) Security (safety and security). It seems that each railway system, given its current performance, has its own set of DSQ priorities. Notwithstanding, all of these customer satisfaction 'moments of truth' depend on an intricate and complex socio-technical system, commonly called the 'railway'.

3.9 Complex Systems

According to Mobus and Kalton (2015) 'the observable universe is a system containing systems; and every system contains subsystems, which are, in turn, systems'. They define *complex systems* as 'systems that comprise many interacting parts with the ability to generate a new quality of macroscopic collective behaviour, the manifestations of which are the spontaneous formation of distinctive temporal, spatial, or functional structures'.

Andrew (2001) quotes Warfield and Staley's (1996: 50–51) identification of seven necessary conditions for a system to be considered 'complex', they are: 'i) a human presence; ii) a generic purpose associated with the human presence; iii) exercise of system inquiry by the human presence; iv) human purpose related infrastructure to make possible the system inquiry; v) system related environment; vi) sensing apparatus for space-time sampling of the situation by the human presence and vi) cognition on the part of the human presence'.

Cook (1998) offers a brief treatise on the nature of failure; how failure is evaluated; how failure is attributed to proximate cause; and the resulting new understanding of (human) safety by stating the following eighteen tenets: 'i) Complex systems (including transportation) are intrinsically hazardous systems; ii) Complex systems are heavily and successfully defended against failure; iii) Catastrophe requires multiple failures—single point failures are not enough; iv) Complex systems contain changing mixtures of failures latent within them; v) Complex systems run in degraded mode; vi) Catastrophe is always just around the corner; vii) Post-accident attribution accident to a 'root cause' is fundamentally wrong; viii) Hindsight biases post-accident assessments of human performance; ix) Human operators have dual roles: as producers and as defenders against failure; x) All practitioner actions are gambles; xi) Actions at the sharp end resolve all ambiguity; xii) Human practitioners are the adaptable element of complex systems; xiii) Human expertise in complex systems is constantly changing; xiv) Change introduces new forms of failure; xv) Views of 'cause' limit the effectiveness of defences against future events; xvi) Safety is a characteristic of systems and not of their components; xvii) People continuously create safety; and xviii) Failure free operations require experience with failure'.

A systemic understanding of a railway, including the underlying role of engineering competencies, is useful to frame rail reform, the technical implications thereof, and the impact of customer satisfaction.

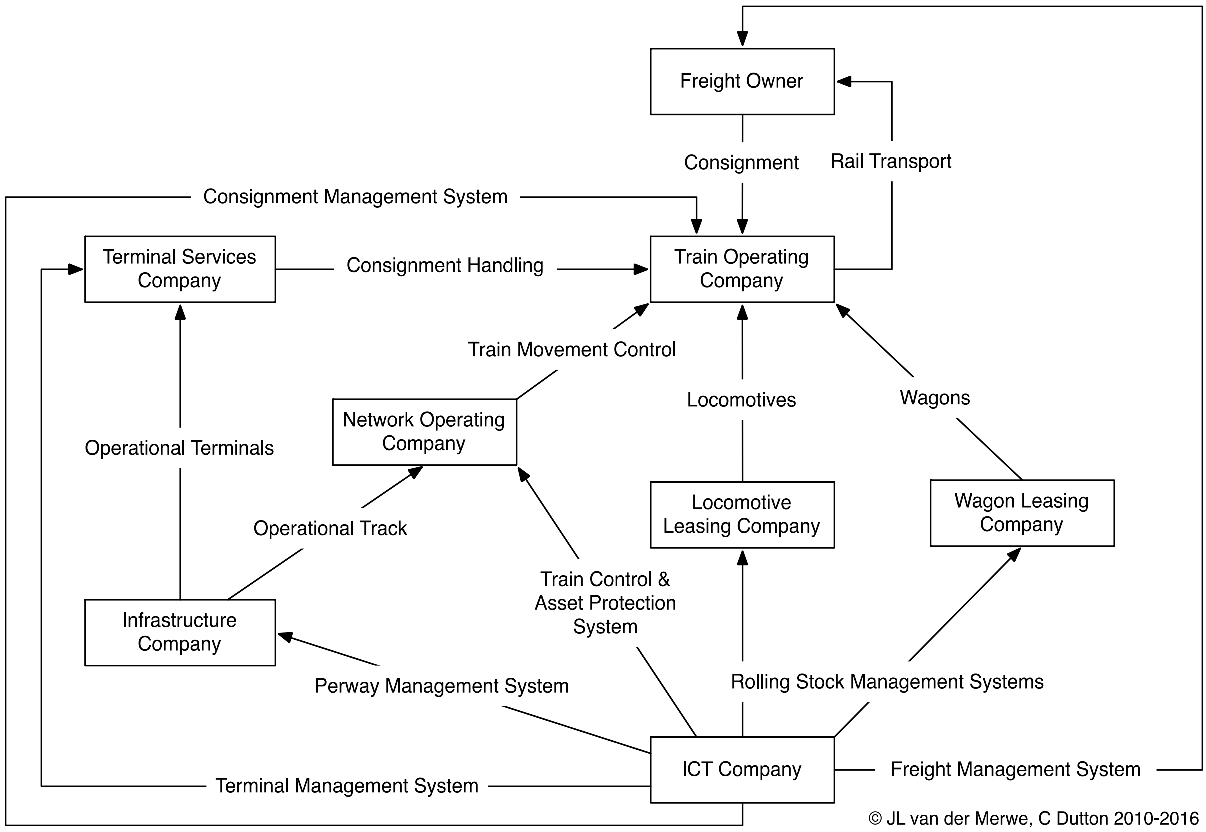
3.10 Railway Reference Models

Systemic View of a Freight Railway Reference Model

Figure 17 offers a systemic view of a freight railway. A similar model can be developed for a passenger railway. Seven inter-dependent role players, denoted in the extreme form of liberalization as companies, have to interact *reliably* to offer freight transport to a consigning Freight Owner. From a Freight Owner's perspective this interaction proverbially takes place 'below the waterline'. The coordinating role of information and communication technology (ICT) is clearly shown in the schematic.

Deviation from a co-ordinated / scheduled plan by and between any of these seven participants places the arrowed output at risk, which ultimately results in an unpredictable rail transport service. Ultimately the service quality is measured at the interface between the Train Operator and the Freight Owner, who is the paying client that offers a consignment for rail transport. Clearly the railway business is a complex social-technical system than requires a strong engineering competency to support precision railroad, which is the basis of a predictable service.

Figure 17: Systemic view of a freight railway

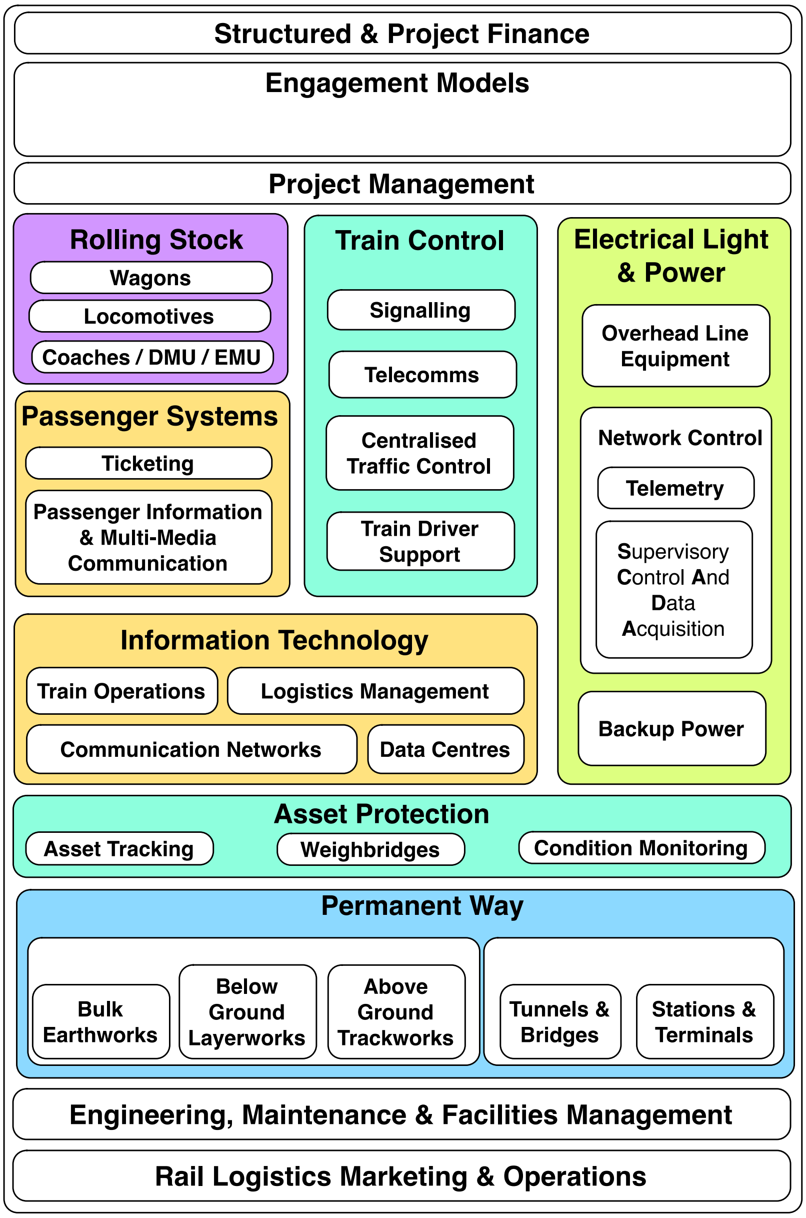


Source: author’s elaboration, with C. Dutton.

Railway Engineering Reference Model

Figure 18 highlights the role of engineering disciplines in a railway business: i) Rolling Stock is associated with Mechanical, Electrical and Electronic Engineering disciplines; ii) Train Control and Asset Protection are primarily associated with Electronic Engineering; iii) Electrical Light and Power is primarily associated with the Electrical Engineering discipline; iv) Passenger Systems and Information Technology are primarily associated with Industrial and Electronic Engineering disciplines; and v) Permanent way is primarily associated with the Civil Engineering discipline. Project Management and Engineering, Maintenance and Facilities Management are multi-disciplinary engineering competencies.

Figure 18: Railway Engineering Reference Model



Source: author's elaboration.

The business model also requires legal, commercial, and financial expertise: i) Structured & Project Finance activities are in the domain of financial expertise; ii) legal expertise is required to procure the appropriate Engagement Models (such as concessions, private contract railways, or public utilities); and iii) Rail Logistics Marketing and Operations are well served by commercial expertise.

The next section looks at the United Nations' Sustainable Development Goals (SDG) adopted in 2015 by South Africa to inform railway modernization compliance.

3.11 Sustainable Development Goals (SDG)

To replace the 2000-2015 Millennium Development Goals, the United Nations adopted 17 integrated Sustainable Development Goals (Figure 19), together with 169 Targets tracked by 232 unique Indicators, with the objective to leave no one behind.

Figure 19: Sustainable Development – SDGs

Source: logos available at https://www.un.org/sustainabledevelopment/news/communications-material/.

According to an Independent Group of Scientists[11] appointed by the Secretary-General, the transport sector, which employs 88 million people globally and result in 14% of all GHG emissions, must be transformed to achieve the SDGs and the Paris Agreement on climate change. Critical changes are required to ensure cleaner electrification, less energy consumption, better use of modal options, and greater use of public transport. (UN Environment 2019).

Greenhouse Gas (GHG) emissions by railways

According to the US Environmental Protection Agency, 'CO_2 accounts for about 76% percent of total greenhouse gas emissions. Methane, primarily from agriculture, contributes 16 percent of greenhouse gas emissions and nitrous oxide, mostly from industry and agriculture, contributes 6 percent to global emissions. All figures here are expressed in CO_2-equivalents.' (EPA 2017). Interestingly, during 2019 in the USA, CO_2 made up 81% of GHG emissions (EPA 2021). Given the dominance of CO_2 as a GHG, is it used to compare the GHG for most industries.

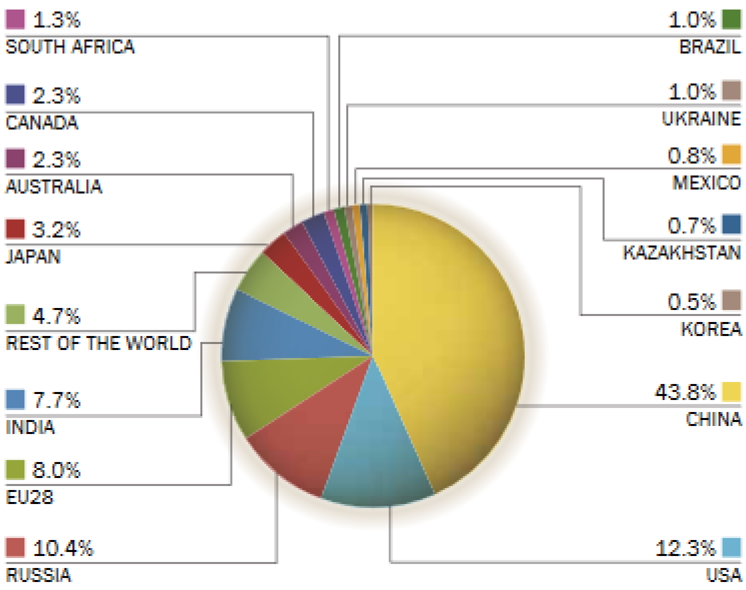
Transport accounts for 15% (Baumert et al. 2017) to 24.7% of global CO_2 emissions, and 28.8% of final energy consumed (The Climate Chance Observatory Team 2018). Whilst rail transport contributes 6.7% of all passenger kilometres and 6.9% of world freight tonne kilometres, it only accounts for 4.2% of global transport's CO_2 emissions, and 1.9% of its final energy demand. Between 2005 and 2015 the rail mode decreased CO_2 emissions by 21.7% per passenger kilometre and 19% per freight tonne kilometre respectively. (IEA and UIC 2017: 18).

Note that the South African surface freight system produces 375 billion of the 32 trillion global tonne kilometres annually, which 1.17% turns out to be 2.4 times more expensive in GDP generated per tonne kilometre than the global average (Havenga 2018). The South Africa passenger

[11] The list of these scientists is available at: https://sustainabledevelopment.un.org/gsdr2019.

and freight railway system is a 1% producer of global rail CO_2 emissions (Figure 20) despite being the eleventh largest national rail system globally[12].

Figure 20: CO_2 emissions from rail transport by country in 2015



Source: reproduced from IEA and UIC (2017: 22, Figure 6), with permission. Based on former online data service 'CO2 Emissions from Fuel Combustion'.[13]

Given that road-dominated transport is the largest GHG emitter, Ang and Marchal (2013) recommend that governments implement Avoid-Shift-Improve (A-S-I) policies to create a meaningful impact, especially in passenger transport. Firstly, encourage people to avoid traveling, secondly shift to greener transport modes such as passenger rail, and thirdly integrate the SDGs into climate friendly transport infrastructure strategies. Essentially, Ang and Marcalm (2013) identify the following obstacles to solve riddle of the lowering GHG in passenger transport: 'Rail and metros projects are often constrained by higher upfront capital costs, relatively lower returns and longer development and payback periods, compared to carbon-intensive investment alternatives such as toll highways. In addition to high capital costs, direct user fares are often set too low to cover operational costs, due to social affordability concerns, thus limiting returns. Public transport infrastructure projects are hence less attractive to private long-term investors than carbon- intensive alternatives.' Private sector investment seeking instruments include: i) public-private partnerships (PPPs); ii) land value capture tools; iii) loans, grants and loan guarantees; iv) green bonds; and v) transitional domestic incentive measures and short-run subsidies.

Sustainable Mobility for All (SuM4All)

According to Sustainable Mobility for All (2018) 'By 2030, annual passenger traffic is set to increase by 50 percent and global freight volumes by 70 percent. By 2050, an estimated 1.2 billion more cars will be on the road.' Given that none of the 17 SDGs explicitly refer to transport, the World

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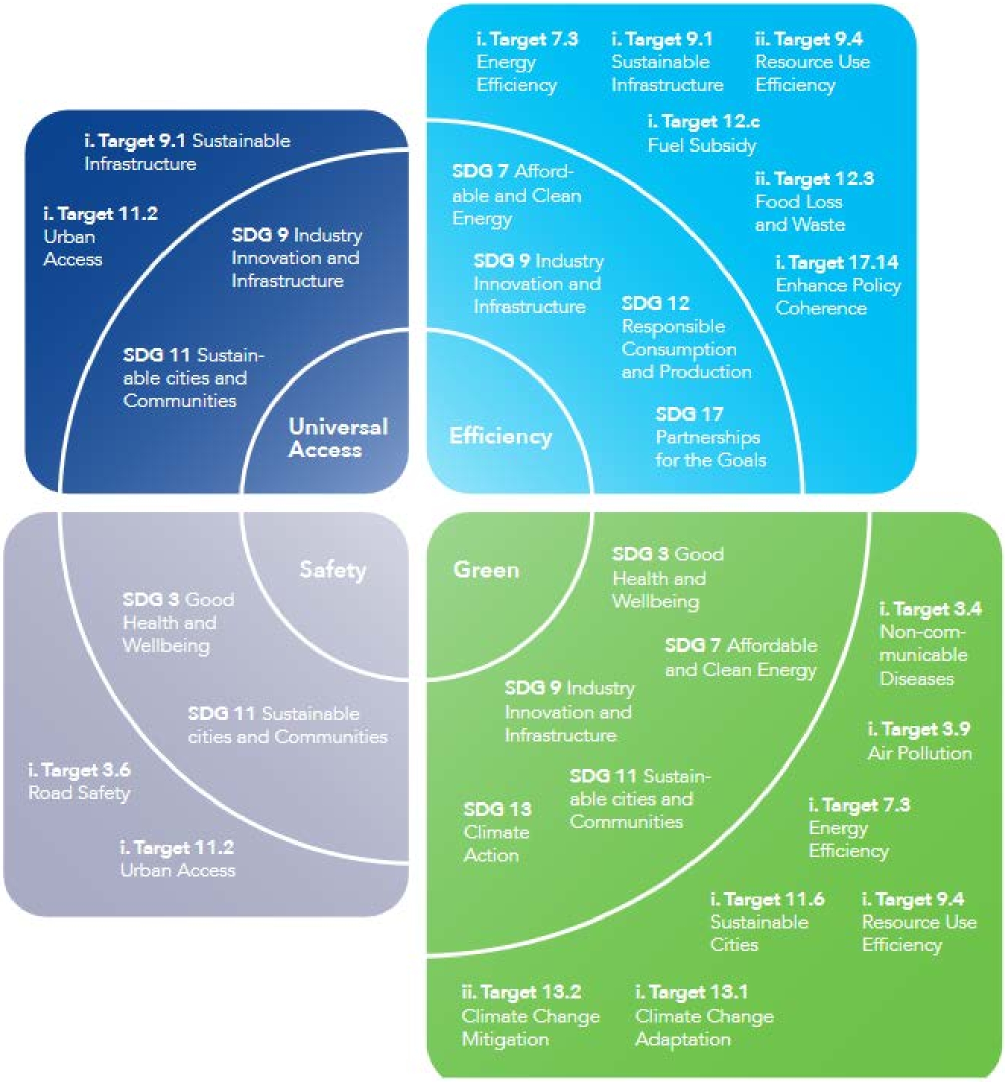
[12] Railway Transport in South Africa 2017: State & Size of the Industry and Key Influencing Factors, www.ResearchAndMarkets.com

[13] See now https://www.iea.org/data-and-statistics/data-product/greenhouse-gas-emissions-from-energy and https://doi.org/10.1787/co2-data-en.

