Fundamentals of Railway-Track Engineering and Technology;
Quotations for achieving sound and healthy Railway-Tracks of high Quality fit for modern “World-Class" Railway-Service

By Dr. F.A. Wingler, April 2018

SUMMERY:

“MODERN RAIL-TRACK TECHNOLOGY HELPS TO CUT LIFE CYCLE COSTS”;
“A TRACK IS ONLY AS GOOD AS WHAT IS UNDERNEATH”;
“A TRACK IS ONLY AS GOOD AS ITS WEAKEST SPOT, BECAUSE A TRAIN MIGHT DERAIL ON SUCH A SPOT”;

Modern High Quality, Heavy Haul Rail-Track; Union Pacific “Sunset-Route”, California, USA: Pict.: EK Verlag, www.eisenbahn-kurier.de

Optimising the all-important Wheel-Rail System
CONSIDERATIONS ON QUALITY AND TRACK BEHAVIOUR:

There is no other country around the world other than India, from where so many nasty Train-Accident Disasters can be reported.

It can never be ethically acceptable that people are killed or seriously injured when moving within a transport system!

Poor quality rail-tracks, not matching the traffic load/volume/speed, are an underlying factor for India’s nasty and unwanted Derailment Accidents.

With every train goes, a track is subjected to aging like “every water-drop adds to the hole in the stone”.

A proper quality of a track and other infrastructure objects represent a basic requirement for train safety and punctuality. Most of the physical systems and their components deteriorate over time. This affects performance and may lead to failures. Albert Einstein said, “You have to learn the rules of the game. And then you have to play better than anyone else.” Only if we understand how the whole system works, taking into account its imperfections, and how the imperfections influence its quality and performance, we will be able to learn the rules of the game, and hence we will “play better".
To keep trains running on a low or poor quality track is not only more risky but also more cost intensive.

A poor or low quality rail track needs more frequent surveillance than a high quality track.

The lower the Track-Quality, the more frequent Track-Inspections and Monitoring are appropriate.

A low Quality Track deteriorates faster than a high Quality Track and hence needs more maintenance expenditures causing higher costs.

Under Overall Life-Cycle Considerations **Quality is no Luxury; it is a Must.**

Life Cycle Costs Considerations are tools for economical Track Strategies. Under such Considerations modern Track-Technologies have been pushed up.

In order to make it cheaper, it is jugglery to hope that through appeals to the ingenuity of the Track-Men technical and physical laws, rules and connections can be overruled. At the end, jugglery short-cut works will turn out to be far more costly and to bring train-passenger`s freedom from bodily harm and injury at risk.

At the end, jugglery short-cut works will turn out to be far more costly and to bring train-passenger`s freedom from bodily harm and injury at risk:
“There is hardly anything in the world, that some man cannot make a little worse and sell a little cheaper. And the people who consider price only are this man`s lawful prey”.

“It is unwise to pay too much, but it is worse to pay too little. If you pay too much, you sometimes lose some money on the long run. On the other hand, if you pay too little, you sometimes lose everything, because the thing you bought was incapable of doing the thing it was bought to do. The common law of business balance prohibits paying a little and getting a lot – it can`t be done. If you deal with the lower bidder, it is well to add something for the risk you run. And if you do that, you will have enough to pay for something better!”

“Quality is always the result of high intention, sincere effort, intelligent direction and skilful execution. It represents the wise choice of many alternatives”.

= Quotations given by University Professor JOHN RUSKIN, Oxford, UK, 1819-1900, which can be evaluated as a summing-up for this economical proof on basis of QUALITY, LIFE CYCLE COSTS and LIFE CYCLE COSTS CONSIDERATIONS.

Quotation by Benjamin Franklin, 1705 -1750, USA

Heavy Traffic Load/Volume causes high wear leading to high maintenance demands and hence to high maintenance expenditures.

A healthy and sound rail-track with a high Inherent Quality keeps its properties under given traffic load/volume/speed longer than a less healthy and sound rail-track. Hence, a low quality track deteriorates faster than a high quality track.

A high quality rail-track ages slower and has a longer service live than a low quality track. A moderate reduction in Initial Quality results in the track condition reaching the threshold for maintenance-intervention much earlier:
The **Inherent Quality** is governed by what is underneath of the super-structure-components (superstructure-components; consisting of Sub-Ballast (Blanket), Sleepers, Rail-Fastening Systems, Rails), and by the bearing quality and property of the sub-structure components consisting of Sub-Soil, Sub-Grade, Formation (Strata):

In cases, where the sub-structure is unhealthy and unsound, Optimising the Rail-Track is not possible.

