Gautrains proudly lined up outside the depot workshop

Gautrain State of Good Repair: three years after the first trains were commissioned

With government-owned assets and the sustainability of service delivery a primary objective, the "State of Good Repair" of the Gautrain rapid rail system will in future play a fundamental role in determining its quality and ability to deliver a world-class transportation service. If not managed responsibly, the system could experience major operational and financial challenges that will result in public discontent and possible ridership decline. This article gives a broad overview of a study that was carried out to determine the Gautrain's State of Good Repair.

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BACKGROUND

The Gautrain system comprises a total of 143 km of railway track – 20 km of tunnel track slab and 123 km ballasted. The tunnel section runs from the Portal (close to Marlboro Station) to Johannesburg Park Station, with the first 5 km stretch between the Portal and Sandton being a double-line and the remaining tunnel section linking Sandton to Johannesburg Park Station via Rosebank being a single line, 10 km in length. The ballasted section includes 46.5 km of double-line track stretching from Marlboro to Hatfield via Midrand, Centurion and Pretoria. Another double-line ballasted section of 15 km links Marlboro to the OR Tambo International Airport via Rhodesfield. Ten stations and dedicated bus feeder and distribution services line the route. The route alignment is shown in Figure 1.

The Gautrain system is the first rapid rail train in South Africa, achieving operational speeds of up to 160 km/h and using a standard gauge track width (1 435 mm). Most other South African railways operate on narrow gauge track (1 067 mm).

The project, consisting of the design, construction and financing of the system, as well as on-going operation and maintenance, has brought together government, the private sector, and a host

Figure 1: Gautrain route alignment

of local and international specialists in an unprecedented manner. The Public Private Partnership (PPP) Project has the government of the Province of Gauteng as the client, and the concessionaire – Bombela Concession Company (BCC) – will transfer the system back to the client at the end of the 15-year operating period. The Gautrain project not only addresses a critical transport need in the province, but also meets the government's objectives of promoting and stimulating economic growth, development and employment creation.

The Gauteng Province has appointed the Gautrain Management Agency (GMA) to oversee the Gautrain Project. The concessionaire (BCC) has subcontracted the operation of the Gautrain system to Bombela Operating Company (BOC), and BOC has in turn subcontracted the perway, wayside and rolling stock maintenance to Bombela Maintenance Company (BMC). Bombardier Transportation supplied the Electrostar Electric Motive Units (EMUs), i.e. the trains that run on the network.

STATE OF GOOD REPAIR

Internationally there has been a shift in the focus of service and service delivery sustainability of strategic assets, specifically within asset intensive organisations such as local governments, transits and government agencies. Accounting reform in the South African public sector has been a primary process driven by the National Treasury since 1998. This process fundamentally requires municipalities to comply with generally recognised accounting practices (GRAP), which, from an asset management perspective, focus on how to recognise assets in the financial statements. From a property plant and equipment perspective (GRAP 17) local government entities are required to recognise these assets, based on the useful life and the remaining useful life, in turn based on condition monitoring and/or actual construction date, and to determine their fair value accordingly. A major portion of developing a fixed asset register is the influence of condition on the asset's fair value.

In recent years the Federal Transit Administration (FTA) in the United States of America also started with a drive in transits, to determine the State of Good Repair (SOGR). As stated on the US Department of Transportation Federal Transit Administration's website, *"Maintaining the nation's bus and rail systems in a State of Good Repair is essential if public transportation systems are to provide safe and reliable service to millions of daily riders. State of Good Repair includes sharing ideas on recapitalization and maintenance issues, asset management practices and innovative financing strategies. It also includes issues related to measuring the condition of transit capital assets, prioritizing local transit re-investment decisions and preventive maintenance practices. Finally, research and the identification of the tools needed to address this problem are vital. The FTA will lead the nation's effort to address the State of Good Repair by collaborating with industry to bring the nation's transit infrastructure into the 21st Century."*

