AFRICAN TRACK & TECHNOLOGY SYMPOSIUM

LECTURE ABSTRACTS

30 September to 4 October 2019

Lifecycle Management

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An efficient rail infrastructure has undeniably been key to the success of most, if not all, affluent industrialised countries. However, for the railway system to be called "efficient" and to be able to transport freight and passengers at cost effective rates, the railway infrastructure must be reliable, available, maintainable, affordable and safe. This can only be achieved if an effective track maintenance strategy is followed which considers the entire track infrastructure as a system, broken down into various subsystems; which considers all activities on the track for its effect on track life and lifecycle cost of the infrastructure. This lecture considers all the lifecycle phases of the infrastructure for its changing demands on maintenance strategies.

The Effect of Maintenance on Network Capacity

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Maintenance to track infrastructure requires a train free window for the safety of trains, track workers and equipment. In this lecture it will be shown how different scenarios affect how maintenance windows are created and how these maintenance windows affect train operations and how train operations affects maintenance. These include:

- different signalling system types
- different train rules
- different train operating methods such as block operating
- different train detection systems including track circuits and axle counters
- the effect of single lines versus double lines
- speed of trains, the unavailability of the line, where trains have been delayed and trains entering and exiting the line in different places

This lecture will also investigate different types of on-track maintenance opportunities such as occupations/possessions and working in-between trains. The criteria for window location selection play a very important role and are also discussed. Last but not least is looking at the costs associated with maintenance windows and the influence it has on the selection of the production and features of maintenance machines.

In this lecture time-space diagrams and the specifics of a fictitious railway line will be used to illustrate some of the different traffic and operating conditions that will affect maintenance, available maintenance time and utilisation and specifications of mechanised machinery as mentioned above.

Safety, Risk and Environment in Feasibility & Design

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The diagram explaining the three states of railway safety will be used in establishing an important understanding of risk and safety during the feasibility and design stage of a project. The Hazard and Operability study (HAZOP) process will be used as a tool to identify possible safety and risk problems during the design stage that can lead to damage or injury to passengers, freight and the environment.

Integrated Railway System Design and Performance

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A systemic engineering approach facilitates the development of a green or brown fields heavy haul railway systems. The understanding and application of systemic engineering thinking within the railway environment has found to be imperative for a sustainable, economic and statutory compliant railway system solution. The success of the railway system project is determined by the identification and application of appropriate systemic engineering fundamentals, appropriate to a railway system project, in the development of a railway system solution.

Railway system performance is a function of system efficiency and effectiveness which is achieved by employing the enabling characteristic of an interdisciplinary approach fundamental to systems engineering. Integration of needs, thought and effort of all railway system disciplines and interested and affected groups into a structured development process that includes opportunity identification, systemic design, system realisation, system implementation and sustainable operation. The appropriate fundamentals are discussed including illustrating the impact of system efficiency and effectiveness upon system performance.

Rail Infrastructure - Efficiencies and Financial Viability

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This presentation will give an exposition of the systemic engineering approach to the design of railway systems, illustrating the rail infrastructure and operating parameters, which differentiates Heavy Haul operations from non-Heavy Haul operations. (34)

Traditionally, the design parameters of new railway systems were based on the permissible axle load and corresponding rail infrastructure material design and construction standards. From a rail functional perspective, the Demand (Mtpa) for freight service, was applied as an indicator to distinguish Heavy Haul systemic and operational design from that of hauling mass freight from mining operations at relatively lower axle loads.(62)

In this paper the parameters used for designing a new green fields railway project, are quantified and their optimization illustrated in terms of the Technical Efficiency and the Operational Efficiency of the Systemic State of the project in relation to the Variable Capex (Rolling Stock Fleet size). The Performance Indicators of the green fields project are related to the variation in typical costs of a project and their impact on the Internal Rate of Return (IRR) as an investment indicator. (78)

The basis for design of rail projects to operate at the lower end of the scale of volume conveyance of mining products, is illustrated. The variation in Operational design parameters and the impact thereof on the risk of assuring the export Demand Performance, is discussed. (45)

Typical results of the Performance and Systemic Rail design and Operational Efficiency factors, taking cognisance of the Technical Design parameters and their Efficiency level requirements of railway freight projects, are illustrated. (31)

A conclusion is drawn based on the scale of the relevant parameters and the context of the classification of Heavy Haul and non-Heavy Haul rail projects.

Geometric Design of Railway Track in Practice

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The geometric design of railway track provides different challenges to a greenfield or brownfield project environment, or a combination of both. The session on geometric design of railway track in practice addresses some practical design experience on a project in a brownfield environment. The focus is specifically on the design methodology and the different stakeholders impacting the design process. The methodology also include a basic layout which were used as an initial design review tool.