For a rail-track with low inherent quality the maintenance intervals become shorter on account of unhealthy, unsound and poor bearing sub-structure as well on account of poor drainage, than for a rail-track of higher inherent quality.

Investment delivers just **Initial Quality**, not service life. Maintenance transforms this initial quality into service life. Thus, neglected Maintenance devalues the investment done.

**“A Rail-Track behaves like an Elephant”!** (Professor P. Veit, Austria): A track can tolerate a lengthy period of overuse, carelessness, neglect and ill-treatment until it will react. Like an Elephant, a Track has a memory for neglected care and ill-treatment:
But be sure, suddenly the track remembers missing care, and it reacts and
like an Elephant running berserk and throwing the train off the track.

“A Track behaves like an Elephant” (Prof. P. Veit, Austria)
When the track reacts, service live is already gone. Thus, when the track takes revenge like an elephant and throws the train off the track, it is already too late for maintenance:
To keep the quality of all rail-roads in India in compliance with the increased traffic load/volume/speed, massive capital investment schemes of long-term certainty are needed. And “long-term” in Railways means really long, covering a period of 5 to 15 years ahead for planning, organisation, logistics and procurements.

Before luring to “take Indian Railways to the League of World-Class Railways” one has to overcome the constraints in Track-Maintenance, -Upgrading-, -Reengineering, -Strengthening, -Modernisation and -Renewal. And one has to catch up with the accumulated back-log in Track-Maintenance, -Upgrading-, -Reengineering, -Strengthening, -Modernisation and –Renewal.

Without sound and healthy Rail-Tracks of high Quality matching the Traffic-Load, -Volume and -Speed there will be no World-Class Railway.

It should be well understood: For maintaining excellent Rail-Service excellent Rail-Tracks are the prerequisite. And many routes in India are not excellent.

The problem in India is not of safety standards but of the execution of standards.
A WORLD-CLASS RAILWAY needs MODERN SOUND AND HEALTHY WORLD-CLASS RAILWAY-TRACKS OF HIGH QUALITY

WITHOUT SOUND AND HEALTHY RAIL-TRACKS OF HIGH QUALITY, MATCHING THE TRAFFIC-LOAD/VOLUME/SPEED, MODERN RAILWAY SERVICE WITH CLOSE-TO-ZERO FATAL TRAIN-DERAILMENTS IS NOT POSSIBLE!!!

Massive Capital-Investment in Track Quality, to optimise the Wheel-Rail System, is no Luxury. It not only cuts overall Life-Cycle Costs but also prevents that Train-Passengers are killed or injured in unwanted nasty Derailment-Disasters!

The costs of improving SAFETY all arise immediately, but the benefits emerge only in long-term. And "long-term" in railways is really a long time, that covers the next 15 years.

Train-Passenger`s Freedom from bodily Harm and Injury matters!
Private mining corporations with their own HEAVY-HAUL rail-roads in Africa, Australia, Brazil and Norway/Sweden have a sense for OVERALL LIFE CYCLE COSTS inclusive the AGGREGATED HINDERANCE COSTS, generated when the trains can only run under speed restrictions, under lower traffic density or cannot run at all. The private undertakings know about the importance of INITIAL TRACK QUALITY, STATE-TO-THE ART RAILROAD TECHNOLOGY and the all-important WHEEL-RAIL INTERFACE. They have learned to manage the wheel-rail system at its optimum by looking out for track friendly rolling stocks (bogies), by target profiling both wheel treats and rail heads for low friction and wear and by top-of-rail and wheel-flange lubrication. This is called “Friction Management”. The economy has pushed the technology already to the performance with 43.5 t axle-load. Developments are under way to increase the axle-load up to 45 t; see Keith Borrow, PILBARA’S HEAVYWEIGHT CHAMPION FLEXES ITS MUSCLES in IRJ, International Railway Journal, November 2015 Volume 55, Issue 11, page 20ff.

Private heavy-haul operators know: Without a well bearing, well drained and stable blanket, sub-soil, sub-grade and formation there will no stable rail-track under given traffic load/volume/speed.

Pilbara Heavy-Haul in Australia catering 43.5 t Axle-Load, Pict.: IRJ

In state owned railways mostly one section feels responsible only for the track and the other section only for the rolling stocks. There is often a lack of mutual understanding, responsibility and cooperation between the disciplines. This has the result that often rail tracks do not match the traffic load they have
to carry vice-versa. The developments of Tracks and Rolling Stocks when running apart are not in compliance.