The FTA will use information related to the SOGR provided by transits to determine to whom, as well as how much,

the FTA will support transits through grants, to maintain/renew/replace a transit's infrastructure assets to an SOGR. This should result in a system that provides sustainable, safe and reliable transport services to the public. To qualify for such grants, transits need to develop a complete asset register, perform a condition assessment on the assets and provide a detailed Transit Asset Management Plan to the FTA to be considered for SOGR grants. Furthermore, the following primary objectives are identified as part of the SOGR initiative to consider reinvestment needs:

- What are the current physical and service conditions of the nation's transit assets?
- How do these conditions compare to an "ideal State of Good Repair"?
- What is the current investment backlog and what level of investment would be required to attain a state of good repair?
- How are unmet reinvestment needs impacting service quality and maintenance needs?

More details on the State of Good Repair initiative can be obtained from the FTA website at www.fta.dot.gov/13248.html and at www.fta.dot.gov/documents/SGR.pdf.

CONDITION MONITORING

The condition of railway track is generally determined by either measuring the absolute track geometry, calculating the roughness of the track (in terms of standard deviations) or, more recently, by measuring the response of a design vehicle travelling on the track in terms of the accelerations caused by track irregularities. The Gautrain concessionaire does all three as part of a comprehensive condition monitoring regime. This article, however, focuses only on the former two aspects.

The greatest challenge of condition monitoring is often not the method of obtaining the data, but rather the task of interpreting the vast amounts of data and setting realistic and useful limits to the calculated parameters or indices.

A literature review was conducted to compare the proposed geometric standards for Gautrain with those of international railways that use the same track gauge (1 435 mm) and maximum speed (160 km/h). Comparisons were made with Swedish National Standards [1], Australian Standards [2], Federal Track Standards (USA) [3], Network Rail [4 & 5], British Standard CEN [6] and Japanese Railways [7]. Based on this exercise, the proposed track geometry limits and track quality index calculations were adjusted to find a balance between South African practice and international standards.

TRACK GEOMETRY

Track geometry is measured in terms of the five most common parameters, namely profile, alignment, gauge, cant and twist. Three limits, namely installation, maintenance and intervention, are then specified for each parameter. Exceedences of these limits are used to programme normal and emergency maintenance interventions. Table 1 shows a summary of the concessionaire's geometry limits. These limits are in line with Network Rail standards [4 & 5].

Track quality

A track quality index (TQI) is calculated for each 200 m section of track, based on a relatively simple weighted sum of different track geometry standard deviations. As before, limits can then be imposed to use the TQIs for classifying the track geometry condition as excellent, good, average or poor.

The formula used by Gautrain incorporates profile, alignment, twist, gauge and cant:

$$TQI = 0.3\sigma_{PRA} + 0.3\sigma_{ALA} + 0.2\sigma_{TWT} + 0.1\sigma_{SUP} + 0.1\sigma_{GAU}$$

where

σ_{PRA} = standard deviation: *Profile Average*

σ_{ALA} = standard deviation: *Alignment Average*

σ_{TWT} = standard deviation: *Twist (3 m base)*

σ_{SUP} = standard deviation: *Superelevation/Cant*

σ_{GAU} = standard deviation: *Gauge*

The ***TQI*** formula [8] gives equal weights to profile, alignment and the sum of twist and cant – two closely related track parameters. Gauge is given a weight of a third compared to the other parameters because of the fact that gauge will not change nearly as

Trains parked at Gautrain depot workshop platforms

Table 1 Gautrain concessionaire's geometry limits

No	Parameter	Measurement length	Limit (mm)		
			Installation	Maintenance	Intervention
1	Profile	10 m chord	-4 ; +4	-10 ; +10	-13 ; +13
2	Alignment	10 m chord	-4 ; +4	-10 ; +10	-13 ; +13
3	Gauge	n/a	-3 ; +5	-5 ; +15	-9 ; +30
4	Cant	n/a	-3 ; +3	-10 ; +10	-15 ; +15
5	Twist	3 m	4 mm or 1:800	7.5 mm or 1:400	10 mm or 1:300

much as the other parameters, due to being constrained by the concrete sleepers, pads and fasteners. Giving equal weights to all five parameters is considered an accepted method, but this approach does not take into consideration the engineering importance of the different parameters.