Bank therefore convened with 55 influential organizations to endorse the Sustainable Mobility for All charter, styled as members of the 'SuM4All Consortium', to pursue four concurrent policy goals in the transport sector, i.e.: universal access, efficiency, safety, and green mobility. Figure 21, developed by the World Bank- staffed SuM4All secretariat, shows a mapping of these policy goals to the Sustainable Development Goals and Targets.

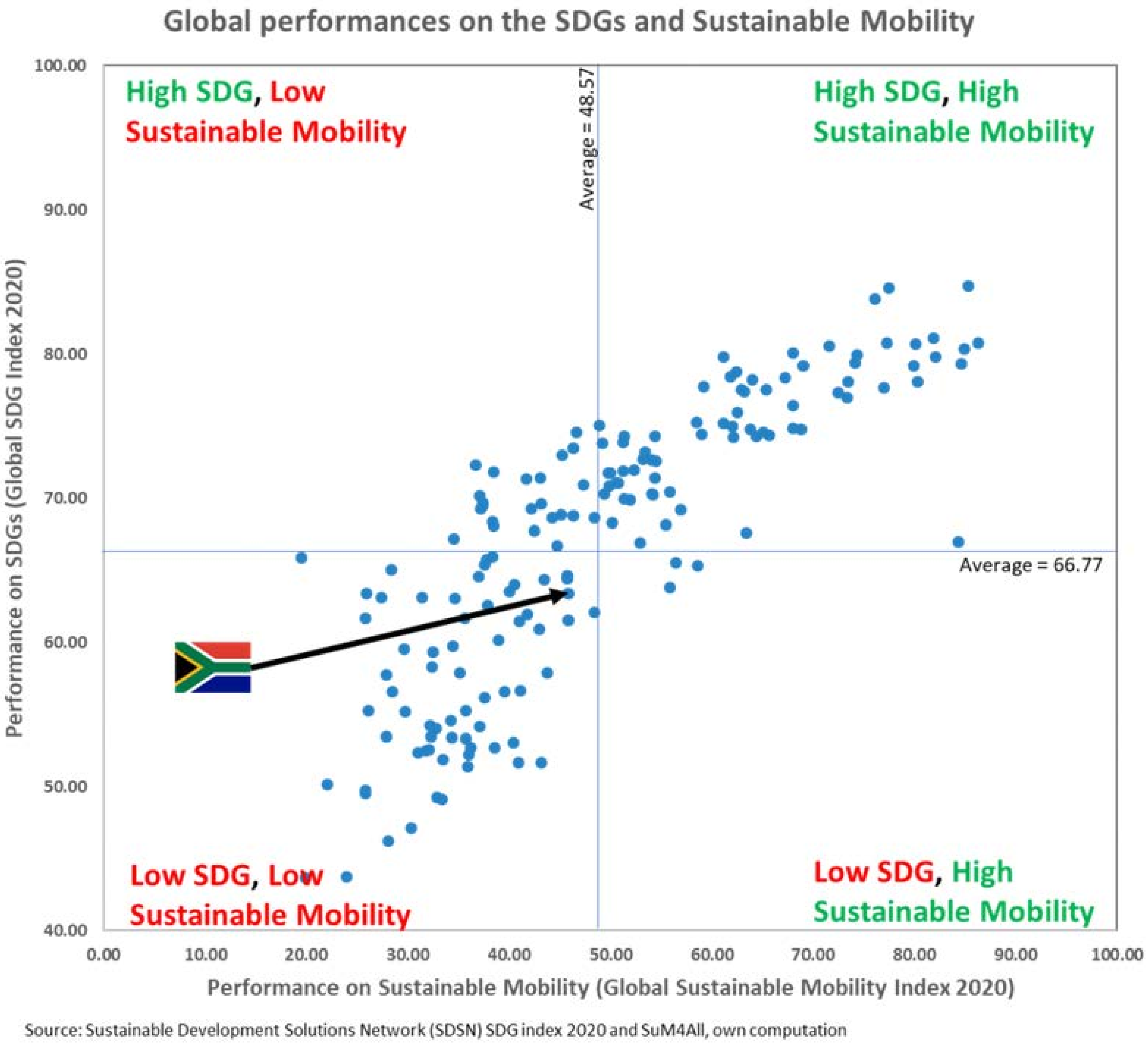
Figure 21: Four policy goals, relevant SDGs and associated targets for transport sector compliance to the 2030 Sustainable Development Goals



Source: reproduced from Figure 1.1 in Sustainable Mobility for All (2017: 27). Licensed under CC-BY 3.0 IGO.

Sum4All is working with the Development Bank of Southern Africa DBSA to finalize a diagnostic of South Africa's transport system as the first country to use the Global Roadmap of Action toward Sustainable Mobility (GRA) to devise a tailored action plan for transport; as well as SuM4All's latest tools, such as its Global Tracking Framework 2.0 to diagnose mobility issues and benchmark the performance of its transport sector against relevant comparator countries (Vandycke and Da Silva 2021). Unsurprisingly, given Apartheid spatial planning and large hinterland industrial and urban concentrations, South Africa finds itself in the lower performance quadrant of the Global SDG Index *vs.* Global Sustainable Mobility Index map (Figure 22).

Figure 22: Global performances on the SDGs and sustainable mobility



Source: reproduced from Vandycke and Da Silva (2021). The World Bank Group authorizes the use of this material subject to the terms and conditions on its website, Legal.

Efforts is now underway to upgrade the GRA in a post-pandemic environment and then to 'produce a prototype action plan consisting of priority policy measures that support South Africa's transition toward sustainable mobility and the SDGs' (Vandycke and Da Silva 2021).

The shipping container revolution proved the positive impact of modularity and standardization as Logistics Genetic Technologies (LGTs). According to the World Bank (2021) more than 90 percent of global freight is shipped in containers. Montreuil's Physical Internet (PI), described in the next section, promises to transform the future transport and must therefore be considered for the modernization of South Africa railways.

3.12 The Physical Internet (PI)

'The Physical Internet (PI) is a holistic Supply Chain Management (SCM) concept that merges many relevant areas of current SCM research, including sustainability, effectiveness and efficiency of global value chains, information flows, as well as horizontal and vertical collaboration' (Treiblmaier et al. 2007). Ballot et al. (2014: 23) defines the PI as 'a global logistics system based on the interconnection of logistics networks by a standardized set of collaboration protocols, modular containers and smart interfaces for increased efficiency and sustainability'. The PI model was inspired by the ISO/IEC 7498 family of standards for a 7-layer Open Systems Interconnection (OSI 7-layer) communications model to create a network of connected computers in a structured fashion.

First used in 2006 by the Economist magazine, a number of researchers came together to assess whether the flow of goods could be organized in a similar manner as the flow of data. Montreuil (2011) defined 13 issues that lead to unsustainable logistics practices.

The 13 unsustainable logistics practices are, *verbatim*: 'i) we are shipping air and packaging; ii) empty travel is the norm; iii) truckers have become the modern cowboys; iv) products mostly sit idle, stored where unneeded, yet so often unavailable where needed; v) production and storage facilities are poorly used; vi) so many products are never sold, never used; vii) products do not reach those who need them the most; viii) products unnecessarily move, crisscrossing the world; ix) fast and reliable intermodal transport is still a dream; x) getting products in and out of cities is a nightmare; xi) networks are neither secure nor robust; xii) smart automation and technology are hard to justify; and xiii) innovation is strangled' (Montreuil 2011).

The 13 principles to address this challenge are, *verbatim*: 'i) objects encapsulated in world standard modular containers; ii) universal interconnectivity; iii) container handling and storage systems; iv) smart network containers embedding smart objects; v) distributed multi-segment intermodal transport; vi) unified multi-tier conceptual framework; vii) open global supply web; viii) product design for containerization; ix) product materialization near the point of use; x) open performance monitoring and capability certification; xi) webbed reliability and resilience of networks; xii) business model innovation; and xiii) open infrastructural innovation' (Montreuil 2011). Sternberg and Norrman (2017) related them in a 13 x 13 matrix.

In 2017 the Alliance for Logistics Innovation through Collaboration in Europe (ALICE) published the PI implementation roadmap until 2050 (ALICE 2017).

A modern standard gauge national rail backbone design must be informed by the PI demands on rail transport in in South Africa. Ultimately the SG railway must enjoy a dominant modal market share for rail-friendly freight where π-containers will at least be consolidated into pallets, and pallets into both shipping and domestic containers.

4 Research Framework

4.1 Research Approach

Figure 23 below details the TOR as a process model. The main activity is to '*Develop a Modern Standard Gauge National Rail Backbone Strategy for South Africa*' thereby transforming the '*National Rail Policy Draft White Paper: -First draft June 2017 (DoT)*' input document and the GAIN 2050 Freight Demand Model into four output deliverables, *viz.* –

- O1: '*High-level long-term plan* for the sequenced, phased and feasibility-based development of a modern standard gauge national rail backbone, built on the principles of open access, multiple concessions, private sector investment, and connectivity to passenger and freight terminals.'

- O2: '*Geographic overview* of how this could be achieved over time as well as a high-level assessment of what could be done first and subsequent sequencing.'

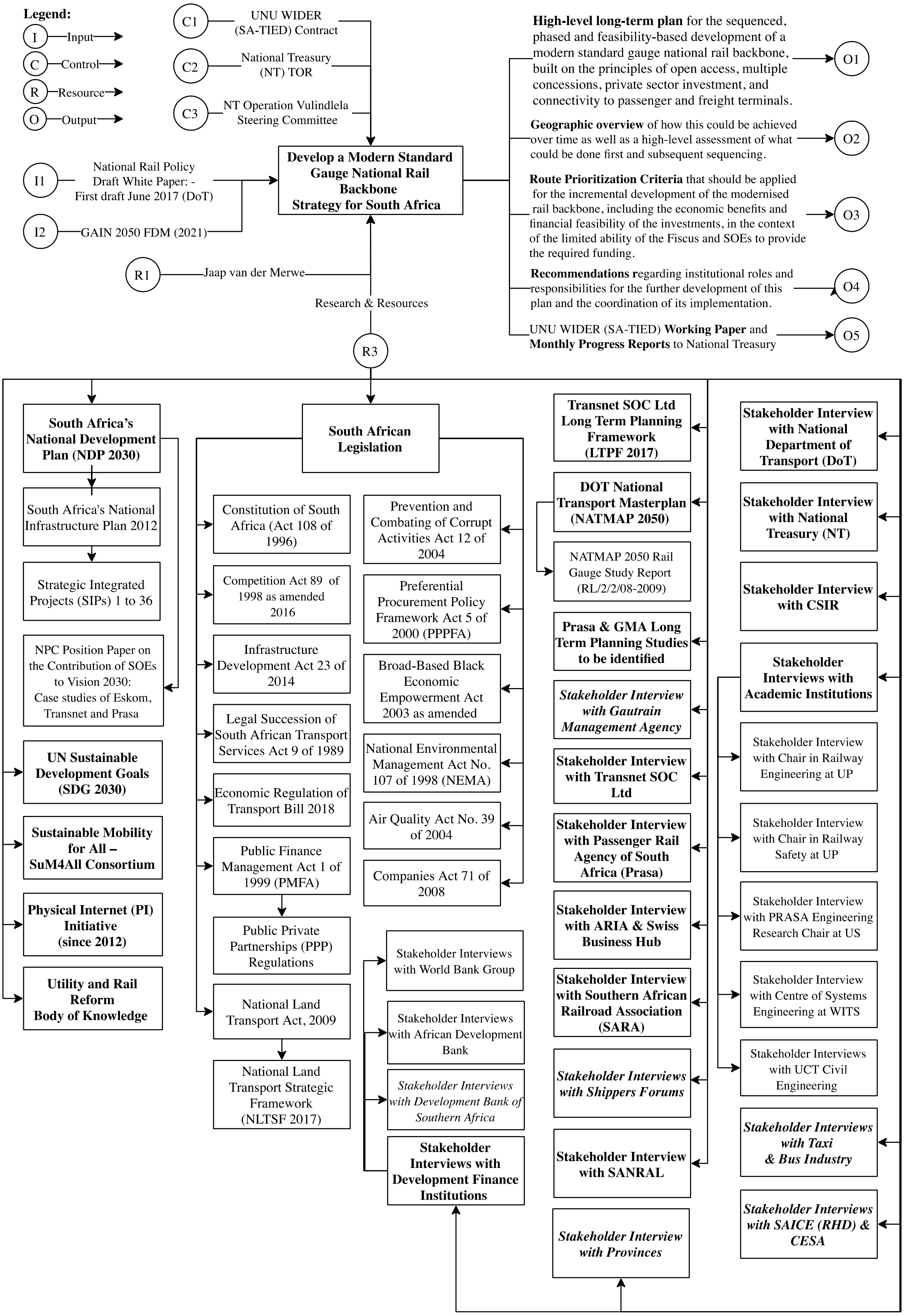
- O3: '*Route Prioritization Criteria* that should be applied for the incremental development of the modernized rail backbone, including the economic benefits and financial feasibility of the investments, in the context of the limited ability of the Fiscus and SOEs to provide the required funding.'

- O4: '*Recommendations* regarding institutional roles and responsibilities for the further development of this plan and the coordination of its implementation.'

Various resources are used during the research including legislation, domestic and global frameworks and models, as well as a number of stakeholder interviews.

The output of this research publication is to be styled as a*n SA-TIED Report*.

Figure 23: IDEF0 process model interpretation of the research project



Source: author's synthesis.

4.2 Research Questions

Five research questions are addressed in this study for each of freight and passenger rail in South Africa. They are:

1. What is the existing rail capacity?
2. What is the traffic demand?
3. Is there enough capacity?
4. How can we improve the existing system?
5. When, Where, and Why do we need a Standard Gauge Railway?

4.3 Research Methodology

The research methodology is anchored in five independent perspectives. Three are quantitative in nature and two are qualitative in nature. They are:

Quantitative:

1. Review of metadata from existing studies, notably NATMAP 2050.
2. Analysis of original data notably provided by:
    a. the Author;
    b. Transnet BSc. Railway Operations Management students enrolled at Glasgow Caledonian University; and
    c. Stellenbosch University Logistics Professor Jan Havenga and his team at the GAIN Group.
3. Benchmarking data, notably from: i) Canadian National Railway, and ii) Sum4All™.

Qualitative:

4. Stakeholder interviews held by the Author with:
    a. Government (National Treasury, and the Department of Transport);
    b. State-owned Rail Operators (PRASA, and Transnet);
    c. Multilateral Development Finance Institutions (African Development Bank, and the World Bank);
    d. Railway Industry Associations (African Rail Industry Association, and the Swiss Rail Industry Association); and
    e. South African Academic Institutions (UCT Chair in Railway Engineering, UP Transnet Chair in Railway Engineering, UP RSR Chair in Railway Safety, US interim PRASA Chair in Railway Engineering, and WITS Transnet Centre for Systems Engineering).

5. Railway Reference Models developed by the Author.

The research process follows a typical Analysis and Synthesis process.

5 Discussion of Research Results

5.1 National Rail Policy Draft White Paper 2017

By listing fourteen project completion milestones, the National Rail Policy Draft White Paper 2017 calls for a major Standard Gauge build programme.

A standardized life cycle is used to develop a large-scale economic infrastructure projects. To secure funding the project cost risk must be minimized, and a high level of cost certainty is required, which could be as much as 5 per cent of the project cost (Schneider-Roos et al. 2014).

The process to determine cost accuracy in the order of 80% to 85% commences with an Opportunity Assessment, Business Case and Technical Studies, Viability Studies and Modelling, and Detail Design.

Institutional Arrangements are finalized as part of Financial Close, and Underwriting & Finance Build Own Operate (FBOO). A variety of models exist to achieve FBOO and can could range from State-Owned, Public Private Partnership (PPP) Concession, to Privately-owned. A Project Company is typically established by the project promoters to accommodate the interest of all parties (World Bank 2014). Note that it typically takes many years from Opportunity Assessment to Financial Close and final Institutional Arrangements. Unless this process is aggressively managed by government, programme fatigue will set in, and the milestones will not be reached.

The next few activities are often referred to as the Engineering Procurement and Construction (EPC) phase. Construction can only start once all of the above has been concluded in Essential Agreements and the funding is available. Post Construction there is a Commissioning phase of at least six months followed by a 2 to 3-year Operations phase where Defects Liability apply. Only once this period has lapsed, can the project be considered complete whereafter the Long-term Operations and Maintenance (O&M) phase commences. Technically the Project Life Cycle is incomplete without a Retirement phase, which in the case of new railways exceeds 50 years.

Figure 24 to Figure 27 below show the most optimistic implementation programme to comply with the Standard Gauge conversion statements expressed in the NRP (Department of Transport 2017). The programme assumes a perfected procurement process, sufficient and available funding, and capable Engineering, Procurement and Construction (EPC) service providers, a favourable investment climate, and so forth. The programme is ambitious and will probably require legislative intervention to avoid stalling.

The Work Breakdown Structure is classified according to Milestone dates ('M') and Activities ('A'). NRP 2017 determine 14 major Activities and 15 Milestones. Cells marked in Red are considered late milestones ('M') that will probably delay the programme, those milestones ('M') marked Yellow are about to delay the programme, and those in Green are NRP (2017) target dates. Cells marked in Gray indicate planned programmed activities ('A') and cells marked in Hashed Gray indicate estimated slack in the planned programme activities ('A') without impacting the Green milestones ('M').

Whereas detail costing of the NRP 2017 programme clearly lies outside the scope of this study, Table 7 provides a good benchmark indication of the rail project costs. The weighted average cost of a High-Speed Rail (>250 km/h) project is U$22,7 million per route-km, and the US$8,4 million per route-km for a 160km/h high-performance conventional project. These costs include expropriation of land and resettlement of communities.