Embankment and Cutting Design and Stability

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Embankments and cuttings are very prevalent track infrastructure assets in a railway network. Their prevalence originates mainly from the need to economically maintain the required ruling grade and acceptable track geometry standards. The failure of embankments and cuttings can bring about bottlenecks and even closures (in some cases) of corridors with dire consequences to the sustainability of the network as a whole. Therefore, an efficient and methodical procedure remains pivotal for investigation, analysis, design and maintenance purposes. For this reason, the aim of this paper is to present the general principles and theory pertaining to embankments and cuttings specifically in a railway environment, followed by a case-study to reinforce these principles.

Drainage Design

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Wet sub-surface or track sub-structure conditions reduces economic life and resilience to dynamic axle loads and therefore necessitates the design and construction of efficient drainage systems at the creation stage of new railway infrastructure.

New railway lines constructed during the last decades in Southern Africa are renowned for deep cuttings and high embankments. Drainage problems are accentuated on such earthworks structures due to high water table conditions, extraction of storm-water from table drains constructed at flat gradients, the erosion of steep side slopes in cuttings and on embankments and the deposit of sediment in the drainage space adjacent to the track super-structure.

This paper illustrates the determination of the design life of a railway line in terms of the number of axle loads passing over the track structure with sufficient sub-grade reaction or elasticity and the required moisture content of the sub-grade. The effect of construction conditions of the track structure and the resultant moisture content in the sub-structure, was researched and is illustrated in that regard.

The effect of reduction in effective life of the sub-structure, with California Bearing ratios of material properties and configured formation layout, is demonstrated in relation to the moisture content of the sub-structure. Various configurations of surface drainage structures are illustrated and suggested for consideration in effective track structure drainage design.

An algorithm is introduced that relates the erosivity of soil material on steep side slopes to soil properties, the side slope and the rainfall intensity. The critical length of storm-water accumulation, at which stage erosion of the soil material is initiated, is determined and erosion protection measures suggested to be installed at such critical point on the side slope. The effect of hydro seeding and density of foliage as erosion protection measures, are also illustrated.

Substructure Design (Formation)

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Substructure Design (Ballast)

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Ballasted track has remained virtually unchanged for centuries and is still the most cost-efficient and maintainable track design. The ballast bed has various very important functions.

However, to fulfil these functions the ballast material must conform to specified characteristics and the ballast bed has to conform to a specified profile.

Poor ballast bed design and/or maintenance affect all the other track material which will result in a rapid deterioration of the entire track structure. This lecture describes these functions and specifications that will ensure the most cost effective track with the longest possible life.

Sleeper Selection, Handling and Transportation

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The purpose of the paper would be to get a better understanding of the elements that plays a crucial role in the design and selection of concrete sleepers. The additional functions that concrete sleepers play in the overall performance of the track would be highlighted. Concrete sleepers are produced through the principle of pre-stressing and the different production methods would be explained. The importance of production quality control, storage and handling of the product as well as using the correct installation methods used on newly constructed track as well as replacement of existing sleepers. The continued monitoring of its performance and preventative maintenance would form part of the presentation and it would not be restricted to open line sleepers only but also include turnout sleepers. The availability of alternative products that are available to overcome certain technical challenges would also be discussed.

Rails – Design, Handling & Transportation

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Rail Joints

Author: Mr Johan de Koker
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The colour light signalling system requires that one track circuit should be insulated from the next by an insulated rail joint in the rail. This requires an expensive high maintenance joint.

This lecture covers problems encountered in track with Insulated Rail Joints and discusses maintenance strategies to overcome those problems.

Rail/Wheel Interaction

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Wheels and rails are the most costly maintenance components on rolling stock and in track. The commercial efficiency, technical sustainability and operational safety of a railway system are significantly influenced by the way the wheels interact with the rails. Wheel / rail interaction is a relatively young engineering discipline based on, and influenced by, contact mechanics, tribology, metallurgy and vehicle dynamics.

This section will introduce various aspects of wheel / rail interaction including: wheelset kinematics, contact patch stresses, creep, rolling radius difference, equivalent conicity, profile design, wear patterns, maintenance strategies and condition monitoring. The difference between the wear regime and the stress regime will be highlighted. Special attention will be given to the critical track condition parameters that affect wheel / rail interaction performance.

Rail Wear & Defects

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There are a number of factors that have to be taken into account when considering rail replacement strategies. These factors can be considered independently or can be used in combination to make and prioritize rail replacement programs. One of the factors that have to be taken into account is rail wear. Another factor is internal or external rail defects. This paper aims to discuss the rail wear limits philosophy employed and rail defects and causes encountered on the Transnet railway lines.

Turnout Design

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Track Deterioration and Failure

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The main objective of infrastructure maintenance is to prolong the life of the infrastructure, reduce lifecycle costs and ensure the reliability and availability of the track infrastructure. Other important objectives for railway infrastructure is safety and ride comfort. Establishing an effective infrastructure lifecycle management regime to achieve this objective requires sound knowledge of deterioration in terms of how and why the infrastructure deteriorates; knowledge of the probability, modes and mechanisms of functional failure and establishing methods for measuring and analysing infrastructure condition. Understanding deterioration is therefore the foundation of a maintenance management regime.