The ***TQI*** parameter provides all parties (operator and maintainer) with an accurate, overall quality index of the track. The parameter can be used to evaluate the general condition of the track, and for studying time- or traffic-related trends in the deterioration of the track. The parameter is insensitive to single exceedences and can therefore not be used for location-specific maintenance planning.

The following general classification [8] is used to describe the four different track classes:

$TQI \leq 1.4$	: Excellent
$1.4 < TQI \leq 1.6$	: Good
$1.6 < TQI \leq 1.8$	: Average
$1.8 < TQI$	: Poor

THE GAUTRAIN STATE OF GOOD REPAIR: SPECIFIC TO TRACK ASSESSMENT

A track geometry condition measurement campaign conducted in March 2013 resulted in approximately 600 000 condition records for five different parameters (profile, alignment, gauge, cant and twist). These parameters were used to calculate the track quality index as presented in the TQI formula for the total system, based on a 200 m running average.

The five parameters are measured every 250 mm, and each 200 m section is therefore made up of 800 records. The running average is calculated by means of analysing records 1–800, followed by 2–801, followed by 3–802, and so forth, in an attempt to minimise the averaging out of poor track areas. This calculation provides a statistical representation (cumulative frequency plot) of the system's overall condition index as presented in Figure 2.

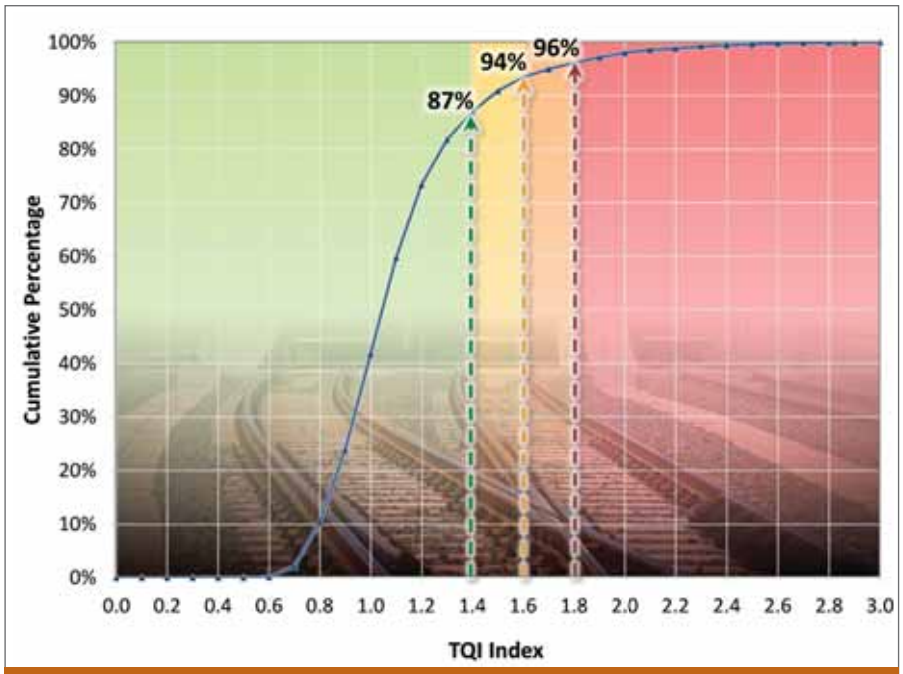

Figure 2: Cumulative frequency plot of the Gautrain system, based on the TQI index (March 2013)

A view from the cab as a Gautrain leaves the depot workshop

Figure 2 is divided into 3 distinctive areas. The first, shown in green, represents the condition of the Gautrain system that performs within the construction or installation parameters. If a section of track performs within this area, it denotes a condition attribute to the section as being in excellent condition. Track in this area requires no maintenance at the specific point in time (March 2013 measurement campaign). The analysis indicates that the performance of the total system is well within the defined standards. In general it can be said that more than 85% of the system is in excellent condition.