Table 7: Benchmark cost of new Standard Gauge railway projects

Project / Territory	Distance	Standard Gauge Project Cost per km	
		HSR (US$)	**Conventional 160km/h (US$)**
EU	3,475 km	17 million	
China	37,900 km	17–21 million	
USA California	832 km	96 million	
UK HS2	531 km	209 million	
EU	6,819 km		8,6 million
Kenya 75km/h freight and 120km/h passenger			
Mombasa- Nairobi	463 km		6,7 million
Nairobi-Naivasha	120 km		12,3 million
Tanzania 75km/h freight and 120km/h passenger			
Dar es Salaam - Morogoro	202 km		5,82 million

Source: author's own research.

Table 8: Estimated CAPEX to implement the NRP 2017 programme

Acivity / Milestone	Distance (km)	Project Cost US$m
Estimated CAPEX	**5,360**	**55,630**
Gauteng–eThekwini HSR	720	16,342
Regional Rapid Transit	150	1,270
Additional urban guided transit corridors (e.g. Cape Town - CTIA - Stellenbosch, King Shaka Airport - Durban)	90	762.05
Gauteng to Cape Town high performance standard gauge national network	1,500	12,701
Gauteng to Nelson Mandela high performance standard gauge national network	1,100	9,314
Gauteng to eThekwini high performance standard gauge national network	720	6,096
Gauteng to Musina high performance standard gauge national network (incl. EMSEZ)	530	4,488
Other high performance standard gauge national network sectors		-
Boegoebaai Port and Rail Infrastructure	550	4,657

Source: author's estimate.

On this basis the NRP 2017 CAPEX programme would amount to some U$55,64 billion, or ZAR792,43 billion (at 28 June 2021 exchange rate of ZAR: US$ = 14,25).

Figure 24: Most optimistic implementation programme to comply with the Standard Gauge conversion statements expressed in the NRP 2017 (1 of 4)

Activity / Milestone	Sub	Acivity / Milestone	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
M1		National Rail Policy enacted																																
M2		Accounting separation of TFR Infrastructure Manager and TFR Train Operator complete and regulated third party access commences																																
M3		National Rail Master Plan completed																																
M4		Local authorities complete planning for additional urban guided transit corridors																																
A5		**Construction of short lead time projects**																																
	A.1	Opportunity Assessment																																
	A.2	Business Case & Technical Studies																																
	A.3	Viability Studies & Modeling																																
	A.4	Detail Design																																
	A.5	Financial Close																																
	A.6	Underwriting & Private Sector Partner Contracting																																
M5		*Construction of short lead time projects commences (followed in later years by longer lead time projects)*																																
	A.7	Construction																																
	A.8	Commissioning																																
		Devolution and assignment of urban guided transit to local authorities																																
		Devolution and assignment of urban guided transit to local authorities completed																																
A6		**Gauteng–eThekwini HSR**																																
	A.1	Opportunity Assessment																																
	A.2	Business Case & Technical Studies																																
	A.3	Viability Studies & Modeling																																
	A.4	Detail Design																																
	A.5	Financial Close																																
	A.6	Underwriting & Private Sector Partner Contracting																																
	A.7	Construction																																
	A.8	Commissioning																																
M6a		*Operating commencement date for Gauteng–eThekwini high speed trains*																																
M6b		*Latest operating commencement date for Gauteng—eThekwini high speed trains*																																
	A.9	Defects Libiablity Period Operations																																
	A.10	Long Term Operations & Maintenance																																
	A.11	Decommissioning & Dismantling																																

Source: author’s assessment.

Figure 25: Most optimistic implementation programme to comply with the Standard Gauge conversion statements expressed in the NRP 2017 (2 of 4)

Activity / Milestone	Sub	Acivity / Milestone	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
A7		**Regional Rapid Transit**																																
	A.1	Opportunity Assessment		■																														
	A.2	Business Case & Technical Studies			■																													
	A.3	Viability Studies & Modeling				■																												
	A.4	Detail Design					■																											
	A.5	Financial Close						■	■																									
	A.6	Underwriting & Private Sector Partner Contracting								■	■																							
	A.7	Construction										■	■	■																				
	A.8	Commissioning													■																			
M8		*Earliest operating commencement date for regional rapid transit trains.*														■																		
	A.9	Defects Libiablity Period Operations														■	■																	
	A.10	Long Term Operations & Maintenance																■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	A.11	Decommissioning & Dismantling																																
A8		**Additional urban guided transit corridors**																																
	A.1	Opportunity Assessment		■																														
	A.2	Business Case & Technical Studies			■																													
	A.3	Viability Studies & Modeling				■																												
	A.4	Detail Design					■																											
	A.5	Financial Close						■	■																									
	A.6	Underwriting & Private Sector Partner Contracting								■	■																							
	A.7	Construction										■	■	■																				
	A.8	Commissioning													■																			
M9		*Earliest operating commencement date for additional urban guided transit corridors.*														■																		
	A.9	Defects Libiablity Period Operations														■	■																	
	A.10	Long Term Operations & Maintenance																■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	A.11	Decommissioning & Dismantling																																
A10		**Gauteng to Cape Town high performance standard gauge national network**																																
	A.1	Opportunity Assessment					■																											
	A.2	Business Case & Technical Studies						■																										
	A.3	Viability Studies & Modeling							■																									
	A.4	Detail Design								■																								
	A.5	Financial Close									■	■																						
	A.6	Underwriting & Private Sector Partner Contracting											■	■																				
	A.7	Construction													■	■	■																	
	A.8	Commissioning																■																
	A.9	Defects Libiablity Period Operations																	■	■														
M10		*Gauteng to Cape Townhigh performance standard gauge national network completed*																			■													
	A.10	Long Term Operations & Maintenance																				■	■	■	■	■	■	■	■	■	■	■	■	■
	A.11	Decommissioning & Dismantling																																

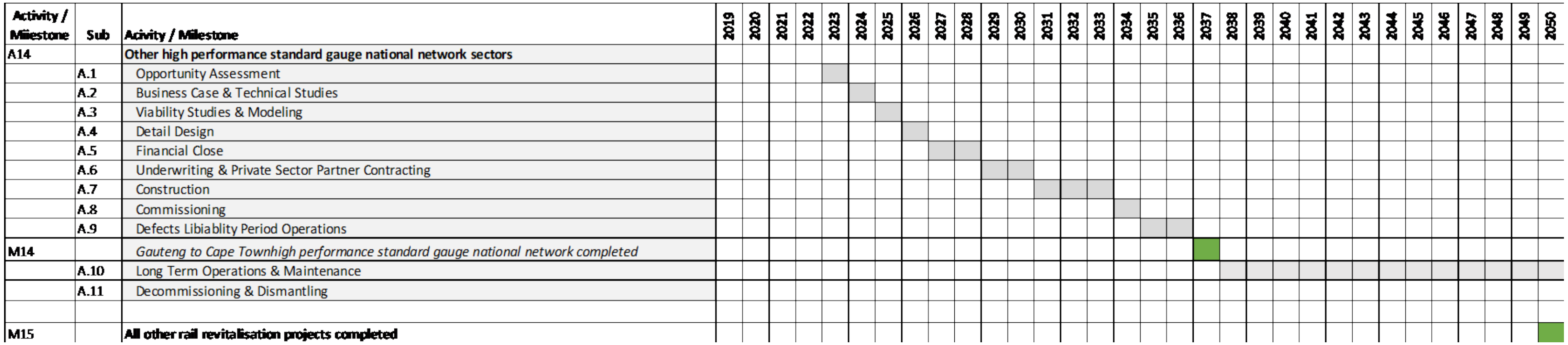
Source: author's assessment.

Figure 26: Most optimistic implementation programme to comply with the Standard Gauge conversion statements expressed in the NRP 2017 (3 of 4)

Activity / Milestone	Sub	Acivity / Milestone	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
A11		**Gauteng to Nelson Mandela high performance standard gauge national network**																																
	A.1	Opportunity Assessment																																
	A.2	Business Case & Technical Studies																																
	A.3	Viability Studies & Modeling																																
	A.4	Detail Design																																
	A.5	Financial Close																																
	A.6	Underwriting & Private Sector Partner Contracting																																
	A.7	Construction																																
	A.8	Commissioning																																
	A.9	Defects Libiablity Period Operations																																
M11		*Gauteng to Nelson Mandela high performance standard gauge national network completed*																																
	A.10	Long Term Operations & Maintenance																																
	A.11	Decommissioning & Dismantling																																
A12		**Gauteng to eThekwini high performance standard gauge national network**																																
	A.1	Opportunity Assessment																																
	A.2	Business Case & Technical Studies																																
	A.3	Viability Studies & Modeling																																
	A.4	Detail Design																																
	A.5	Financial Close																																
	A.6	Underwriting & Private Sector Partner Contracting																																
	A.7	Construction																																
	A.8	Commissioning																																
	A.9	Defects Libiablity Period Operations																																
M12		*Gauteng to eThekwini high performance standard gauge national network completed*																																
	A.10	Long Term Operations & Maintenance																																
	A.11	Decommissioning & Dismantling																																
A13		**Gauteng to Musina high performance standard gauge national network**																																
	A.1	Opportunity Assessment																																
	A.2	Business Case & Technical Studies																																
	A.3	Viability Studies & Modeling																																
	A.4	Detail Design																																
	A.5	Financial Close																																
	A.6	Underwriting & Private Sector Partner Contracting																																
	A.7	Construction																																
	A.8	Commissioning																																
	A.9	Defects Libiablity Period Operations																																
M13		*Gauteng to Cape Townhigh performance standard gauge national network completed*																																
	A.10	Long Term Operations & Maintenance																																
	A.11	Decommissioning & Dismantling																																

Source: author's assessment.

Figure 27: Most optimistic implementation programme to comply with the Standard Gauge conversion statements expressed in the NRP 2017 (4 of 4)



Source: author’s assessment.

5.2 Exploitation of Rail Genetic Technologies in the various Rail Market Spaces

Save for Bus Rapid Transit (BRT) preferred over Light Trail (trams) in South Africa, Figure 28 provides a roadmap for each of the rail market spaces.

Increasing exploitation of the three rail genetic technologies (RGT) is increasingly (not necessarily linearly—more likely exponentially) costly and technically complex and must be validated through viability studies:

i) ***Bearing* of heavy loads.** Heavier bearing requires deeper special formation layer works to disperse higher load pressure; larger cross-tie sleepers to bulk up the rails; higher flange rails with harder and larger rail heads to endure frequent rail grinding to eliminate more easily forming fatigue cracks; special wheel tyres to match the head-hardened rails; special wheel bearings to avoid crushing under load and seizing up wheel movement; stronger rail fasteners to hold the rail upright under dynamic loading conditions; harder and more flexible crossing mechanisms in turnouts to withstand higher lateral shocks; more regular screening and tamping of faster wearing ballast crushed stone; better braking systems; more energy-efficient train handling; more wayside monitoring of rail breaks, wheel profiles, dragging equipment; etc.—all at increased CAPEX and OPEX and reduced track availability to allow for on track and wayside maintenance. *Australia* leads globally on the *bearing RGT* with iron ore trains loaded to 40 tonnes per axle on standard gauge. South Africa underperforms by 25% against the *Australian*s in terms of the *bearing RGT*, which requires at least a standard gauge to ensure the requisite stability of the freight wagon.

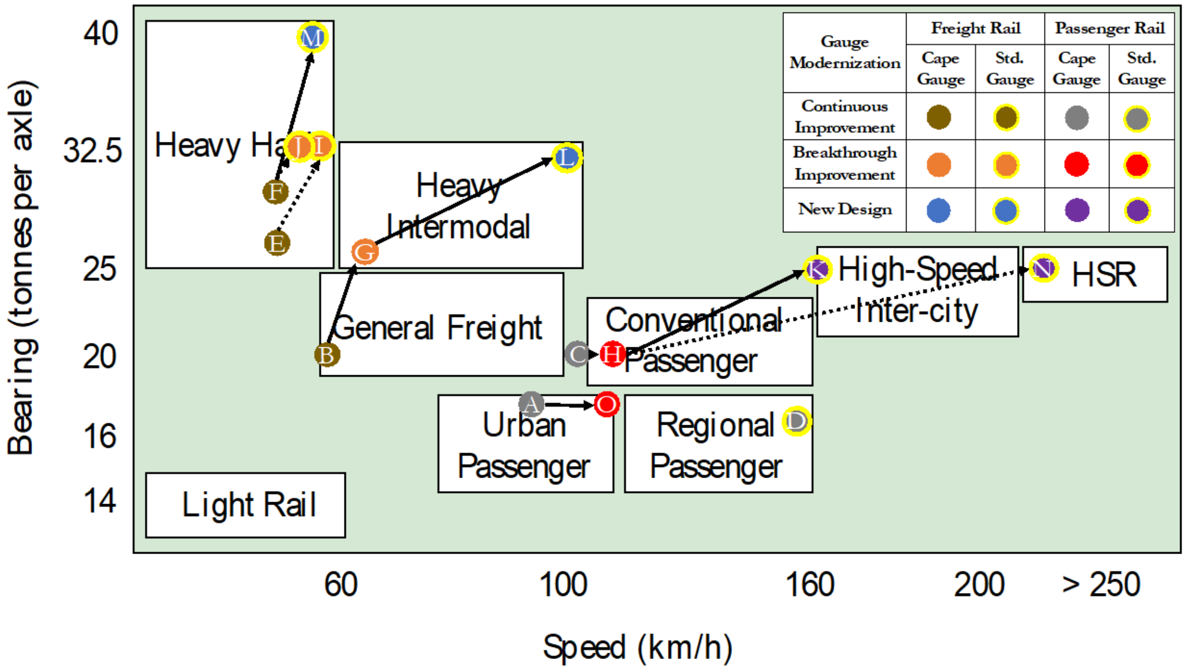
ii) ***Coupling* of long trains.** Longer coupled trains require longer passing loops on single lines; longer signalling track occupation blocks; better distribution of power throughout the train to prevent excessive forces from breaking draw-gear; smarter and longer-range train integrity / train completeness devices; better braking systems; more energy-efficient train handling; flatter vertical curves to avoid the train operating across more than to gradients; more wayside monitoring of rail breaks, wheel profiles, dragging equipment; etc.—all at increased CAPEX and OPEX and reduced track availability to allow for on track and wayside maintenance. Both *South Africa*'s 374-wagon multi-rake iron ore (loaded to 30 tonnes per axle) and manganese (loaded to 20 tonnes per axle) combination trains and the 342-wagon multi-rake iron ore trains (loaded to 30 tonnes per axle) lead in the in exploitation of the *coupling RGT* as the longest and second longest trains in the world on any rail gauge. *South Africa* outperforms the nearest global competitor by between 3,6% (pure iron ore rake trains) and 13,3% (mixed iron ore and manganese rakes) in terms of the *coupling RGT*. South Africa exploited the coupling RGT to compensate for gauge stability limitations associated with higher wagon centre gravity required to exploit the bearing RGT.

iii) ***Guiding* to allow for energy efficient travel at high speeds on a perfected road.** Faster guided trains require hyper-responsive signalling and telecommunication systems, perfect track conditions such as guaranteed cant on curves and rail head profiles; much longer turnouts; longer horizontal curves; flatter vertical curves; more wayside noise suppression; dedicated track; advanced braking systems; guaranteed stable overhead power supply; perfected catenary and contact wire tensions; more wayside monitoring of rail breaks, wheel profiles, dragging equipment; etc.—all at increased CAPEX and OPEX and reduced track availability to allow for on track and wayside maintenance. China leads globally on the *guiding RGT* with 37 900km of HSR track operating at a minimum of 250km/h to 380km/h. Note also that China operates the 8minute / 30km Shanghai airport link using a magnetically levitated (MAGLEV) train running at 431km/h, and Japan has tested its MAGLEV train successfully at 603km/h. Whilst the Spanish Frecciarossa 1000 train is Europe's fastest train with a maximum operating speed of 400km/h, the Chinese CRH380A train operates at a maximum speed of 380km/h, China is the market leader on the guiding RGT with ten times more HSR track than all of Europe combined (3 475km). South Africa underperforms by 60% (at 250km/h) to 73,7% (at 380km/h) against China in terms of *guiding RGT*. Trains operating at high speed require a wide gauge to ensure ride comfort—the aforementioned Chinese CRH380A train is designed to be vibration free at high speed.

5.3 Modernization Strategy

Refer to Figure 28 and Table 9 and Table 10.

Figure 28: Modernization Roadmap for South African Rail Market Spaces



Source: author's elaboration.

Table 9: Quantified Modernization Roadmap for South African Passenger Rail Market Spaces

Market Space	Description	From Volumes	To Volumes	Roadmap Vector	Continuous Improvement				Breakthrough Improvement				New Idealized Design			
		TKM; PKM; Mtpa; Mpax pa	TKM; PKM; Mtpa; Mpax pa		OPEX	Time	Rail	Corridor	CAPEX	Time	Rail	Corridor	CAPEX	Time	Rail	Corridor
					Rbn; Level	(years)	IRR	EIRR	Rbn; Level	(years)	IRR	EIRR	Rbn; Level	(years)	IRR	EIRR
Urban Passenger	Metrorail post-COVID Lockdown Rehabilitation	10m Ppa	270m Ppa	A	Low (R1,9bn)	2	2014/15	2014/15								
	120kph Modernization Program	270m Ppa	1bn Ppa	A → O					High (R76,8bn)	10	2023/24	2023/24				
		1bn Ppa	1,1bn Ppa	O	Low	10	2034/35	2034/35								
Regional Passenger	Gautrain Rapid Rail Link Continuous Improvement	14m Ppa	14m Ppa	D	Low	6	2026/27	2026/27								
		14m Ppa	30m Ppa	D									High	10	2049/50	2049/50
		TBD	TBD										High	10	2049/50	2049/50
Conventional Passenger	Shosholoza Meyl post-COVID Lockdown	0,2m Ppa	2,8m Ppa	C	Low	2	2009/10	2009/10								
	Shosholoza Meyl speed & safety improvement (120kph; ATP)	2,8m Ppa	3m Ppa	C → H					Low	2	2014/15	2014/15				
	Shosholoza Meyl CI	3m Ppa	3,3m Ppa	H	Low	3	2014/15	2014/15								
High Speed Inter-City	Shosholoza Meyl 160kph	3,3m Ppa	5m Ppa	H → K									High	10	2049/50	2049/50
	Shosholoza Meyl 160kph CI	5m Ppa	5,5m Ppa	K	Med	10	2049/50	2049/50								
HSR	Gauteng - Tthekwini HSR	3,7m Ppa	3,7m Ppa	H → N									High	10	2049/50	2049/50
				N	High	10	2049/50	2049/50								

Source: author’s elaboration.