A railway consists not only of individual components viewed separately, but of the ENTITY of "ROLLING STOCK/WHEEL - TRACK" System. Rail-Road and Rail Vehicle interact actively. Defective tracks ruin rolling stocks and ruined bouncing, yawing, rolling and pitching rail vehicles distort and deteriorate an already poor track further as an INTERACTIVE MUTUAL SELF DESTROYING SYSTEM.

The individual components of a rail-road: Sub-soil, sub-grade, formation, sub-ballast (blanketing, formation protective layer (FPL), ballast, sleepers, rails and fastening materials, behave interactive and have to be treated as an entity. Strategies must be based on treating the track as a whole structure rather than treating the individual elements or components. Each of the components interacts with the other components individually. Strengthening only one component to a level well beyond the strengths of the other components will provide only incremental and inefficient overall strength improvements.

As an typical example: Sri Lankan Track Policy and Strategy of the last decades has clearly demonstrated, that the “SOLO FIDDLE ON THE SUPERSTRUCTURE COMPONENTS” (sleepers, rail fastenings, rails) without a proper appropriate sub-grade, sub-soil and formation strengthening and without taking the water out and keep the water away from the track-bed by a proper surface water drainage management led only to a further degradation of the rail-roads; see also Mike Knutton and Malcom Owens in IRJ, International Railway Journal, August 2004, p. 25.

The track must:

• guide vehicles in a smooth way without risks of derailments and without excessive wear and tear of rails, wheels and rolling stocks,

• take up vertical and horizontal vehicle forces,

• off-load these forces via the track grid and ballast/sub-ballast bed onto the bearing formation, sub-grade and sub-soil,

• ensure high riding comfort, passenger comfort, satisfaction and safety,

• high availability for train traffic under low OVERALL LIFE CYCLE COSTS and low AGGREGATED HINDERANCE COSTS (costs generated, when the trains are not running or only with speed and traffic load restrictions).
The Rail-Wheel System transmits vertical and horizontal forces onto the track. Furthermore the track is subjected to the influence of longitudinal forces arising because of changes in temperature. It gets stressed by the acceleration and brake deceleration efforts of the rail vehicles. The track is also stressed by quasi-statistic, low frequency and dynamic force components of high frequencies (wheel roaring on corrugated rails).

The figure below schematically represents the WHEEL-TRACK-SYSTEM. The individual parts of this system are linked by components exerting elastic and damping effects. The elastic and damping elements between vehicle bodies, as well as between bogie and wheel set, are well known, and their behaviour can be very well expressed mathematically:

SCHEMATIC DEMONSTRATION OF THE WHEEL-TRACK SYSTEM.
From the TRACK COMPENDIUM, Track System Substructure Maintenance Economics by B.Lichtberger, eurail-press, HAMBURG, 2011, p.21, ISBN 978-3-7771-0421-

The track itself with its elasto-plastic properties cannot be expressed by an exact analysis because of the inhomogeneous behaviour of the ballast bed,
the formation protective layer (FPL) or blanketing material/sub-ballast on top of the bearing formation, sub-grade and sub-soil. Empiric parameters and connections found out by experiments are used for this purpose.

The strength of these forces is a function of the axle-load, of changes in wheel loads when negotiating curves, or in case of unequal loading, of braking and starting forces and the rolling of ovalized unbalanced wheels on a defective track.

The track grid has to distribute these forces in such a way that the maximum admissible values for ballast compression below the sleepers and the admissible compressive strain on the bearing soil will not be exceeded.

A rail track on rigid concrete sleepers needs therefore a better bearing and wider formation and a thicker damping ballast cushion with harder ballast stones under the sleepers than a rail track on wooden or timber sleepers. This means that when changing from wooden sleepers to concrete sleepers the bearing formation has to be strengthened, widened, and a thicker ballast spreading, best with harder ballast stones on a sub-ballast bed, provided, otherwise the formation will get damaged. The lower elasticity of concrete sleepers has to be compensated by higher elastic rail-pads and by a deeper ballast cushion/bed:

![Diagram of load bearing components](image)

**Average Contribution (%) of each Load bearing Component towards the overall elastiv Behaviour of the Track-System.**

Steel-Sleepers have the advantage of longevity and toleration of troublesome and narrow formations with less ballast; but they do **NOT TOLERATE WET MUD**. The bottom of concrete sleepers touches the ballast stones only by an area of 10 to 11%. Moving or "dancing" concrete sleepers crush the ballast edges to dust, forming with water a slurry and fouling the ballast bed and its elasticity. With under-sleeper pads the contact-area can be increased from 10 to 35% and the tamping intervals prolonged by 2.75 times.