The second portion in Figure 2, shown as two variations of the colour orange, represents the section of line that requires planned maintenance. This can be translated into the distance of the railway section requiring planned maintenance. Planned maintenance is defined as activities that will not disrupt the immediate service delivery to passengers. These activities are planned in advance according to standard processes and procedures developed and implemented throughout the Gautrain organisation. These maintenance sections are recorded as work orders in Gautrain's work management system, and coordinated with the train operations unit (BOC), where the maintenance organisation (BMC) will apply for work permits to execute the required maintenance at specified locations. The train operations unit, granting these working permits, ensures that the required capacity is maintained, thereby enabling availability of the infrastructure at a required and specified standard. In March 2013, Gautrain's track geometry condition resulted in approximately 94% of the line performing within the "good" track classification band (i.e. $TQI \leq 1.6$).

The section indicated in red in Figure 2 represents the portion of the line that requires corrective maintenance. Corrective maintenance is required when the geometry of a section of line is above the threshold level, requiring intervention to rectify the problem. It should be stated that these areas have to be investigated and analysed in

detail to determine the root cause(s) of the underlying problem. Furthermore, it should also be noted that some of these areas or sections that perform below the defined intervention thresholds could be built-in defects within the system. For example, a turnout condition performance, utilising the track geometry data, will indicate an area performing below the required standard due to the nature of a turnout's function and its configuration within the system. This should be taken into consideration when determining the performance of the total system. Figure 2 reveals that in March 2013 only 4% of the total system fell within this category. Compared to world best practice, it is expected that approximately 15-20% [9] of the total maintenance activities will be related to reactive/corrective maintenance.

CONCLUSION

Related to the State of Good Repair, and based on best practice condition assessment data of a transportation facility, it can be expected that some natural deterioration would occur due to utilisation. From the analysis results it is clear that the Gautrain system's current State of Good Repair is predominantly in excellent condition. It is the opinion of the authors that the system, specifically related to track (superstructure as well as substructure) is performing according to design, is well maintained and that currently, only normal, planned maintenance is required. The system can be qualified "as good as new" after approximately three years of operation from OR Tambo International to Sandton, and after 20 months for the remainder of the network.

REFERENCES

[1] Banverket 1997. Control and quality standards of track geometry irregularities. BVF 587.02, Banverket, Borlänge, Sweden.

[2] Australian Rail Track Corporation 2011. Track Geometry Standards for Construction, Upgrading and Maintenance Works. ETF-05-01, ARTC, Engineering (Track and Civil), Australia.

[3] Federal Railroad Administration 2008. Track Safety Standards Compliance Manual, Part 213, Subpart G, Office of Safety Assurance and Compliance, Track and Structures Division, United States of America.

[4] Network Rail 2005. The Inspection and Maintenance of Permanent Way. NR/SP/TRK/001, Network Rail, London, UK.

[5] Network Rail 2009. Inspection and Maintenance of permanent way – Installation requirements, maintenance limits and intervention limits. NR/L2/TRK/001/C01, Network Rail, London, UK.

[6] CEN 2005. Railway applications – Track – Track geometry quality – Part 5: Geometric quality assessment, German version, prEN 13848-5:2005.

[7] Zicha, J K 1989. High-speed Rail Track Design. *Journal of Transportation Engineering*, 115(1):68–83.

[8] Gräbe, P J 2012. Gautrain Track Geometry Standards – Review of the Concessionaire's Proposal and Recommendations, Report PJG1201 Version 05 (Final).

[9] Mitchell, J S (Editor) 2007. *Physical Asset Management Handbook*. Clarion Technical Publishers, 466 pp.