Table 10: Quantified Modernization Roadmap for South African Freight Rail Market Spaces

Market Space	Description	From Volumes	To Volumes	Roadmap Vector	Continuous Improvement				Breakthrough Improvement				New Idealized Design			
		TKM; PKM; Mtpa; Mpax pa	TKM; PKM; Mtpa; Mpax pa		OPEX Rbn; Level	Time (years)	Rail IRR	Corridor EIRR	CAPEX Rbn; Level	Time (years)	Rail IRR	Corridor EIRR	CAPEX Rbn; Level	Time (years)	Rail IRR	Corridor EIRR
General Freight	Corridor traffic excluding Manganese Exports via Saldanha	14b TKM	28b TKM	B	Low	2 – 3	2019/20	2019/20								
	Domestic Intermodal	nil	8bn TKM	B → G					Med	03-Feb	2019/20	2019/20				
Heavy Inter-modal	Domestic Intermodal	8bn TKM	9bn TKM	G	Low	2 – 3	2019/20	2019/20								
		9bn TKM	14b TKM	G → L									High	> 5	2049/50	2049/50
		14b TKM	16b TKM	L	Low	>10	2049/50	2049/50								
Heavy Haul	Coal Export	72 Mtpa	81 Mpta	E	Low	1 – 2	2010	2010								
		81 Mpta	91 Mtpa	E → I	High	5 – 7	2020	2020								
		91 Mpta	91 Mtpa	I	Low	1	2025	2025								
	Iron Ore Export	60 Mtpa (52bn TKM)	65Mtpa (55bn TKM)	F	Low	1 – 2	2010	2010								
		65Mtpa (55bn TKM)	78Mtpa (67bn TKM)	F → J					Med	2– 3	2025	2025				
		78Mtpa (67bn TKM)	78Mtpa (67bn TKM)	J	Low	1	2025	2025								
		78Mtpa (67bn TKM)	123 Mtpa (76,16b TKM)	J → M									High	5	2049/50	2049/50
		123 Mtpa (76,16b TKM)	123 Mtpa (76,16b TKM)	M									High	5	2049/50	2049/50

Source: author’s elaboration.

5.4 Urban Passenger Market Space

cf. Roadmap Vector AO in Figure 28.

PRASA currently operates the Metrorail service, which has been decimated by vandalism over many years. Since the insourcing of security staff at the end of 2019, the number of security related incidents escalated dramatically in the run-up to the March 26, 2020 COVID-19 pandemic Level 5 hard lockdown. PRASA publicly estimates the COVID-19 pandemic era vandalism at R1.9bn. A Continuous Improvement programme, in the style of a post-WWII 'Marshall Plan' is probably required to recover from the last 15 months of excessive vandalism.

Note that both the Preferential Procurement Policy Framework Act 5 of 2000 (PPPFA) and the Public Finance Management Act (PFMA) allow for the respective ministers to approve exemptions to the provisions of the acts: i) *PPPFA section 3:* 'The Minister may, on request, exempt an organ of state from any or all the provisions of this Act if (a) it is in the interests of national security; (b) the likely tenderers are international suppliers; or (c) is in the public interest.' ii) *PFMA section 92:* 'The Minister, by notice in the national Government Gazette, may exempt any institution to which this Act applies, or any category of those institutions, from any specific provisions of this Act for a period determined in the notice.' The outcome of the 'Marshall Plan' should be to restore the Metrorail patronage from 10 million passengers trips per annum back to the 2014/15 business case of 270 million.

Around 2010 PRASA embarked on a national 120 km/h modernization programme. This entails comprehensive re-signalling of the Gauteng (by Siemens), Western Cape (by Thales) and KwaZulu Natal (by Bombardier, now acquired by Alstom) metro networks, station modernization including platform-train interface (PTI is a major safety risk) correction and procurement of 600 new trains from Alstom. Given a CAPEX of some R76,8 billion this programme can be considered as a Breakthrough Improvement and should grow patronage capacity from 270 million passenger trips per annum (2014/15 business case) towards 1 billion passenger trips per annum (2023/24 business case). Once achieved Continuous Improvement should extend the system by at least 10% for a nominal 2034/35 business case of 1.1 billion passenger trips per annum. Note that these estimates must be validated and finalized by careful and exhaustive analysis of the new signalling system headway running times, which falls outside the scope of this research project. Note also that the accelerate – decelerate – stop cycle over the relative short distances between Metrorail stations, sharp curvature and crossovers all militate against a change of rail gauge to exploit rider comfort and faster speed.

5.5 Regional Passenger Market Space

cf. Roadmap Scalar D in Figure 28.

The Gautrain Rapid Rail Link (GRRL) is the only Regional Rail system that presently operates in South Africa. It is built to the global standard of 160km/h on Standard Gauge and requires only Continuous Improvement. Expansion of the Gautrain network should be a simple case of 'more of the same', perhaps with different technology providers as long as interoperability of trains and systems is guaranteed. Note that although GRRL trains are controlled by the 'standardized' European Train Control System (ETCS) Level 2, the Swiss Rail Industry Stakeholder Interview explicitly warned against Standard / Technology / Vendor complacency during procurement if full interoperability across the multi-phase GRRL network is envisaged.

5.6 Conventional Rail Market Space

cf. Roadmap Vector CH in Figure 28.

PRASA operates a Main Line Passenger Services (MLPS), branded as 'Shosholoza Meyl', on an access-arrangement across the Transnet Freight Rail network. The service has collapsed by 92,8% from 2,8 million passenger trips per annum in 2009/10 to 200 thousand in 2019/20. In 2013 PRASA controversially procured 70 new 'Afro 4000' main line locomotives from Vossloh España via a controversial BB-BEE intermediary, Swifambo Rail Leasing, for R3,5 billion. Subsequently in late 2015 Stadler Rail acquired the OEM business from Vossloh AG. Apart from legal disputes pertaining to this purchase, it is not clear that PRASA can recover market share and grow the business back to 2,8 million passenger trips per annum. Furthermore, given that this MLPS service is subject to access on the Transnet Freight Rail network, the most realistic modernization strategy is a relatively low-cost Continuous Improvement drive. The MLPS business case must be significantly review to warrant either Breakthrough Innovation or a New Idealized Design. In terms of global standards, both such interventions will require a Standard Gauge railway. At the low-end, the future MLPS network will resemble the European 160km/h Conventional Passenger market space; and at the high-end the future MLPS network will resemble the European 250km/h 'slow' HSR market space. Both options will require a new dedicated route alignment with a number of costly tunnels and many grade easing bridges to navigate the escarpment between Gauteng and Durban, and also Cape Town.

5.7 High Speed Intercity Market Space

cf. Roadmap Vector HK in Figure 28.

As per Table 7, the average cost to migrate Conventional Passenger rail from 120km/h on Cape Gauge to the 160km/h on Standard Gauge High-Speed Intercity Market Space is US$8,4 million per route-km.

5.8 High Speed Rail (HSR) Market Space

cf. Roadmap Vector HN in Figure 28.

As per Table 7, the average cost to migrate Conventional Passenger rail from 120km/h on Cape Gauge to the HSR Market Space amounts to U$22,7 million per route-km. NATMAP 2050 calculated the cost implications of HSR. At ZAR1000 per seat-trip (2009 Rands), the service must carry 10 800 passengers per day, or 3.7 million passengers per 350-operating days annum.

5.9 General Freight Market Space

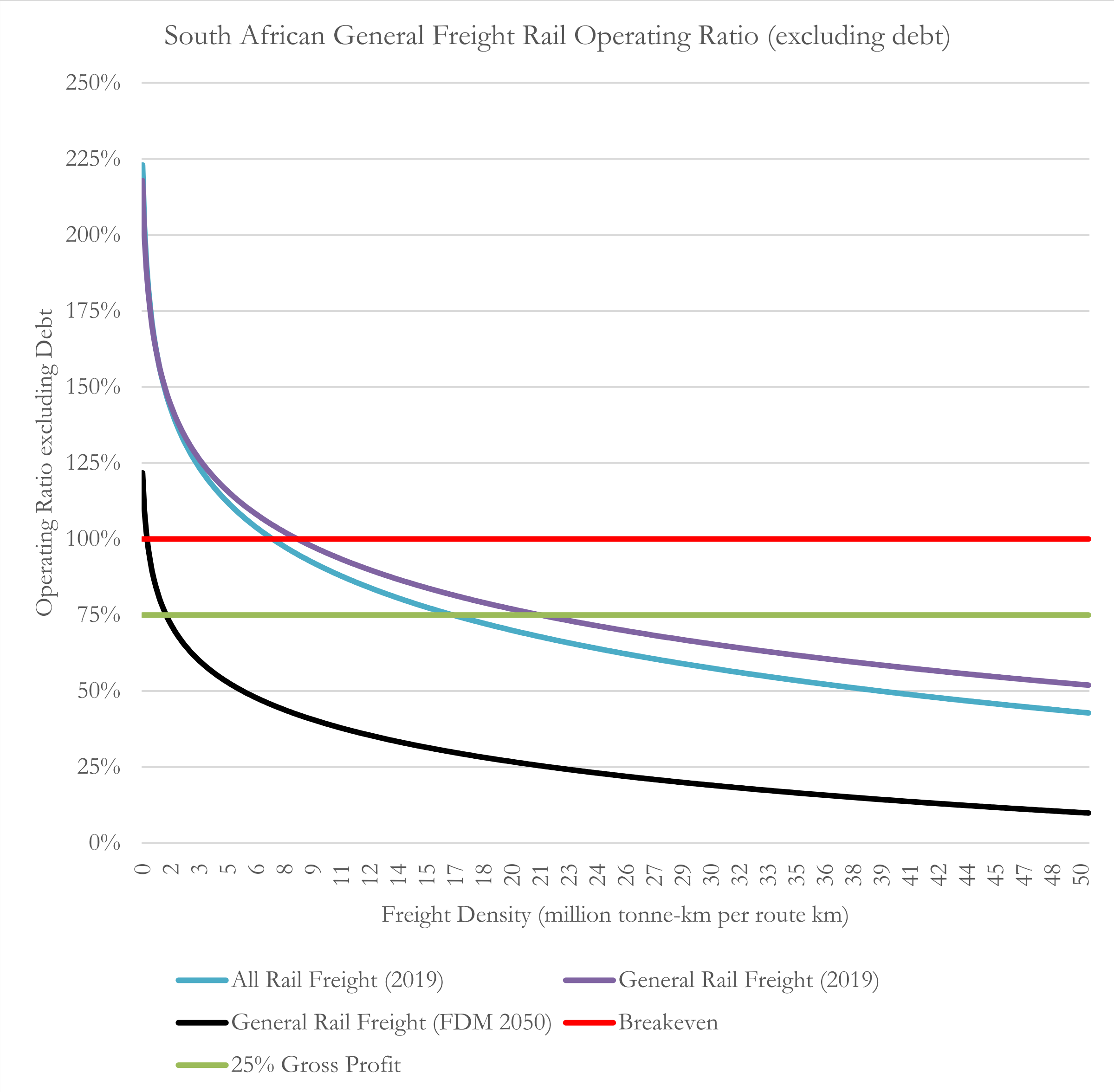
Roadmap Vector B in Figure 28 covers the following existing Transnet Freight Rail corridors used in the analysis of all Freight Market Spaces: i) Northcor (covering the Ystervarkfontein - Sentrarand – Musina area); ii) Eastcor (covering the Steelpoort - Clever – Mozambique border area); iii) Southcor (covering the Calitzdorp - Gqeberha area); iv) Sentracor (covering the Kazerne – Welgedag area); v) Capecor (covering the Houtheuwel - Cape Town area); vi) North Westcor (covering the Lephalale - Pendoring – Atlanta area); vii) Natalcor (covering the Kaydale - Durban - Port Shepstone area); viii) Richards Baycor (covering the Welgedag - Richards Bay area) excluding the heavy-haul coal exports on the corridor; ix) North Eastcor (covering the Tzaneen - Golela via Swaziland area); x) Saldanha (covering the Saldanha – Sishen area) excluding the heavy-haul iron ore exports on the corridor; xi) Westcor (covering the Lichtenburg - Pudimoe – Langlaagte area); xii) Free State (covering the Winburg - Maseru - Springfontein area); xiii) South Eastcor (covering the Aliwal North - East London area); and xiv) Namibia (covering the Kakamas – Nakop border area).

Analysis of the Transnet Freight Rail 2018/19 actual traffic on these corridors resulted in a reference logarithmic curve estimating the Rail Corridor Operating Ratio excluding capital cost as a function of Freight Traffic Density in South Africa (Table 11, Figure 29).

Table 11: Rail Traffic Operating Ratio excluding capital cost as a function of Freight Traffic Density in South Africa (Source: Author's analysis).

Rail Traffic	Operating Ratio Function (2019 Actual)	Freight Demand Model Operating Ratio Function (2050)
General Freight and Heavy Haul Traffic	y = -0,29ln(x) + 1,5624	
General Freight Traffic only	y = -0,312ln(x) + 1,5217	y = -0,18ln(x) + 0,803

Figure 29: Rail Corridor Operating Ratio vs. Freight Traffic Density in South Africa



Source: author's analysis.

Table 12 lists the 2018/19 to 2049/50 coordinates for each of the fourteen general freight corridors and classifies them for the most likely pragmatic Modernization Strategy. Each corridor is assessed on three criteria: i) the ability to service debt from operating profits as indicated by the anticipated Operating Ratio; ii) the end state density that speaks to operating cost and level of macro-economic interest in a specific corridor; and iii) the quantum of change anticipated in the corridor density over the next 30 years.

Whereas heuristically: i) a corridor that will become highly densified off a low base can probably afford substantial CAPEX for an New Idealized Design; ii) a corridor that will experience significant densification off an solid base probably can raise the moderate CAPEX required to increase performance from a Breakthrough Improvement of the existing design; and iii) a corridor that shows modest growth off a modest or low base probably can only afford the OPEX budget to implement a Continuous Improvement programme.

Table 12: Breakdown of the Recommended Freight Rail Modernization Strategy for Freight Corridors in South Africa

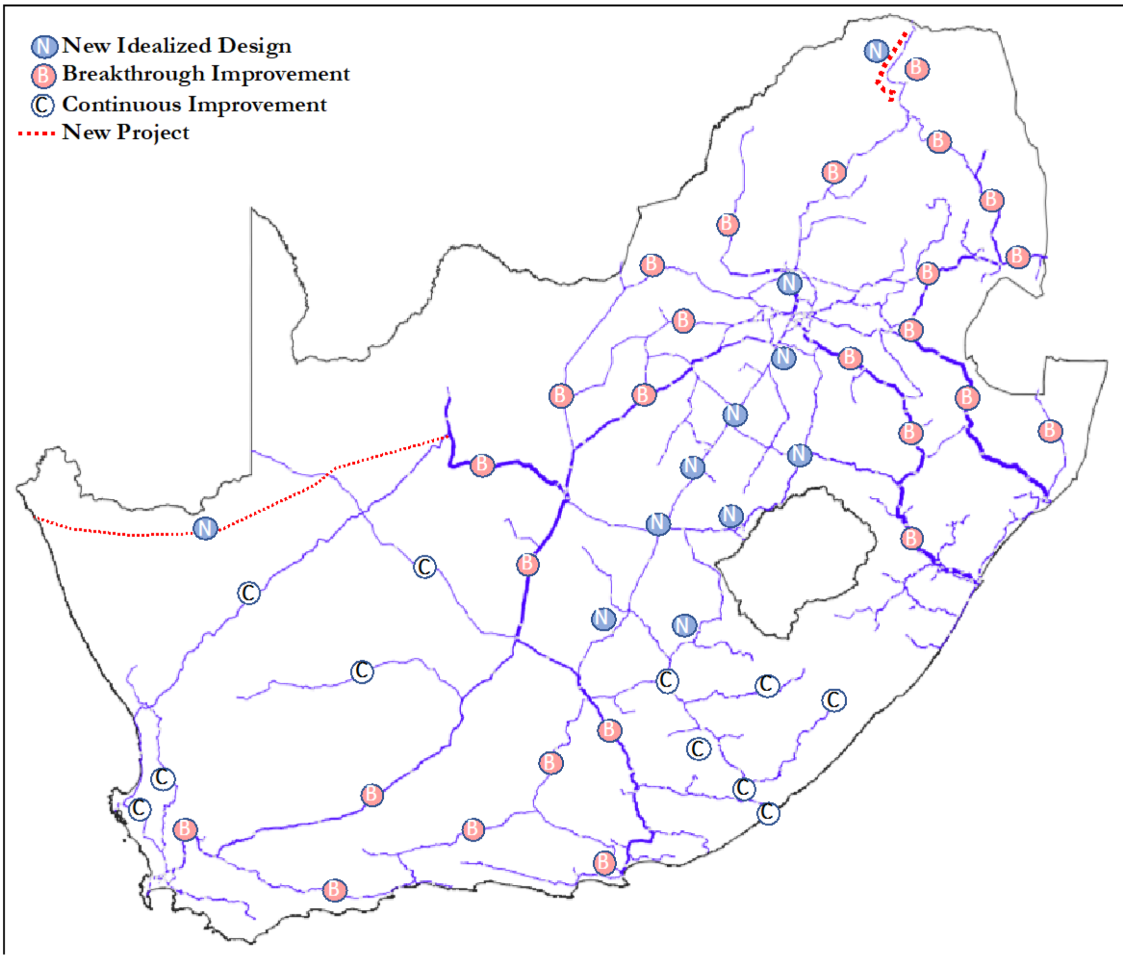
Existing Freight Corridors Density Projections (NTK million per Route-km)	Density FY 2018	Max. Link Density FDM 2050	Anticipated Gap in Corridor Density 2018 to 2050	Anticipated 2050 Operating Ratio	Anticipated Variance in Density 2018 to 2050	Recommended Modernization Strategy
Mokopane - Mopane EMSEZ line	n/a	57,00	n/a	20%	New Project	New Idealized Design
Sentracor	3,55	34,60	31,05	28%	875%	New Idealized Design
Postmasburg - Boegoebaai Corridor	n/a	21,00	n/a	50%	New Project	New Idealized Design
Freestate	0,25	14,30	14,05	59%	5620%	New Idealized Design
Natalcor	6,26	35,10	28,84	27%	461%	Breakthrough Improvement
Richards Baycor (General Freight)	10,87	37,50	26,63	25%	245%	Breakthrough Improvement
North Westcor	4,07	24,00	19,93	41%	490%	Breakthrough Improvement
Southcor	4,23	22,70	18,47	43%	437%	Breakthrough Improvement
Eastcor	3,76	20,30	16,54	47%	440%	Breakthrough Improvement
Capecor	4,40	16,80	12,40	54%	282%	Breakthrough Improvement
Northcor	1,17	9,90	8,73	73%	746%	Breakthrough Improvement
Westcor	0,28	5,10	4,82	96%	1721%	Breakthrough Improvement
North Eastcor	9,36	19,20	9,84	49%	105%	Continuous Improvement
Sishen - Saldanha (General Freight)	5,07	12,20	7,13	65%	141%	Continuous Improvement
South Eastcor	2,89	3,10	0,21	114%	7%	Continuous Improvement
Northern Cape - Namibia	0,77	0,80	0,03	162%	4%	Continuous Improvement
R Baycor (Heavy Haul)	41,65					Continuous Improvement
Sishen - Saldanha (Heavy Haul)	58,99					Continuous Improvement

Suitable Modernization Strategy Legend
New Idealized Design
Breakthrough Improvement
Continous Improvement

Source: author's synthesis.