In Austria lacing the sole of the concrete sleepers with a rubber pad has become standard. This increases the life-time of the ballast and the track by up-to 38% and reduces maintenance expenditures:
It has to be well understood that without comprehensive drainage and formation/sub-grade rehabilitation, reengineering and strengthening a moribund track cannot be brought to a level matching the traffic load in order to render a smooth, risk free and overall economical train service. It must be understood, that the main track structure is provided by the ballast, sub-ballast (blanket) and the well-drained compact broad and well bearing formation. A Broad Gauge concrete sleeper single track needs a 7.5 to 7.80 m wide top formation. The solo fiddle on the superstructure only with rail, sleepers and fastenings provides only a short lasting and jugglery cheaper alleviation.

The Track-Quality can be estimated by the Deterioration Rate under given Traffic Load, by the loss of Alignment Parameters and Track Support Modulus with the time under given traffic load; see the contributions of Prof. P. Veit and Dr. B. Lichtberger in RTR Special, MAINTENANCE AND RENEWAL, July 2007, ISBN 978-3-7771-0367-9, DVV Media Group GMBH, Hamburg, Germany).

The Longevity of a Track Rehabilitation depends, if the water has been taken out and kept away from the track bed, and if the bearing capacity of the formation had been strengthened. The formation is by 40% responsible for the elasticity of a rail-road. DRAINAGE of the track is the single most important factor for proper maintenance. Proper drainage is vital as excess water reduces the bearing capacity of the sub-soil as well as its resistance to shear. Water in the sub-grade or sub-soil is mostly the cause for a misalignment-memory effect; see M.M. Agarwal in INDIAN RAILWAY TRACK, 15th revised edit., reprint 2007, Prabha & Co., Delhi, India, ISBN: 81-900613-1-3, page 461, 229, 233.; Dipl. Ing. Dr. P. Veit in RTR Special MAINTENANCE & RENEWAL, July 2007, ISBN 978-3-7771-0367-9, eurail-press, Hamburg, page 11.

Track Engineers should be aware that very often the memory for track defects, misalignments and settlements is buried in the uneven and faulty formation, sub-grade and sub-soil with fluctuations of the bearing capacity subjected to climate seasons and rain down fall patterns. Seasonable fluctuations of the ground water level can contribute to the MEMORY EFFECT. An appropriate surface-water management is therefore essential.
The Intervention Threshold for formation rehabilitation is given, when the support modulus falls below 10 MN/m². Given norms, parameters and values should be known for the BEARING CAPACITY OF THE FORMATION (measured by the plate load bearing test or by the dynamic plate load method; see Chapter 18 in INDIAN RAILWAY TRACKS – A TRACK ENGINEERING COMPENDIUM; free for download http://www.drwingler.com), and as well for the characteristic soil parameters: Compaction ratio, water content, plasticity parameters, shear strength, the tensional and expansion behaviours and effective tension; see Dr. B. LICHTBERGER in TRACK COMPENDIUM, 2nd edition, ISBN 978-3-7771-0421-8, eurail-press, Hamburg, Germany, 2001, Chapter 7/8; RDSO Pamphlet “Guidelines and Specifications for Design of Formation for heavy Axle-Load”, Report No. GE: 0014, 2009, Lucknow, India.

The specific tracks should be determined by their TRACK SUPPORT MODULUS in the unit [N/mm²] or [MN/m²] or [MPa], measured as deflection of the track under given load. According Prof. A. Kerr, FUNDAMENTALS OF RAILWAY TRACK ENGINEERING, Simmons- Boardman, Books, Inc. Omaha, NE 68102, USA, ISBN: 0-911382-40-2, page 89, for a wooden sleeper track with dog spikes a Modulus of approx. 6 N/mm² is sufficient whereas for a track with the stiff concrete sleepers the Modulus should be in the range of 40 N/mm². The stiffer concrete sleepers transmit to the sub-grade a higher pressure and may create sub-grade failures where none existing when wooden sleepers were used.

By physical laws the track stability, stiffness parameters and moduli have to be increased by 62%, if one wants to increase the train velocity from 80 to 100 kmph under the same traffic load. The necessary increase of stiffness and strength goes logarithmic with the velocity. With increase of the train speed not only the short wave length misalignments but also the long wave misalignments have to be rectified to a minimum of few millimetres.