Figure 30 shows the geographic breakdown of the recommended freight rail modernization strategy for South Africa derived from the existing freight flows, the 2050 freight demand model, the performance gap, and available railway engineering opportunities to exploit rail's genetic technologies.

Figure 30: Geographic Breakdown of the Recommended Freight Rail Modernization Strategy for South Africa



Source: author's synthesis with permission from GAIN Group to use their Freight Demand Model for 2050 map.

Note that:

i) The current Iron Ore export Channel originating in the greater Sishen–Postmasburg area in the Northern Cape and following an 861km rail line to the Port of Saldanha, is subject to a 60Mpta Air Emission Licence (AEL) limit as determined by the National Environmental Management Act No. 107 of 1998 (NEMA), its Regulations and mandated officialdom.

ii) Future growth in Iron Ore exports is discount as a New Idealized Design project along the Postmasburg–Boegoebaai Corridor.

iii) Furthermore, given the global aspirations to be coal-fired power 'free' by 2050, the so-called '2050 Coal Cliff', we excluded significant investment growth in coal freight rail demand, and hence the stunted need for Modernization.

iv) A New Idealized Design will also be required for the planned 12Mtpa Energy and Metal Special Economic Zone, licensed by the Department of Minister of Trade, Industry and Competition since 2017.

5.10 Heavy Haul Market Space

cf. Roadmap Vectors EI, FI, and FM in Figure 28.

Steam Coal exports through Richards Bay Port

Richards Bay Coal Terminal (RBCT), with six Cape size berths and continuous offloading balloon loop, has an installed capacity of 91Mtpa. Despite a rail Operational Capacity of 81Mtpa, the Practical Capacity with up to 16 x 200-wagon train slots departing on the hour seldom exceeds 72 to 73 Mtpa. This is equivalent to 12 to 13 trains per day in a 350-day working year. Addition of just the 'lost' 3 to 4 four trains per day to the normative 16 tpd schedule through Continuous Improvement, can boost throughput by 17 to 23Mta. This will not only exceed the 81Mtpa Operational Capacity, but it will exceed the RBCT capacity as well.

Since the sustained level of steam coal exports is increasingly under threat from a global move away from pulverized coal power generation, the aptly-named impending '2050 Coal Cliff' (derived from the 2015 Paris agreement on climate) change militates against long term expansion of throughput. Realistically one can expect steam coal exports through RBCT to reduce by 20 to 30% towards 2040–2050. Given this scenario, although technically feasible to give effect to Vector EI using a Breakthrough Innovation of conversion from CG to SG (to mitigate the CG centre of gravity problem with higher rail wagons producing heavier loads), it is unlikely that feasibility studies will produce a useful investment case. The preferred approach should rather be Continuous Improvement of the status quo to exploit the 81Mpta Operational Capacity (Scalar E).

Iron Ore exports through Saldanha Port

Iron Ore export volume through Saldanha Port is legally limited by a 60Mtpa Air Emissions License (AEL) issued by the Department of Forestry and Fisheries and Environmental Affairs. At an average port loading rate of 8500 tonnes per hour, the port needs to be loading vessels for 7,000 hours per annum, equivalent to 5 x 342-wagon loaded ore trains per day for a 350-day operational year. Intense Continuous Improvement should be able to expand throughput by up to 10%, nominally 5Mtpa, or one extra train every other day to 65Mtpa (55bn TKM). (Scalar F). A Breakthrough Innovation in the form of a continuous offloading balloon loop that replaces the current stop-block shunting model will increase train offloading capacity by at least 20% to 78Mtpa (67bn TKM) (Vector FJ). Since Vector FJ offers only an eight percent advantage over the status quo, it is an unlikely scenario to include a change of gauge and axle load.

Iron Ore and Manganese Exports through the new port of Boegoebaai

Alternatively, given the new Saldanha IDZ development and urban encroachment from Langebaan side and if the AEL limit remains at 60Mtpa, a more likely scenario for the extra 18Mpta to 78Mtpa export volume can be established through the new deep-water port of Boegoebaai. This level can then be sustained through Continuous Improvement (Scalar M). In the latter case, the feasibility studies will determine if the rail line branches off south of the Orange River crossing off the existing Sishen-Saldanha line, perhaps at the Halfway Loop 10, or whether a New Idealized SG heavy-haul rail line will be built from the Northern Cape iron ore and manganese complex roughly along the N14 and N7 national highways and including a new major bridge over the Orange River (Vector FM).

Domestic Iron Ore railing between Mokopane and the new EMSEZ at Mopane

A new 200km 45Mtpa Heavy Haul rail link between from Mokopane to Mopane in the Limpopo province is envisaged to supply iron ore in the form of Mokopane Magnetite (including Vanadium and Titanium) to the Energy and Metals Special Economic Zone (EMSEZ) located within the Musina-Makhado SEZ. It is not realistic to upgrade the current line between Pyramid South in Tshwane and Beit Bridge for this application. This project will carry 9bn TKM of heavy haul traffic and is clearly predisposed to a new Standard Gauge line (Scalar M).

Manganese Exports through Saldanha Port

Since exposure to Manganese causes manganism,[14] the AEL conditions are onerous, especially in populated port areas. Arguably, Manganese is best exported through a remote industrial port, such as Boegoebaai in the Northern Cape.

Manganese exports through Saldanha is a pseudo– Heavy-Haul operation inasmuch as the 20 tonnes per axle wagons are 5 tonnes per axle lighter than the Heavy-Haul threshold, and the annual volume is limited by (temporary) AEL to 5 million net tonnes (6,4 million gross tonnes) – substantially less than the classic definition of 20 million gross tonnes per annum. Given the uncertainty of a sustainable and substantial Mn AEL for Saldanha port, we foresee only Continuous Improvement of this operation. Mn treatment is included in Scalar F.

Manganese Exports through Ngqura port

Manganese exports through the ports in Nelson Mandela Bay (Port Elizabeth / Gqeberha and Ngqura) is also a pseudo– Heavy-Haul operation inasmuch as the 20 tonnes per axle wagons are 5 tonnes per axle lighter than the Heavy-Haul threshold, and the annual volume of less than 10 million net tonnes (13 million gross tonnes) –substantially less than the classic definition of 20 million gross tonnes per annum. For purposes of this study Manganese through these two ports should be treated as Scalar B. Note that actions are under way to permanently relocate the outdated Mn terminal in the Port Elizabeth to Ngqura.

5.11 Heavy Intermodal Market Space

cf. Migration of Roadmap Scalar B to a Roadmap Vector BG to a Roadmap Vector GL in Figure 28.

Traditionally the Heavy Intermodal Market Space is associated with double stacked ISO containers used in sea freight. In the South African context there are only a few but long intercity corridors radiating from the Gauteng province's metropolitan cities to the port city metros of Cape Town and Durban (eThekwini), and to a lesser extent to the city of Gqeberha (formerly Port Elizabeth). A 'land bridge' corridor also exists along the northern border of Lesotho to connect the metros of Cape Town and Durban (eThekwini). A disproportionately large portion of seaborne containers travel by road as do almost all of the rail-friendly / rail-natural palletized Fast Moving Consumer Goods (FMCG). There is also a disproportionate amount of bulk minerals running between concentrator plant at mines, beneficiation smelters, consolidation centres and ports. All of these

[14] 'Manganism is a permanent neurological disorder with symptoms that include tremors, difficulty walking, and facial muscle spasms often preceded by irritability, aggressiveness, and hallucinations.' Source: the Agency for Toxic Substances and Disease Registry (ATSDR), a U.S. Federal Department of Health and Human Services federal public health agency based in Atlanta, Georgia. Available at: https://www.atsdr.cdc.gov/toxprofiles/tp151-c2.pdf. (accessed on 28 June 2021).

traffic flows can be containerized with heavy-load domestic-only containers that exploit the existing 20 tonne axle load Cape Gauge network. Currently (2019/20) data from the GAIN Freight Flow Model shows that general freight rails approximately 14 billion net tonne-km (NTK). A domestic intermodal solution can add 8 billion NTK immediately to the existing rail network. The GAIN Freight Demand Model (FDM) estimates that by 2050, implementation of a Domestic Heavy Intermodal solution can add 14 billion NTK to the natural progression of the status quo - i.e. only double the current traffic. A Breakthrough Innovation in container and lightweight skeletal wagon design, together with the placement of number of terminals and freight villages, will add this traffic to the existing Cape Gauge network.

6 Conclusions

7) Rail Market Spaces can be characterized in terms of Rail Genetic Technologies.

    a. Whereas Cape Gauge rail can fully exploit the Coupling RGT, full exploitation of the Bearing and Coupling RGTs require Standard Gauge rail.

    b. In both cases the 34% extra width of the rail gauge offers a lower centre of gravity which allow for more product in higher wagons, double stacking of containers (in well wagons), and faster trains with more stability and improved rider comfort.

8) Save for the current preference of Busines Rapid Transit (BRT) over Light Rail, all of the other Rail Market Spaces have been assessed for viability in the Modernization Strategy.

    a. The natural 'cut-over' threshold from Cape Gauge to Standard Gauge is reached at a bearing of 32,4 tonnes per axle, and / or a train speed of 160 km/h.

    b. Below these two thresholds, Cape Gauge functions adequately.

9) The proposed Standard Gauge Modernization Programme in the Draft National Rail Policy (Department of Transport 2017) will require a CAPEX of approximately ZAR792,73 billion (U$55,63 billion at ZAR: US$ = 14,25 as at 28 June 2021).

    a. An average ZAR147,92 million (U$10,38 million) per route-km, of which 29% will be spent on a new 720km High Speed Railway between Johannesburg in Gauteng and Durban in eThekwini.

    b. Given the current underutilized and vandalized status of the South African rail system; and the new post COVID-19 economic realities that followed the publication of NRP 2017, this programme is ambitious.

    c. This programme will require efficient spending of ZAR26,424 billion per annum for 30 years, which comes down to ZAR112,4 million per working day for 235 business days (out of 365 calendar) or ZAR14 million per hour. Unless the procurement and project management capabilities can reliably scale to this spending rate, the programme will not complete on-time, on-budget and on-specification.

10) Basing the Modernization Strategy on a gauge conversion is costly endeavour.

a. Conversion or upgrading of the existing national Cape Gauge network to Standard Gauge offers little more than a 20% advantage over Cape Gauge in the long-term.

b. Excluding the direct and consequential costs associated with service disruptions during construction, conversion of up to 15,000 km of Cape Gauge national 'Core Network' to dual Cape- and Standard Gauge arrangement will require a CAPEX in excess of ZAR172 billion (or US$12 billion based on a R100 billion estimate at a 2009 exchange rate of ZAR: US$ =8.28).

c. Given the existing underutilized network capacity and the relative low cost of a number of lower-cost untapped available Breakthrough Innovations, scarce capital must be directed accordingly. Only once these next S-curves are well established should a wholesale gauge conversion become imperative.

d. The Standard Gauge modernization programme required by NRP 2017 would require a 30-year CAPEX programme of some ZAR792,43 billion (or U$55,64 billion at 28 June 2021 exchange rate of ZAR: US$ = 14,25).

11) Unlocking latent capacity can reduce capital intensity.

Corollary 1: The long-established assumptions of a 'Standard Capacity Model' results in a high levels of capital intensity.

Corollary 2: The Standard Capacity Model comes at a significant premium of Rands invested per tonne moved.

Corollary 3: Save for new projects along new routes, the decision to build new (Standard Gauge) track to increase capacity must follow unlocking of existing latent capacity.

a. The Standard Capacity Model allows for 35% loss of Theoretical Capacity in favour of an Operating Allowance (the amount of time a train can run behind schedule without interfering with the following trains), Schedule Recovery Allowance (the amount of time added to the terminal turn-around time to allow for recovery from accumulated delays on the preceding trip), and time allowed for track maintenance.

b. This 65% Operational Capacity is further reduced by externalities such a Theft and Vandalism that leaves about 50% Practical Capacity to trade in the market.

c. After allowing for train cancellations and unsold train slot, the Used Capacity is in the order of 30% to 40% of Theoretical Capacity.

12) The proposed Modernization Strategy is compliant with the AU policy on Standard Gauge.

7 Recommendations

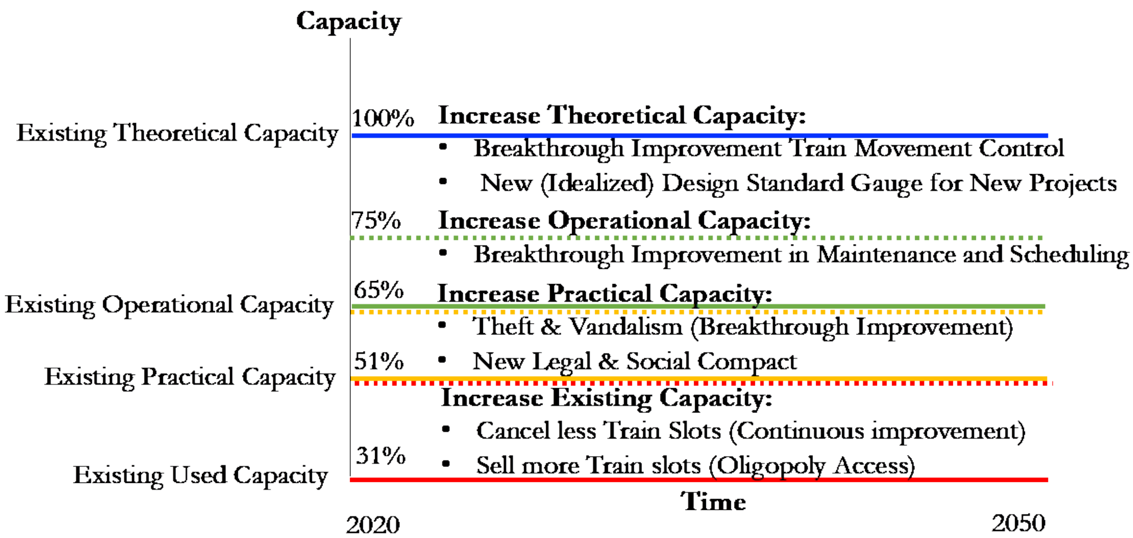
The following recommendations are proposed as a Modernization Strategy.

7.1 Technical

11) Unlock latent freight and passenger rail capacity through Continuous Improvement of the current system's S-curve, Breakthrough Improvement to deliver the Next S-curve and Idealized Design for New S-curves.

    a. For both passenger and freight rail (Figure 31 - illustrative), exploit the existing capacity model through a combination of Continuous Improvement (completing Puzzles), Breakthrough Improvement (addressing Problems), and selective Idealized Design (dealing with Messes). (Table 13) with due cognisance of Pidd's (2009) *caveat* that 'one of the greatest mistakes that can be made when dealing with a mess is to carve off part of the mess, treat it as a problem and then solve it as a puzzle – ignoring its links with other aspects of the mess'.

Figure 31: Proposed freight rail capacity modernization strategy



Source: author's conclusion.

Table 13: Approach to Messes, Problems and Puzzles

Complexity	Solution Methodology	Horizon	Business Model	Approach
Messes	Idealized Design	3 to 5 years	New S-curve	Strategic
Problems	Breakthrough Improvement	1 to 3 years	Next S-curve	Innovative
Puzzles	Continuous Improvement	< 1 year	Current S-curve	Deterministic

Source: author's elaboration.

12) Organize Modernization Teams first according to Market Spaces (Figure 28), and then according to impact (Table 13).

c. Aggressively deploy Transnet's more than 800 Six Sigma Black Belt certified Continuous Improvement process expert employees with a strong mandate to question every capacity constraining assumption or process.

d. A large portion of this team should be redeployed into a project structure and also made available to PRASA on a non-partisan basis.

13) Arrest the destructive effects of vandalism.

a. A specific 'Marshall Plan' recovery programme must be launched urgently to recover the Urban Passenger network of PRASA to restore the Metrorail patronage from 10 million passenger trips per annum (2019/20) back to the 2014/15 business case of 270 million.

b. Similarly, a specific 'Marshall Plan' recovery programme must be launched urgently to recover the lost train minutes on the Transnet Freight Rail network due to vandalism.

c. This will require ministerial determinations provided for in both the Preferential Procurement Policy Framework Act 5 of 2000 (PPPFA) and the Public Finance Management Act (PFMA) allow for the respective ministers to approve exemptions to the provisions of the acts, respectively:

i. *PPPFA section 3:* 'The Minister may, on request, exempt an organ of state from any or all the provisions of this Act if (a) it is in the interests of national security; (b) the likely tenderers are international suppliers; or (c) is in the public interest.'

ii. *PFMA section 92:* 'The Minister, by notice in the national Government Gazette, may exempt any institution to which this Act applies, or any category of those institutions, from any specific provisions of this Act for a period determined in the notice.'

d. The 'Marshall Plan' requires establishment a Special Programme Office, that operates independently and is protected from operational, political interference, or other forms of interference. It must be staffed with its own dedicated team of experienced (large-scale) project management, procurement, contract management, engineering, operational, safety and security, and Continuous Improvement specialists.

14) Exploit the natural advantages of Rail Genetic Technologies.

a. Existing network:

i. Fix & Continuously Improve:

1. National New Social and Legal Compact ('It's your railway, cherish it').

2. Metrorail: Complete the 120kph programme.

3. Transnet Freight Rail:

a. Implement a Predictable Service,

b. Integrated peri-urban Terminals,

c. Redirect best resources to Heavy Domestic Intermodal,

d. Dynamic (Re)planning system to respond to market dynamics.

ii. Implement Breakthrough Improvement to increase Operational and Theoretical Capacity, for example: densify corridors with Moving Block and Automatic Train Protection.

b. New Projects on SG:

i. Expand Gautrain as planned on Standard Gauge,

ii. UAR Corridor 4,

iii. Develop the Boegoebaai Port and Rail Infrastructure – SIP21(o) Northern Cape Govt,

iv. Develop the Energy and Metals Special Economic Zone (EMSEZ) – Mokopane Heavy Haul Line on Standard Gauge,

v. Regional 160kph is less than price of HSR.

c. Radically re-engineer processes and timelines for: Procurement, Project Management, Project Development.

7.2 Institutional

15) Urgently establish a central Rail Modernization Programme Office that can develop and provide the requisite procurement and project, contract and asset management skills, and provide non-partisan assistance to incumbent rail operators.

16) Apart for its other regulatory functions, the Single Transport Economic Regulator (STER) must insist on Network Statements based on auditable Asset Management standards, such as ISO 55000, as a perquisite for tariff determination. Ultimately the Reliability, Availability, Safety, and Sustainability (RAMS[2]) of a network train slot is embedded in the access charge. STER should use its regulatory power to incentivize innovation and foster RAMS[2].

17) Offer the Sishen-Saldanha Heavy Haul line, inclusive of the Saldanha Iron Ore export terminal on a Vertically-Integrated basis to the Mining industry to operate as a Horizontally-Separated Concession.

c. Engineering criticality and maintenance cost of maintaining the wheel-rail interface under heavy axle load and large throughput heavy-haul conditions prefer vertically integrated ownership and operations.

d. Globally the competitors of South African iron ore exports in Brazil (Vale) and Western Australia (BHP Billion, Fortesque Metals Group, Rio Tinto, and Roy Hill all own and operate their respective mines, rail links and port terminals on an integrated basis.

18) Separate the rest of the network between a State-Owned Infrastructure Manager and an Oligopoly of public and private sector Train Operators.

19) Devise a special dispensation for the ~70Mtpa Coal Export Industry between Ermelo and Richards Bay by providing Open Access to an oligopoly of public- and private sector Train Operators growing with the Richards Bay Port Master plan.

    a. Presently approximately 30% of the traffic is classified as General Freight and 70% is dedicated to Coal Exports using a world-class heavy haul operation to the largest privately-owned coal terminal in the world. All indications are that coal exports will decline towards 2050 as the so-called 'Coal Cliff' for pulverized coal-fired power stations loom.

    b. Implementation of the 2045 Richards Bay Port Master plan as espoused in the Transnet Long Term Planning Framework (LTPF 2017) will drastically broaden the 'coal port' to the premier 'industrial port'.

20) Initiate devolution of the Urban Passenger Market in Gauteng, KwaZulu Natal and the Western Cape to from the National to the Provincial Sphere only once the recovery 'Marshall Plan' shows signs of stability. In the long term the devolution of the Urban Passenger Market Space to local government is a foregone conclusion globally.

21) Develop a comprehensive surface Passenger Flow Model (PFM) and a Passenger Demand Model (PDM) for South Africa. Whereas South Africa has access to a mature integrated Freight Flow Model (FFM) and Freight Demand Model (FDM) for both road and rail freight, the paucity of a Passenger Flow Model (PFM) and a Passenger Demand Model (PDM) covering the spectrum of Car, Minibus, Bus, BRT, Urban Rail, Regional Rail, Conventional Rail, High-Speed Inter-City, and HSR is a serious shortcoming in our macro-economic planning toolset.

8 Future Research

Whereas South Africa has access to a mature Freight Flow Model (FFM) and Freight Demand Model (FDM) for both road and rail freight, the paucity of a Passenger Flow Model (PFM) and a Passenger Demand Model (PDM) covering the spectrum of Car, Minibus, Bus, BRT, Urban Rail, Regional Rail, Conventional Rail, High-Speed Inter-City, and HSR is a serious shortcoming in our macro-economic planning toolset. Although an integrated surface PFM and PDM is absent, pockets of excellence exist at local government level among urban spatial planners. It is proposed that a research programme be launched to consolidate available resources and integrated the data to be on par with the decade-old existing FFM and FDM annually-tracked research programme.

Whilst the FFM and the FDM is well-researched on the demand side, the rail capacity is not matched in the Geographic Information System. It is proposed that the headway train minutes, a traditional indicator of signalled network capacity, be included on detailed level to the FFM and FDM data.

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Annexure

Annexure I: Selected Abbreviations

AAR means Association of American Railroads.

BCC means Bombela Concession Company.

CG means Cape Gauge rail, viz. 1,067mm between rail heads.

CGR means Narrow Gauge Railway measuring 1,067mm between inner rail heads.

DBSA means the Development Bank of Southern Africa.

DOT or *NDOT* means the National Department of Transport of the GORSA.

Fe means Iron Ore.

GHG means Greenhouse Gas**.**

GMA means Gautrain Management Agency.

GORSA means the Government of South Africa.

IDEF0 means Icam DEFinition for function modelling, where ICAM is an acronym for 'Integrated Computer Aided Manufacturing' designed to model the decisions, actions, and activities of an organization or system.

IM means Infrastructure Manager.

Mn means Manganese.

MLPS means Main Line Passenger Services.

NG means Narrow rail Gauge, measuring 1,067mm between inner rail heads between rail heads for all SADC countries. There are some 1,000mm (measured between inner rail heads) track in Tanzania and smaller heritage gauges in the region, which are not considered useful in this context.

NGR means Narrow Gauge Railway measuring 1,067mm between inner rail heads.

OD means an unincorporated Operating Division.

OLI means the seven-layer Open Logistics Interconnection model. Layers are denoted as *L1* to *L7*.

PI means Physical Internet.

PPP means Public Private Partnership.

PRASA means Passenger Rail Agency of South Africa.

SADC means Southern African Development Community.

SARCC means South African Rail Commuter Corporation.

SDG means Sustainable Development Goals.

SG means Standard Gauge measuring 1,435mm between inner rail heads of the track. The Gautrain network is the only operational SG network in SADC presently (2021). A 206km from Dar es Salaam port to Morogoro section (of the 950km Central Line SRG project) is presently under construction in Tanzania.

SGR means 1,435mm Standard Gauge Railway.

SOC means State-Owned Company.

SOE means State-Owned Enterprise.

TFR means Transnet Freight Rail.

TOC means Train Operating Company.

UNDP means United Nations Development Programme.

UNU WIDER means United Nations University World Institute for Development Economics Research.

(SA-TIED) means Southern Africa – Toward Inclusive Economic Development.

USA means United States of America.

USD or *US$* or *U$* or *$* mean dollars of the United States of America.

Annexure II: Terms of Reference (TOR)

TOR 1. Develop a high-level long-term plan for the sequenced, phased and feasibility-based development of a modern standard gauge national rail backbone, built on the principles of open access, multiple concessions, private sector investment, and connectivity to passenger and freight terminals.

TOR 2. Provide a geographic overview of how this could be achieved over time as well as a high-level assessment of what could be done first and subsequent sequencing.

TOR 3. Identify the criteria that should be applied to prioritize routes for the incremental development of the modernized rail backbone. These criteria should include the economic benefits and financial feasibility of the investments, in the context of the limited ability of the fiscus and SOEs to provide the required funding.

TOR 4. Make recommendations regarding institutional roles and responsibilities for the further development of this plan and the coordination of its implementation.

Annexure III: Stakeholder Interviews

Public Finance at National Treasury

The following questions were used to guide the 7 April 2021 discussion with Public Finance at National Treasury:

Question 1. Given the establishment of the Gauteng Transport Authority (Gauteng Transport Authority Act 2, 2019) to develop and integrated transport system in the province, including owning property (section 6(b)) do you foresee that the two local government spheres will be encouraged to develop their own Standard Gauge (SG) metro networks as new assets, rather that partake in Cape Gauge (CG) devolution?

Responses to Question 1:

- Broader mobility of what users and local government can afford.
- Look for economies of scale for a city-based network; co-ordinate with the Cities Support Programme team within Inter-Governmental Relations (IGR) at National Treasury.
- Let's not build the cities into bankruptcy.
- We are probably looking at a hybrid between provinces and cities:
  - Metros, such as the City of Cape Town (COCT) and eThekwini can run the trains, but probably not afford the network.
  - In the Western Cape case there are multiple institutional players such as COCT, Stellenbosch and Paarl, perhaps with only COCT as the operator on behalf of all municipalities in the provinces.
  - Metro rail services Gauteng province probably requires a unique solution, given that the metros of Tshwane, Mogale City, Johannesburg, and Ekurhuleni, as well as Emfuleni Local Municipality host a large integrated CG network. In this case the Gauteng Transport Authority is probably the best positioned to take over the existing and future metro rail network.

Question 2. What, in your view, are the three most important considerations to ensure multiple successful concessions of the new SG rail network to ensure success?

Responses to Question 2:

- Stable market demand.
- We need to be very clear what the real problem with CG is, especially on the general freight network.
- Additionally, why would we deploy SG, and if so, will the user or the taxpayer pay?
- What about road to rail?
- Ideologically, what is the role of the state? Are we not just appeasing the labour movement?

- What are the contingent liabilities on the fiscus?
- Are we creating an artificial market failure, where it doesn't exist?
- What are the true expected gains?

Question 3. What percentage of Private Sector Investment in South Africa's rail network should be primarily focused on building a new SG network for freight and passenger; and in the CG network (to improve existing capacity and increase utilization) – as both gauges will compete for Private Sector Investment?

Responses to Question 3:

- Essentially then market will decide on capital allocation.
- Is this a race to the Treasury?
- How do we ensure interoperability inefficiency of traversing networks?
- Will there be subsidization across modes and networks?
- What are the true expected gains?

Question 4. Do you foresee only large terminal or large station integration between the CG and SG networks designed for cargo buffering or lay-over waiting? If not, how do you see predictable schedule integration of the aged CG systems with the new SG systems.

Responses to Question 4:

- The market will not favour integration across gauges unless the CG system is reliable.
- We anticipate an oligopoly.

Question 5. What are the top five factors in your view that will determine investment in a new long distance SG passenger rail network?

Responses to Question 5:

- Intercity passenger rail will probably not be revived.
- The principle should be: Access is a Social Benefit, and Mobility is a Private Benefit.
- Trade-off between equity and efficiency.
- Non-exclusivity in consumption?
- Human settlements policies are directed at family units with localized lifestyle, and not aimed at migrant labour. The contribution to mobility is not only seasonal, but perhaps also a perpetuation of Apartheid policies?
- The focus should be on inter-generational mobility, not only adult migrant workers.

Question 6. Where there is the potential for route density competition, should the final investment decision in new SG rail network be predicated on a minimum capacity utilization level of the existing CG routes? If so how do we ensure capacity utilization of the CG network realizes the expectation? If not, how do we prevent the new SG network from cannibalising of existing CG traffic?

Responses to Question 6:

Not discussed.

Question 7. What are the top 3 institutional levers that you foresee will promote the gauge modernization of the South African rail system?

Responses to Question 7:

- Increase the prices on road.
- We must include the cost of externalities for road.
- The incentives that we make better use of the existing CGR network, are not well set.
- Are not 'putting all our eggs in one basket', by focusing on SGR?

Question 8. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Responses to Question 8:

No suggestions.

Inter-Governmental Relations (IGR) at National Treasury

The following questions were used to guide the 20 April 2021 discussion with Inter-Governmental Relations at National Treasury:

Question 1. Given the establishment of the Gauteng Transport Authority (Gauteng Transport Authority Act 2, 2019) to develop and integrated transport system in the province, including owning property (section 6(b)) do you foresee that the two local government spheres will be encouraged to develop their own Standard Gauge (SG) metro networks as new assets, rather that partake in Cape Gauge (CG) devolution?

Responses to Question 1:

Whereas historically PRASA and Transnet (the two dominant SOEs responsible for rail) carried themselves and there was no need for intervention by NT, now all three rail SOEs, inclusive of Gautrain, have failed due to leadership and governance and this puts the fiscus at risk. Transnet, whilst showing excellence in its two heavy-haul corridors for iron ore and coal exports, has failed in its general freight network business, where most of its resources are allocated. PRASA has failed and has to be recapitalized and revitalized. Both PRASA and Transnet have been, and continues to be, severely vandalized since the COVID-19 lockdown stages commenced. The only operational SGR in South Africa, the Gautrain Rapid Rail Link, had a 5 times CAPEX overrun from R7.5bn to some R35bn during construction, and the concession (valid until 2026) depends since hand-over on a provincial government ridership guarantee the quantum of which is now exacerbated with dwindling passenger numbers during the COVID-19 pandemic.

Our Constitution is clear that if you can show capability, then transport and human settlements must be devolved to local government, and hence the funds must follow. For the last seven years IGR assisted the large metropolitan municipalities ('metros') through the Cities Support Programme with *transit-oriented development of human settlements*. IGR now consider the metros' plans to be excellent, definitely better than those of both provincial and central government.

Therefore, IGR believes that the metros have developed the planning competency to accept devolution, which strengthens the devolution argument, underpinned by the core fiscal principle that *funds must follow function*. Both the Constitution and financial legislation are clear that the flow of money must go to the municipalities. Note that whereas 97% of provincial revenue comes from central government, the opposite is true for metros.

Unfortunately, given the rising cost of debt servicing, South Africa cannot afford a new rail system. It also does not make sense to devolve something that is not functioning well. The existing rail system must rather be fixed before an new investment can be discussed. At best all road transport be devolved and the rail system to remain with central government. The provinces should focus on building roads.

Question 2. What, in your view, are the three most important considerations to ensure multiple successful concessions of the new SG rail network to ensure success?

Responses to Question 2:

First and foremost we need to fix the leadership in these SOEs by replacing the board members with competent professionals who can instil investor confidence and properly deal with governance issues. The private sector is quick to respond to positive government signals, but government has to move first.

Question 3. What percentage of Private Sector Investment in South Africa's rail network should be primarily focused on building a new SG network for freight and passenger; and in the CG network (to improve existing capacity and increase utilization) – as both gauges will compete for Private Sector Investment?

Responses to Question 3:

Logically speaking the private sector should only invest new money in new assets. Hence no private sector money would be allocated to the existing CGR. Government should also not prescribe private sector investments to fix existing old assets. Government should only intervene where there is market failure, and not overreach (as is the current tendency). Unfortunately there is now mistrust between government, through its SOEs, and the private sector.

Question 4. Do you foresee only large terminal or large station integration between the CG and SG networks designed for cargo buffering or lay-over waiting? If not, how do you see predictable schedule integration of the aged CG systems with the new SG systems.

Responses to Question 4:

We should have an integrated approach as is the case of PRASA CGR and Gautrain SGR integration at both Rhodesfield and Park stations.

Question 5. What are the top five factors in your view that will determine investment in a new long distance SG passenger rail network?

Responses to Question 5:

Question 6. Where there is the potential for route density competition, should the final investment decision in new SG rail network be predicated on a minimum capacity utilization level of the existing CG routes? If so how do we ensure capacity utilization of the CG network realizes the expectation? If not, how do we prevent the new SG network from cannibalising of existing CG traffic?

Responses to Question 6:

Not discussed due to time limitations.

Question 7. What are the top 3 institutional levers that you foresee will promote the gauge modernization of the South African rail system?

Responses to Question 7:

We need to create incentives to achieve the desired result. PSI will respond positively to the correct incentives.

The merits of Carbon Tax and incentives to reduce the fuel levy should best be discussed with the NT Tax unit, who specializes in these matters.

Question 8. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Responses to Question 8:

The worst thing we can do is for government to create a new (SOE) entity, that would be overreaching. We must rather consolidate what we have.

WITS Transnet Centre of Systems Engineering

The following questions were used to guide the 20 April 2021 discussion with the Transnet Centre of Systems Engineering at the University of the Witwatersrand:

A) The merits of Standard Gauge rail

Question 1. What are the Top-5 advantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 1:

A 32% wider gauge lowers the centre of gravity allows for *freight*: an improved carrying capacity (from vertically higher loads and increased volume), improved stability of rolling stock, increased line speed, less rolling stock (due to load volume and higher axle load), standardization of the OEM supplier interface (no need for global rolling stock and locomotive OEMs to include gauge conversion, especially in small order quantities), standardization of the maintenance supplier interface (track-laying equipment do not require gauge conversion, leasing is easier, and the market power of gauge-specific maintenance suppliers is reduced); and for *passenger*: increased line speed, and double decking of passenger rail cars.

Question 2. What are the Top 5 disadvantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 2:

The CAPEX is higher due to the 32% increase in track and formation width. Gradients and curves are more forgiving and therefore longer and more demanding of cut and fill earthworks, wider culverts and bridges. The implementation cost of NGR replacement to SGR is higher than rehabilitation of NGR.

B) Cape Gauge to Standard Gauge conversion in South Africa.

Merits of Standard Gauge rail

Question 3. Should South Africa convert any of its for Passenger of Freight Cape Gauge Rail (CGR) lines to Standard Gauge?

Responses to Question 3:

Refer to the 2009 NATMAP 2050 Gauge Report which indicates the breakeven point to justify the NGR to SGR conversion. If so, a gauge conversion should probably only be made for passenger rail to take advantage of increased line speed.

Question 4. How would you determine the selection and priorities for gauge conversion for Passenger Rail; and for Freight Rail?

Responses to Question 4:

<u>Passenger rail.</u> High-Speed passenger Rail (HSR) should be a zero-based design. Interoperability with road must be ensured and (50-year) whole of life costing must be done.

Freight rail. For a closed system, it is easy to take an SGR decision. However, in a networked system this not possible. The business case for a dual gauge solution must carefully consider the (50-year) whole life cost comparison of extending the existing line as opposed to building a new line. Any new SGR should also consider use of the line as a multi-purpose / multi-use facility to share the CAPEX cost. In any event it is very important to clarify definitions and the associated business benefits.

C) Engineering Procurement Construction with Finance (EPC/F), Operations and Maintenance (O&M) and Original Equipment Manufacturer (OEM) readiness for Standard Gauge Railway (SGR) in South Africa.

Engineering Procurement Construction with Finance (EPC/F), Operations and Maintenance (O&M) and Original Equipment Manufacturer (OEM) readiness for Standard Gauge Railway (SGR) in South Africa.

Question 5. What are the success factors to secure funding for a new SGR, possibly in competition with the existing CGR?

Responses to Question 5:

South Africa has only demonstrated rail competency in heavy-haul mine-to-port (iron ore and coal) export corridor operations. A new SGR for networked rail operations will require third party operations and higher speed (~160km/h) passenger rail.

Lessons from the UK show that the IMs should remain state-owned and the operations could be privatized or concessioned.

Question 6. What are the success factors to ensure a timely domestic EPC capability and capacity exit in SA?

Responses to Question 6:

Technical Excellence. We need to establish 'shortlisted capability' ahead of project demand. It should clearly identify where experienced people (engineers down to technicians) will be hired from to help develop tangible capacity; and what the scope of work is that we will hire for. Early contractor involvement to work alongside new entrants is important to pre-develop competency. In the case of Transnet, the generalized Project Lifecycle Process (developed by the Hatch – Mott MacDonald – Goba joint venture) must be re-evaluated and customized for specific rail projects.