The Strength of a Rail-Track is determined by the bearing capacity of the well-drained formation. The fatigue of a low quality track under increasing train load stress can be proportional to the 4th or 5th power (exponent) of the load, as can be the damage to the ballast. The damage inflicted by the traffic load onto a poor quality track is by exponents higher than onto a good quality track. A bad quality track deteriorates much faster than a good quality track. The quality of a track can be measured in physical terms by the deterioration rate, by the loss of alignment and the track support modulus under given traffic load with the time.

The loss of quality under traffic stress of a track, which is not in compliance with the traffic load, causes an immense increase in routine-maintenance expenditures. Since a poor quality track deteriorates much faster than a high quality track under the same traffic load stress, a poor quality track needs much higher maintenance costs, which can be 10- fold higher. It is highly uneconomical to render a railway service on a poor quality track not matching the traffic load; see Prof. R.A. Smith, Vice President of Institution of Mechanical Engineers, London, UK, in IRJ Vol. 949, Issue 2, Feb. 2009, page 9; A. Beck et al. in Permanent Way Technology Management, Netz
The Initial Track Quality after track renewal is of the highest importance for the low TRACK DETERIORATION RATES and LONGIVITY (low LIFE CYCLE COSTS, LCC). The deterioration rate is dependent on the current quality. The original initial track quality can never subsequently be reproduced by maintenance and certainly never exceeded. A high quality track deteriorates slower than a low quality track. Track quality can be measured in physical terms by the deterioration rate, the loss of alignment with the time under the given traffic load. Therefore TRACK QUALITY is no LUXURY, but it is an economic necessity; see Prof. Dr. P. Veit, “TRACK QUALITY – LUXURY or NECESSITY?” in RTR SPECIAL Maintenance & Renewal, eurail-press, Hamburg, ISBN 978-3-7771-0367-9, July 2007, page 8, and Dr. B. Lichtberger, THE TRACK SYSTEM and its MAINTENANCE, ibid., page 14.

It should be realised that it is uneconomical to run a rail service on the lowest possible track quality level at the threshold next to accidents and derailments with numerous speed precautions and under heavy wear and tear inflicted onto the rolling stocks – on a rail-road not matching in its quality the traffic load it carries, in order just to keep the trains running, - and on a track, which needs maintenance “nearly as every train goes”.

It must be considered by all railway men, engineers inclusive the top management that in order to run the traffic at appropriate speed, the rail-wheel and track-rail vehicle interactive forces have to be well understood. “It is urgently necessary to remind the responsible persons repeatedly about the mechanism of wheel-rail interactivity in order to secure the safe rail-wheel contact”. = Prof. Dr. Klaus Rießberg, Technical University of Graz, Austria, in ETR 10/2007, eurail-press, Hamburg, page 621.

“For successful implementation of a TRACK MANAGEMENT SYSTEM (strategic planning, track policy) it is essential that detailed guidance lines are available for the maintenance units to carry out all track operations in an appropriate manner. Thus there is a need for track maintenance manuals, which describe the methodology for carrying out all track maintenance operations. Most of the world wide railway systems have track maintenance manuals, which incorporate all the technical information required by the track man for maintenance of tracks in a safe and efficient manner”; see contribution technical paper “APPROPRIATE TECHNOLOGY FOR RAILWAY TRACK CONSTRUCTION AND MAINTENANCE” by J.S. Mundrey to the conference of the heads of the Railway Organisation of BIMSTEC/GANGA MEKONG DELTA COUNTRIES, held in BANKOK on 3th Dec. 2007.
Available Books, Gazettes and Literature for Experts in FUNDAMENTALS OF RAIL-ROAD TECHNOLOGY, ENGINEERING WORKS and RAILWAY SAFETY; Bibliography - Reference List


*RAILWAY GAZETTE INTERNATIONAL*, DVV Media UK ltd., Sutton, UK, ISSN 0373- 5346.

*EI, EISENBAHN TECHNISCHE RUNDSCHAU*, eurail-press, Hamburg, Germany, ISSN: 0013-2845.

*RTR, RAIL TECHNOLOGY REVIEW, SPECIAL SERIES*, eurail-press, Hamburg, Germany.

See also the “MEDIA LIBRARY” in PLASSER&THEURER MACHINES&SYSTEMS-MOBILE RAIL RECTIFICATIONS (-TAMPING)”. 

![Track-Renewal; Sketch from Plasser&Theurer](image)