Procurement excellence. The procurement rules and regulations must be updated to enable capacity development.

Financial excellence. Include hedging of exchange rate risk.

Question 7. What the success factors to ensure a timely domestic O&M capability and capacity exit in SA?

Responses to Question 7:

Include Decommissioning and Disposal in planning, which is quite different from maintenance *per se*.

Question 8. What the success factors to ensure a timely domestic OEM capability and capacity exit in SA?

Responses to Question 8:

It is important to differentiate between OEMs and integrators. We should address how the COVID-19 'Green Swan' event will impact the approach. Specifically, Transnet should clearly understand its role in an OEM supply chain carefully considering its 'as-is' and 'to-be' disposition, and applicable trends, structures and mental models.

Closing Comment

Question 9. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Responses to Question 9:

Use Critical Systems Thinking to develop the plan. Remove ambiguity to show viability and the business case. Use peer-review and peer-assist forums as well as early contractor involvement (without conflict of interest) to finalize the new SGR plan.

(Interim) PRASA Chair in Engineering Research at Stellenbosch University

The following questions were used to guide the 23 April 2021 discussion with the (Interim) PRASA Chair in Engineering Research at Stellenbosch University:

Merits of Standard Gauge rail

Question 1. What are the Top-5 advantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 1:

SG exploits rail genetic technologies well:

- *Guiding* that allows for perfection of the route alignment (gradients, horizonal and vertical curves). Large scale roll-out of High-Speed Rail (HSR) has been proven in Japan (originator), Europe, Korea, and China (market leader) on SG. Designs respond well to energy intensive heavy-haul rail operations such as: i) Haoji railway transporting 200Mtpa coal over 1,813km in China; and ii) the three export lines of BHP Billiton (426km Mount Newman Railway), Rio Tinto (1,300km Hamersley & Robe River Railway), Fortesque Metals Group (260km Fortesque Railway), and Roy Hill (344km Roy Hill Railway) from the Pilbara iron ore region to various ports in Western Australia.

HSR will enable people to reside further outside the metro CBDs where accommodation is normally cheaper and life style is more rural, yet still access economic opportunities in the cities.

Question 2. What are the Top 5 disadvantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 2:

Cost. Since the 1,435mm SG is 34% wider than CG, the formation is wider, the distance between track centres is wider for double track, sleepers are longer, ballast volume is higher, bogie axles are wider etc.

A new rail gauge in South Africa will require existing rail industry service providers to procure additional track maintenance equipment. New SGR will require collaboration with the rail industry to prepare domestic capacity and capability for construction and maintenance.

Cape Gauge to Standard Gauge conversion in South Africa.

Question 3. Should South Africa convert any of its for Passenger of Freight Cape Gauge Rail (CGR) lines to Standard Gauge?

Responses to Question 3:

If you can't afford to convert the existing CG system, why build and maintain a new SGR?

Question 4. How would you determine the selection and priorities for gauge conversion for Passenger Rail; and for Freight Rail?

Responses to Question 4:

The existing metro-rail backlog is so big, we should focus on first getting this out of the way before considering a new SGR.

Engineering Procurement Construction with Finance (EPC/F), Operations and Maintenance (O&M) and Original Equipment Manufacturer (OEM) readiness for Standard Gauge Railway (SGR) in South Africa.

Question 5. What are the success factors to secure funding for a new SGR, possibly in competition with the existing CGR?

Responses to Question 5:

We must quantify the value to justify the cost of a new SGR?

Question 6. What are the success factors to ensure a timely domestic EPC capability and capacity exit in SA?

Responses to Question 6:

Question 7. What the success factors to ensure a timely domestic O&M capability and capacity exit in SA?

Responses to Question 7:

If affordable, perhaps we should migrate from CG to SR using a dual gauge approach for a while to allow O&M supplier some continuity to prepare for new SGR.

Question 8. What the success factors to ensure a timely domestic OEM capability and capacity exit in SA?

Responses to Question 8:

Perhaps we can learn from the Motor Industry Development Program (MIDP). However, in the rail market being and OEM is not enough. Quite different from the high-volume automotive market, Gibela (seeded by Alstom in France and now run by South Africans) is faced with a once-off order to deliver 600 metro trains and then there is no follow-on market, which will result in the closure of the factory and loss of jobs. Locking in regional demand through the African Continental Free Trade Agreement (AfCFTA) is probably required to develop the OEM market for SGR.

Closing Comment

Question 9. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Responses to Question 9:

The current passenger rail system of PRASA has some pockets of excellence, but overall does not perform well. The long-standing problem with changes in leadership has negatively impacted systems and procedures in procurement and maintenance that resulted in equipment and network failures. The size of rail gauge, old or new, is irrelevant if the institution is not capable of running a railway. Without effective and competent leadership and human capital and the ability to spend money well, available technology and funding will not recover our passenger rail system and we should not attempt to build new SGR.

Africa Rail Industry Association (ARIA)

The following questions were used to guide the 26 April 2021 discussion with the Africa Rail Industry Association (ARIA):

Question 1. What are the Top-5 advantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 1:

Only practical as a High Speed Rail (HSR) in excess of 300km/h subsidized passenger rail system between Gauteng and KwaZulu Natal.

Question 2. What are the Top 5 disadvantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 2:

- There was insufficient consultation on the AU SG resolution. What works well in Europe and China, does not necessarily work well in Africa. Generally speaking, save for HSR, we do not see much benefit for a new SGR in South Africa since: i) we do not have the fiscal space to afford a new SGR in South Africa; ii) it will confuse PSI in the CGR; iii) empowering youth and women through rail-related jobs and opportunities in rail is not a rail gauge consideration; iv) a working railway is more important to road cost reduction than a specific gauge.

- If we wish to open the SA rail market for Foreign Direct Investment (FDI) while at the same time announcing a second rail gauge, will only confuse investors.

- Ongoing investment to ensure CG network improvement will be eroded with SGR on the horizon.

- A new SGR will leave a significant portion of the CG locomotives and wagons stranded. One could argue that SGR in African cold easily become a dumping ground for old, inefficient, and environmentally unfriendly rolling stock from developed countries – similar to right-hand drive Japanese second hand cars dumped into Africa.

- Interoperability between gauges introduces unnecessary complexity and cost as evidenced by the new SGR between Mombasa port and Nairobi in Kenya and die 1000mm Narrow Gauge from Nairobi to Uganda. Of the 18Mtpa SGR capacity, only 4Mtpa was transported last year.

- Although access to Chinese EPC/F led development should easier with SG than CG, the Chinese model in Africa, cynically referred to as 'economic imperialism' has not resulted in much in-country value spending, or sustainable local skills and operations.

Question 3. Do you foresee that the provincial and/or municipal spheres of government will be encouraged to develop their own Standard Gauge (SG) metro networks as new assets, rather that partake in Cape Gauge (CG) devolution?

Responses to Question 3:

No. Notwithstanding our constitutional ideals, the lack of fiscal space remains a major obstacle.

Question 4. Should South Africa convert any of its for Passenger of Freight Cape Gauge Rail (CGR) lines to Standard Gauge?

Responses to Question 4:

No.

Question 5. How would you determine the selection and priorities for gauge conversion for Passenger Rail; and for Freight Rail?

Responses to Question 5:

Gauge conversion is not a realistic objective. However, a new premium-service HSR on SG between the CBDs of Johannesburg and Durban, funded by the state on merits of economic returns flowing from a strong economy between the Gauteng and KwaZulu Natal provinces, is conceivable as long as the fiscal space exists for whole-life subsidy.

Question 6. What are the success factors to secure funding for a new SGR, possibly in competition with the existing CGR?

Responses to Question 6:

A new SGR must be government funded. A sovereign-guarantee will not succeed.

Question 7. What are the success factors to ensure a timely domestic EPC capability and capacity exit in SA?

Responses to Question 7:

Traditional large civil contractors have the capacity to lead such a project. Track works by local specialists is also possible. However, unless there is exemption from the monopoly-friendly criteria imposed by the Construction Industry Development Board (CIDB), there is little transformational opportunity for new entrants to develop in good time. Furthermore, transformation seems to be hampered by divergence between the DITIC's local content imperatives and the actual execution by SOEs.

Question 8. What are the success factors to ensure a timely domestic O&M capability and capacity exist in SA?

Responses to Question 8:

Ibid.

Question 9. What the success factors to ensure a timely domestic OEM capability and capacity exit in SA?

Responses to Question 9:

Whereas rail wagons are fairly simple devices, locomotives contain highly specialized intellectual property (IP). Whereas global OEMs have spent decades to develop this IP, it is unrealistic to expect Transnet to develop an 'African Locomotive' to comparable standards, and with a robust supply chain. This is evidenced by the lack of sales to date.

Question 10. What, in your view, are the three most important considerations to ensure multiple successful concessions of the new SG rail network to ensure success?

Responses to Question 10:

- *Concessions must be fundable on a standalone basis*. Since vertically integrated concessions simply replaces a state-owned monopoly with a number of privately-owned monopolies, we strongly support third party access on a state-owned network. At best and at the risk of introducing unnecessary complexity, sections of the infrastructure can be conceded to (IMs) – similar to the SANRAL model for the N1, N3, and N5 highway concessions. Since there is a risk that such concessions will require subsidy anyway, we prefer a single state-owned network operator selling traversing slots across the network. Note that there is significant trade union opposition to concessions.

- *Third Party Access*. Contrary to road transport, characterized by short loading/offloading dwell times and small parcel sizes, rail transport has long dwell times of 2 to 4 hours for containers and bulk respectively at origins and destinations given the large parcel sizes. Consequently, rail needs to make up time by continuously traveling for long distances. Generally speaking, the rail competitive distance in South Africa is in excess of 300km. Since very few branch lines in South Africa exceeds 300km, unless provision is made for unfettered end-to-end network traversing rights, the current Transnet branch line concession model is not financially justifiable.

- *Economic growth*. Since rail transport demand derives from economic output (for freight) and jobs activity (for passenger), the business opportunity for rail concessions depend on a thriving economy.

Question 11. What percentage of Private Sector Investment in South Africa's rail network should be primarily focused on building a new SG network for freight and passenger; and in the CG network (to improve existing capacity and increase utilization) – as both gauges will compete for PSI?

Responses to Question 11:

Unless there is policy certainty, Private Sector Investment (PSI) will remain low and the rail opportunities unattractive. High-efficiency locomotives and ultra-lightweight rail wagons will attract PSI. To secure PSI for rolling stock, we advocate for the implementation of the 'game changing' third party access and Luxembourg Rail Protocol[15] combination.

Question 12. Do you foresee only large terminal or large station integration between the CG and SG networks designed for cargo buffering or lay-over waiting? If not, how do you see predictable schedule integration of the aged CG systems with the new SG systems.

Responses to Question 12:

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[15] See https://otif.org/en/?page_id=116.

SGR is only supported for inter-provincial CBD-to-CBD main station HSR.

Question 13. What are the top five factors in your view that will determine investment in a new long distance SG passenger rail network?

Responses to Question 13:

Adequate fiscal space. A new SGR must be government funded. A sovereign-guarantee will not succeed.

Question 14. Where there is the potential for route density competition, should the Final Investment Decision (FID) in new SG rail network be predicated on a minimum capacity utilization level of the existing CG routes? If so how do we ensure capacity utilization of the CG network realizes the expectation? If not, how do we prevent the new SG network from cannibalising of existing CG traffic?

Responses to Question 14:

We must first fix the existing system capacity and then enhance it with innovations (such as moving-block signalling). To determine this potential, government must implement proper mathematical models to objectively inform decisions (as opposed to politically-motivated decision-making).

Question 15. What are the top 3 institutional levers that you foresee will promote the gauge modernization of the South African rail system?

Responses to Question 15:

- Third Party Access.
- Effective tax regime to incentivize investment by operators.
- Single Transport Economic Regulation.
- Effective law enforcement to deal with corruption, theft and vandalism,

Closing Comment

Question 16. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Responses to Question 16:

Whereas SOEs see the private sector as competition (both as operators and supplies) government and the SOEs must consult continuously and intensively with industry expert forums, or user groups. Similarly, whereas government presently promotes SOEs only when reaching out to international opportunities (e.g. Ghana, Mozambique, Zimbabwe), it should include the private sector.

African Development Bank (AfDB)

The following questions were used to guide the 26 April 2021 discussion with the African Development Bank (AfDB):

Question 1. Given the establishment of the Gauteng Transport Authority (Gauteng Transport Authority Act 2, 2019) to develop and integrated transport system in the province, including owning property (section 6(b)) do you foresee that the two local government spheres will be encouraged to develop their own Standard Gauge (SG) metro networks as new assets, rather that partake in NG devolution?

Response to Question 1:

We don't see much sub-national rail transport authorities in practice. There is no great municipal examples of mass or metro transit rail devolution, but rather light rail systems.

Question 2. What, in your view, are the three most important considerations to ensure multiple successful concessions of the new SG rail network to ensure success?

Response to Question 2:

A new SGR should only be built if: i) there is a clear market demand for new rail capacity; ii) the existing railway has reached the end of its useful life; iii) the cost and complexity of operating across a gauge break is justified; and iv) the advantages of building a new SGR vs. renewing a CGR far outweigh the disadvantages.

There a not many successful integrated rail concessions and we must caution against integrated rail concessions that simply replace a state-owned monopoly with private ownership. It seems that governments are better at investing in fixed infrastructure and the private sector prefers investment in moving infrastructure. Lack of investment in infrastructure forced the governments of Kenya, Mozambique, Tanzania, Uganda and Zambia to revoke concessions. It seems that once private operators prefer to invest on a 10 to 15-year window in rolling stock and not in longer-term infrastructure.

Question 3. What percentage of Private Sector Investment in South Africa's rail network should be primarily focused on building a new SG network for freight and passenger; and in the NG network (to improve existing capacity and increase utilization) – as both gauges will compete for PSI?

Response to Question 3:

Good data and information will determine clear PSI opportunities. The 'smart money' will always seek out high-return opportunities, irrespective of rail gauge. As in the 'pipeline' type industry, railways excel under traffic densification – and these routes will attract PSI. Integrated passenger rail systems should remain with the state, and dedicated freight rail applications can be conceded on an integrated basis. (The MRS concession in Brazil is a good example of a successful high-density pit-to-port system operating on contract. (–ed.).

Question 4. Do you foresee only large terminal or large station integration between the CG and SG networks designed for cargo buffering or lay-over waiting? If not, how do you see predictable schedule integration of the aged CG systems with the new SG systems.

Response to Question 4:

It is quite conceivable that a phased rollout of new SGR will result in a unified African SG rail system by 2063, as contemplated by the AU vision. However, gauge unification will be costly and schedule interoperability will be an important indicator of operational excellence.

Question 5. What are the top five factors in your view that will determine investment in a new long distance SG passenger rail network?

Response to Question 5:

The 'top five factors' that will determine investment in a new long distance SG passenger rail are: i) Traffic Demand, ii) Traffic Demand, iii) Traffic Demand, iv) Traffic Demand, and v) Traffic Demand.

Question 6. Where there is the potential for route density competition, should the Final Investment Decision (FID) in new SG rail network be predicated on a minimum capacity utilization level of the existing CG routes? If so how do we ensure capacity utilization of the CG network realizes the expectation? If not, how do we prevent the new SG network from cannibalising of existing CG traffic?

Response to Question 6:

Ibid Question 5. In terms of service considerations for passenger rail, at a premium cost SG should outperform CG on: i) Comfort – derived from lower centre of gravity than CG); ii) higher speed (*ibid.*); iii) safety; iv) train frequency; v) transit time – door-to-door transit times for a CBD-to-CBD HSR is attractive if it beats the same for air travel via outlying airports.

Question 7. What are the top 3 institutional levers that you foresee will promote the gauge modernization of the South African rail system?

Response to Question 7:

Typically the National Treasury and DOT should perform a gaps analysis and introduce reforms to ensure:

- A legal framework that encourages PSI;
- A regulatory environment strengthened for competition, safety and financial sustainability; and
- Government has to be the 'first mover' by showing a PSI-conducive environment, not only in policies, but demonstrably in practice.

Question 8. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Response to Question 8:

PSI favours transparency by DOT in project development. Ultimately, an some stage and long before 2063, Africa needs to convert to SG and HSR.

South African National Roads Agency SOC Ltd (SANRAL)

The following questions were used to guide the 03 May 2021 discussion with the South African National Roads Agency SOC Ltd (SANRAL):

Question 1. What are the Top-5 advantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Question 2. What are the Top 5 disadvantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Question 3. Do you foresee that the provincial and/or municipal spheres of government will be encouraged to develop their own Standard Gauge (SG) metro networks as new assets, rather that partake in Cape Gauge (CG) devolution?

Question 4. Should South Africa convert any of its for Passenger of Freight Cape Gauge Rail (CGR) lines to Standard Gauge?

Question 5. How would you determine the selection and priorities for gauge conversion for Passenger Rail; and for Freight Rail?

Question 6. What are the success factors to secure funding for a new SGR, possibly in competition with the existing CGR?

Question 7. What are the success factors to ensure a timely domestic EPC capability and capacity exit in SA?

Question 8. What the success factors to ensure a timely domestic O&M capability and capacity exit in SA?

Question 9. What the success factors to ensure a timely domestic OEM capability and capacity exit in SA?

Question 10. What, in your view, are the three most important considerations to ensure multiple successful concessions of the new SG rail network to ensure success?

Question 11. What percentage of Private Sector Investment in South Africa's rail network should be primarily focused on building a new SG network for freight and passenger; and in the CG network (to improve existing capacity and increase utilization) – as both gauges will compete for Private Sector Investment (PSI)?

Question 12. Do you foresee only large terminal or large station integration between the CG and SG networks designed for cargo buffering or lay-over waiting? If not, how do you see predictable schedule integration of the aged CG systems with the new SG systems.

Research Output 2: *Geographic overview* of how this could be achieved over time as well as a high-level assessment of what could be done first and subsequent sequencing.

Question 13. What are the top five factors in your view that will determine investment in a new long distance SG passenger rail network?

Question 14. Where there is the potential for route density competition, should the Final Investment Decision (FID) in new SG rail network be predicated on a minimum capacity utilization level of the existing CG routes? If so how do we ensure capacity utilization of the CG network realizes the expectation? If not, how do we prevent the new SG network from cannibalising of existing CG traffic?

Question 15. What are the top 3 institutional levers that you foresee will promote the gauge modernization of the South African rail system?

Question 16. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Interview Approach.

The interview was held in the style of an informed dialogue as opposed to mechanistically processing the 16 questions, which were used to rathe provided guidance.

Salient remarks from the ensuing discussion.

The interview group consisted of three senior and seasoned SANRAL executives. Below are the salient remarks in no order of importance:

- To rectify the widely-vandalized (peri)urban mass transit passenger rail system in the main metros in South Africa, requires a 'social compact' to weed out crime and associated social ills (such as encroachment of human settlements on the rail reserve).

- Although SGR allows for increased loads through by double stacking containers on rail, it is important to increase the utilization of the existing rail system first. As an example:

    - SANRAL uses both traffic volume (vehicle count) and load (Equivalent Axle-load Traffic units) to plan route capacity on a 20-year basis.

    - Ideally existing road capacity runs when the traffic volume reaches its design maximum and the road reaches the end of its useful life given the design work load.

    - Should an existing road reach its capacity by year 15 in the 30-year SANRAL planning window, SANRAL will schedule the requisite capacity extension now.

- SANRAL supports the correct sharing of freight transport between the road and rail modes. Ideally, SANRAL would prefer to see freight competition that attract loads from road to rail based on fair competition and sound economics:

    - On some roads, it is imperative to move the heavy loads to rail as soon as possible.

    - A shift from road to rail will assist SANRAL in managing its financial obligation to compensate concessionaires on excess wear and damage to the road surface.

    - This will also assist SANRAL with the management of overloaded vehicles.

    - SANRAL collaborates with incumbent Transnet Freight Rail on an initiative to decongest trucks in Cape Town harbour and simplify port terminal operations. This consists of a new trans-loading facility on the N1 Koelenhof exchange near Stellenbosch in the Western Cape province for fresh produce. Whereas all traffic traditionally was railed to the Belville hub yard and then trucked into port, the

Koelnhof innovation now allows for 'first mile' farm- to- rail-head trucking and then direct train shuttles into the port.

- Among other factors, this requires knowing the cost of a train slot.
  - It does not make sense to regauge the existing CG network in South Africa if the train slot cost of railing cargo on SG is the same as for SG.
  - The rail Infrastructure Manager (IM) must know its rail network train slot cost and be able to price it by commodity in the market to third party Train Operating Companies (TOCs). Just as SANRAL, the national road network IM, knows the cost of providing a transport slot associated with trucking the proverbial 'can of beans' on the national concession routes (e.g. 'ZAR0.0001 per can of beans on the N4'), so must the rail IM. know the cost on the existing and intended New SGR routes.
  - Historically going back as far as 1999, road-rail modal integration initiatives such as RoadRailer™ or RailRunner™ failed to realize in South Africa. One of the main reasons was the inability of the incumbent rail IM, the vertically integrated rail division of Transnet, to provide a train slot price that could be associated with a cargo flow.
- Imminent economic regulation by the Single Transport Economic Regulator ('STER') must be cognisant of potential claims by SANRAL road concessionaires in respect of Material Adverse Government Action ('MAGA') impacting on their concession rights.
- A New SGR must take into consideration the gauge break impact on the regional spatial frameworks:
  - What is the impact on SADC rail integration?
  - How does the gauge break comply with existing agreements with neighbouring countries?
  - How will the gauge break work with cross-border international rail operations?
  - Note that even with One Stop Border Posts (OSBP), international border crossing of in-bond cargo by rail is much more efficient than time-consuming cross-border truck clearance.

The South African Institution of Civil Engineering (SAICE) Railways and Harbours division (RHD)

SAICE (RHD) declined the Stakeholder interview as the institution continues to debate the SGR subject internally and has not yet succeeded in developing a formal disposition.

University of Pretoria Chair in Railway Engineering and Railway Safety (UP Chairs)

The following questions were used to guide the 14 May 2021 discussion with the University of Pretoria Chair in Railway Engineering and Railway Safety (UP Chairs):

Question 1. What are the Top-5 advantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 1:

- It is easier and cheaper for OEMs to provide SG equipment and rolling stock on a common-off-shelf basis than for CG.
- The South-African designed and proven Scheffel self-steering rail car bogie (US 'truck') is now also well-established worldwide on SG.

Question 2. What are the Top 5 disadvantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 2:

- Duplication of equipment for maintenance.
- Split between SG and NG service providers in a small market.
- SG probably requires new tunnels and structures, rather than upgrades.

Question 3. Do you foresee that the provincial and/or municipal spheres of government will be encouraged to develop their own Standard Gauge (SG) metro networks as new assets, rather that partake in Cape Gauge (CG) devolution?

Responses to Question 3:

- Not addressed due to time limitations.

Question 4. Should South Africa convert any of its for Passenger of Freight Cape Gauge Rail (CGR) lines to Standard Gauge?

Responses to Question 4:

- Only if it makes financial sense.

Question 5. How would you determine the selection and priorities for gauge conversion for Passenger Rail; and for Freight Rail?

Responses to Question 5:

- Ibid.

Question 6. What are the success factors to secure funding for a new SGR, possibly in competition with the existing CGR?

Responses to Question 6:

- Ibid.

Question 7. What are the success factors to ensure a timely domestic EPC capability and capacity exit in SA?

Responses to Question 7:

- We have the construction skills to deploy SG but not the equipment.

Question 8. What the success factors to ensure a timely domestic O&M capability and capacity exit in SA?

Responses to Question 8:

- We have the maintenance skills to deploy SG, but not the equipment.

Question 9. What, in your view, are the three most important considerations to ensure multiple successful concessions of the new SG rail network to ensure success?

Responses to Question 9:

- Not addressed due to time limitations.

Question 10. What percentage of Private Sector Investment in South Africa's rail network should be primarily focused on building a new SG network for freight and passenger; and in the CG network (to improve existing capacity and increase utilization) – as both gauges will compete for Private Sector Investment (PSI)?

Responses to Question 10:

- I can see a clear application of SG for HSR.

Question 11. Do you foresee only large terminal or large station integration between the CG and SG networks designed for cargo buffering or lay-over waiting? If not, how do you see predictable schedule integration of the aged CG systems with the new SG systems.

Responses to Question 11:

- Train scheduling is important in all operations.

Research Output 2: *Geographic overview* of how this could be achieved over time as well as a high-level assessment of what could be done first and subsequent sequencing.

- Not addressed due to time limitations.

Question 12. What are the top five factors in your view that will determine investment in a new long distance SG passenger rail network?

Responses to Question 12:

- Not addressed due to time limitations.

Question 13. Where there is the potential for route density competition, should the Final Investment Decision (FID) in new SG rail network be predicated on a minimum capacity utilization level of the existing CG routes? If so how do we ensure capacity utilization of the CG network realizes the expectation? If not, how do we prevent the new SG network from cannibalising of existing CG traffic?

Responses to Question 13:

- Not addressed due to time limitations.

Question 14. What are the top 3 institutional levers that you foresee will promote the gauge modernization of the South African rail system?

Responses to Question 14:

- Not addressed due to time limitations.

Question 15. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Responses to Question 165:

- Not addressed due to time limitations.

University of Cape Town Chair in Railway Engineering (UCT Chair)

The following questions were used to guide the 14 May 2021 discussion with the University of Cape Town Chair in Railway Engineering (UCT Chair):

Question 1. What are the Top-5 advantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 1:

- SG will be more efficient in a 'clean-slate' new track scenario.
- What benefit will SG implementation really bring to the SADC regional rail system?

Question 2. What are the Top 5 disadvantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 2:

- Short-term, it is very costly.
- It will require a lot of work to assess the impact of SG conversion on existing infrastructure such as the track, bridges, tunnels.

Question 3. Do you foresee that the provincial and/or municipal spheres of government will be encouraged to develop their own Standard Gauge (SG) metro networks as new assets, rather that partake in Cape Gauge (CG) devolution?

Responses to Question 3:

- A well-functioning metro rail system is a CSF for devolution. The current metro system is not devolvable.
- In principle devolution can only succeed if the receiving sphere of government can ensure efficiencies.
- PRASA is just too big and seems to have lost control of the whole. Perhaps breaking it up into smaller 'chunks' with integration points could be useful.

Question 4. Should South Africa convert any of its for Passenger of Freight Cape Gauge Rail (CGR) lines to Standard Gauge?

Responses to Question 4:

- A single gauge system should be the most efficient.
- Access to multi-gauge infrastructure will be problematic for rolling stock providers.

Question 5. How would you determine the selection and priorities for gauge conversion for Passenger Rail; and for Freight Rail?

Responses to Question 5:

- Existing bridges and tunnels must be inspected for fatigue.
- Some bridging structures might be able to handle the SG at a higher axle load, but at an increased fatigue rate.
- Generally speaking, at around 180km/h the train dynamics take over as the bridge–train coupling creates fatigue risks in both for the train sets and for passengers.
- Transition zones are more impacted by axle load than by train speed.

Question 6. What are the success factors to secure funding for a new SGR, possibly in competition with the existing CGR?

Responses to Question 6:

- Not addressed due to time limitations.

Question 7. What are the success factors to ensure a timely domestic EPC capability and capacity exit in SA?

Responses to Question 7:

- Local companies can partner with internally-rated EPCs, but we have a paucity of rail construction skills.
- The rail sector in South Africa is very small and, given the state of PRASA, skills can essentially only be developed in concert with Transnet Freight Rail.
- From an engineering point of view, Taiwan – a country subjected to risk of earthquakes and typhoons – has the best HSR expertise.
- We need to start developing the requisite skills 5 to 6 years ahead of the large projects.

Question 8. What the success factors to ensure a timely domestic O&M capability and capacity exit in SA?

Responses to Question 8:

- Ibid.

Question 9. What, in your view, are the three most important considerations to ensure multiple successful concessions of the new SG rail network to ensure success?

Responses to Question 9:

- Concessions open up scale, opportunities, competition, and manged pricing.
- Concessions will only work in a well-managed economy.

Question 10. What percentage of Private Sector Investment in South Africa's rail network should be primarily focused on building a new SG network for freight and passenger; and in the CG network (to improve existing capacity and increase utilization) – as both gauges will compete for Private Sector Investment (PSI)?

Responses to Question 10:

- Not addressed due to time limitations.

Question 11. Do you foresee only large terminal or large station integration between the CG and SG networks designed for cargo buffering or lay-over waiting? If not, how do you see predictable schedule integration of the aged CG systems with the new SG systems.

Responses to Question 11:

- Not addressed due to time limitations.

Question 12. What are the top five factors in your view that will determine investment in a new long distance SG passenger rail network?

Responses to Question 12:

- Not addressed due to time limitations.

Question 13. Where there is the potential for route density competition, should the Final Investment Decision (FID) in new SG rail network be predicated on a minimum capacity utilization level of the existing CG routes? If so how do we ensure capacity utilization of the CG network realizes the expectation? If not, how do we prevent the new SG network from cannibalising of existing CG traffic?

Responses to Question 13:

- It is an econometric question.

Question 14. What are the top 3 institutional levers that you foresee will promote the gauge modernization of the South African rail system?

Responses to Question 14:

- Since we have a large economy with many nodes, the regulatory framework and common standards are important.

Question 15. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Responses to Question 15:

- We need to figure out how to fix PRASA post the COVID-19 unguarded lockdown.

Transnet SOC Limited (Transnet)

Three sessions were held with Transnet. The first was exploratory at Group Level on 5 May 2021. The second session on 18 May 2021was introductory to the executive of Transnet Freight Rail, the rail Operating Division of Transnet. The third session on 23 June 2021 was a presentation by the consultant of the preliminary research outcomes to a combined team from Transnet Group and Transnet Freight Rail. At this session Transnet confirmed their own view to be broadly aligned with the Author's preliminary recommendations.

Passenger Rail Agency of South Africa (PRASA)

The following questions were used to guide the 25 May 2021 discussion with the Passenger Rail Agency of South Africa (PRASA):

Question 1. What are the Top-5 advantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 1:

- Stability.
- Track stiffness.
- Higher speeds for freight and passenger – note that South Africa requires a network speed of at least 40km/h for a growing economy and road operates around 30-35km/h vs. rail at 60km/h.
- Passenger comfort. Although the Blue Train is comfortable on CG, this required a rolling stock upgrade; availability of rolling stock.

It would be useful to split the existing CG urban passenger network from the freight system given the different train lengths and operating priorities anyway, even if the gauge remains the same.

Ultimately later generations will ask us why we did not convert to SG in 2021, as we now question the 1910 decision by government to do away with CG in favour of NG.

Question 2. What are the Top 5 disadvantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 2:

- Although it is too expensive to covert the existing system, there are only a few disadvantages for new long-distance track.
- The 2 x 10-year CG urban rolling stock modernization projects (one presently in execution) has committed at least more than R50bn (2021) to EMUs on CG.
- Execution across a gauge break is requires schedule integration and reliable execution thereof to avoid stranded passengers and freight.

- The typical short distance between urban stations in South Africa's metros limits the maximum practical line speed to avoid passenger discomfort during acceleration and braking.

Question 3. Do you foresee that the provincial and/or municipal spheres of government will be encouraged to develop their own Standard Gauge (SG) metro networks as new assets, rather that partake in Cape Gauge (CG) devolution?

Responses to Question 3:

- Devolution of Quality Management of the PRASA-operated process makes sense, not of the actual operations.

- The devolution policy is sound, but the problems lie in implementation.

- Until such time that the Minister of Transport, the Provincial MEC for Transport, and the Municipal Mayoral Committee all execute their respective mandates effectively and in concert, devolution cannot succeed.

Question 4. Should South Africa convert any of its for Passenger of Freight Cape Gauge Rail (CGR) lines to Standard Gauge?

Responses to Question 4:

No (see question 2).

Question 5. How would you determine the selection and priorities for gauge conversion for Passenger Rail; and for Freight Rail?

Responses to Question 5:

- New long distance PRASA plans, presently on hold should benefit from SGR.

- Presently the planned extension of the PRASA network to service the Moloto corridor is not fundable, as the DOT still has to conform it final position on this.

- PRASA is also considering developing the Bloemfontein – Thaba 'Nchu corridor, which could be on SG.

- New metro corridors planned by PRASA include: i) Motherwell in Nelson Mandela Bay; and ii) the Blue Downs link in Cape Town.

Question 6. What are the success factors to secure funding for a new SGR, possibly in competition with the existing CGR?

Responses to Question 6:

Not addressed.

Question 7. What are the success factors to ensure a timely domestic EPC capability and capacity exist in SA?

Responses to Question 7:

Not addressed.

Question 8. What are the success factors to ensure a timely domestic O&M capability and capacity exist in SA?

Responses to Question 8:

Not addressed.

Question 9. What, in your view, are the three most important considerations to ensure multiple successful concessions of the new SG rail network to ensure success?

Responses to Question 9:

Not addressed.

Question 10. What percentage of Private Sector Investment in South Africa's rail network should be primarily focused on building a new SG network for freight and passenger; and in the CG network (to improve existing capacity and increase utilization) – as both gauges will compete for Private Sector Investment (PSI)?

Responses to Question 10:

Not addressed.

Question 11 Do you foresee only large terminal or large station integration between the CG and SG networks designed for cargo buffering or lay-over waiting? If not, how do you see predictable schedule integration of the aged CG systems with the new SG systems.

Responses to Question 11:

Refer to Question2: 'Execution across a gauge break is requires schedule integration and reliable execution thereof to avoid stranded passengers and freight.'

Question 12. What are the top five factors in your view that will determine investment in a new long distance SG passenger rail network?

Responses to Question 12:

High-speed Rail.

- HSR is very far down the road for PRASA.
- The GP – Durban route will be practical if we commercial flight schedules can be adjusted to allow for 'greener' rail to compete (as is the case recently announced in France).
- The long-distance travelling population is not large enough to justify an investment in HSR.

- Although the NDP calls for 10% investment in network industries (including transport) to solve an economic backlog, it is not clear how HSR will meaningfully contribute to this outcome.

Question 13. Where there is the potential for route density competition, should the Final Investment Decision (FID) in new SG rail network be predicated on a minimum capacity utilization level of the existing CG routes? If so how do we ensure capacity utilization of the CG network realizes the expectation? If not, how do we prevent the new SG network from cannibalising of existing CG traffic?

Responses to Question 13:

- Due to the devastating impact of unsecured / un-Policed vandalism since PRASA cancelled the security contracts in 4Q2019 and through the COVID-19 Lockdown period, PRASA now faces many immediate infrastructure recovery and operations problems that urgently require management attention. Only once this has been stabilized, which could take many years, can PRASA consider an expansive view again.

- The immediate priority now is re-opening the full service on the Mabopane corridor in Gauteng, and the Central Line in Cape Town.

Question 14. What are the top 3 institutional levers that you foresee will promote the gauge modernization of the South African rail system?

Responses to Question 14:

Not addressed.

Question 15. Outside of the attached TOR, what other guidance do you wish the consultant to consider?

Responses to Question 15:

The ineffective slow Procurement Process of PRASA is a massive problem, which has left the organization's engagement with the supplier market moribund. Some projects have been tendered three times without appointing contractors, and supplier fatigue has set in.

Unless we find an innovative and accelerated Procurement Process, as allowed for by the PMFA and the PPPFA, PRASA will not recover its network to a useful operational standard any time soon.

Swiss Railway Association

Question 1. What are the Top-5 advantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 1:

21% of the Swiss network is on Metre Gauge and 79% is on Standard Gauge. The narrow gauge is ideal for the mountainous parts of Switzerland, where sharp curves, steep gradients and slower speed render Standard Gauge too costly and unnecessary.

On easier terrain SG is useful as it safely improves stability and rider comfort at higher speeds of 160km/h. The French TGV high speed trains enter into Switzerland where the HSR service terminates.

SG is a convenient gauge to access a broad market of suppliers.

Question 2. What are the Top 5 disadvantages of implementing Standard Gauge Rail (SGR) for new track in South Africa?

Responses to Question 2:

It is very costly to maintain two different gauges in one country. Not only in terms of the cost of managing transshipment and passenger transit across the gauge break, but also in terms of multi-gauge maintenance equipment and skills differences.

It is time consuming and costly to implement a new standard gauge project.

There is also a lack of know-how to operate different gauges.

Question 3. What are the success factors to secure funding for a new SGR, possibly in competition with the existing CGR?

Responses to Question 3:

Not address.

Question 4. How can the Swiss Rail Industry assist with a timely domestic SGR EPC capability and capacity in SA?

Responses to Question 4:

The Swiss Rail Industry believe the work can be done without the need for the 'Big EPCs'

Question 5. How can the Swiss Rail Industry assist with a timely domestic SGR O&M capability and capacity in SA?

Responses to Question 5:

South Africa does not need a new railway, they need to existing railway to work to the high operating standards it achieved many years ago already.

A concerted programme to mobilize community participation in reconstruction and societal ownership of the utility value is key. The Medellin Metro (Columbia) is a Swiss made case study where the social slogan 'The metro is yours, love it!' resulted in complete economic transformation of the city. Perhaps PRASA should get a famous and respected brand ambassador to champion the loyalty programme to 're-love' metro rail and get the community to shun vandals.