This lecture draws on various track deterioration curves to illustrate the principles of deterioration and maintenance, the importance of the position of a threshold for minimum allowable condition, the importance of a high initial quality, the negative effects of an underinvestment in maintenance and the difference between potential and functional failure.

The availability and understanding of maintenance standards is indispensible for effective maintenance. Standards are required to know what the minimum condition is for maintenance to commence and to know what the required condition should be after maintenance. Standards are also discussed in this lecture.

Infrastructure Geometry Measuring and Recording

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A strategy of condition based preventive maintenance will ensure the longest life from the track at the lowest possible lifecycle cost. This requires maintenance intervention before the track deteriorates to a point below a minimum condition which implies that the condition of the track must be determined on a regular basis through inspection, measuring and recording.

The use of infrastructure geometry measuring vehicles has become an indispensible tool for effective maintenance management. This lecture investigates the infrastructure components and parameters that can be measured as well as how the measuring results can be analysed and reported.

Ultrasonic Rail Flaw Detection

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Ground Penetrating Radar – Principles and Applications

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The characterization of track substructure is an integral component of track maintenance and rehabilitation. Traditionally this is done by determining the geotechnical properties of the track formation layers discretely by excavating test pits and sampling the substructure layers. The development of geophysical investigation techniques such as ground penetrating radar (GPR) allows for continuous assessment of the track substructure condition.

The lecture will commence with a theoretical background to GPR principles and technology, followed by a brief overview of the established and proven capabilities of GPR in the field of railway engineering. Further research will then be described using GPR to develop a track substructure characterization model that provides classifications for both the ballast and formation layers. The ballast and formation are classified into four classes, namely very good, good, moderate and poor. When applying the model to two sections of track (with generally good and poor quality) 82% and 100% of classes had only one class difference compared to the traditional characterization tests for the formation and ballast layers respectively. The developed GPR track substructure characterization model therefore compares well with traditional characterization techniques and will result in significant cost and time reduction. The characterization of the track using GPR provides a continuous classification and enhances the accuracy of the data on which maintenance engineers can base decisions.

Machine Ownership and Contracting Options

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Modern mechanised track inspection, construction, maintenance and renewal machines are characterised by the use of sophisticated hydraulic and electronic circuits. These machines are working under severely harsh conditions making it a challenge to achieve reasonable reliability to ensure that production targets can be achieved so as to limit the number of maintenance windows and machines required.

Maintenance of the machines is naturally key to its reliability. There are various factors that determine how effectively the maintenance can be carried out such as spares availability, training and skill of staff and commitment of staff. The type of ownership, operating and maintenance functions of the machines have shown to have a major influence on all of these factors.

The type of ownership refers to a strategy of either in-house, outsourced or a combination of in-house and outsourced mechanised infrastructure maintenance. Each strategy has certain advantages or disadvantages. This lecture lists and discusses various considerations and costs related to machine ownership.

Track Infra Requirements for the Digital Railway

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Railways across the world are experiencing a Digital Revolution that challenges traditional practices and the proven technologies that were developed during the age of automated production, electronics and computers. The integration of systems and processes certainly offers greater capability from existing assets and should increase the capacity, performance and connectivity of the railway. For over 2 centuries, conventional track infrastructure consisting of ballast, sleepers and steel rails has successfully retained its position as the preferred track structure for freight and most passenger railways. But what would track infrastructure requirements be in the future?

- Smart Infrastructure incorporates sensors and integrated, digital communication networks to report on its current state and performance.
- New Internet of Things (IoT) devices are now being developed at an exponential rate and can measure track parameters and asset condition, from simple temperature measurements to high frequency accelerations in three dimensions.

- Big Data in combination with Machine Learning methods enable engineers to replace cyclic maintenance actions with condition-based and predictive maintenance interventions.

The lecture focuses on track infrastructure and includes examples of bridge, track transition, rail, ballast and formation requirements and condition monitoring with the emphasis on advanced research and digital technologies and solutions.

Rail Welding

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Rail Profiling / Grinding

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With the passage of wheels, rails suffer wear, fatigue and damage. The primary rail maintenance intervention used restore the rail to a safe and economic operational condition is rail grinding. In this section the rail damage mechanisms treatable by rail grinding will be highlighted. Different rail grinding related maintenance philosophies and strategies will be explained. Technical details relating to practical rail grinding will be examined. The planning, implementation and quality control required for executing a successful grinding campaign will be discussed. Alternatives to traditional rail grinding will be mentioned.

Rail and Wheel Flange Wear and Lubrication

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In a curve, the train's wheel flanges steer against the side of the rail crown causing severe wear unless this interface is lubricated.

This lecture covers the extent of this wear, methods to alleviate it, lubricants used and their application, problems encountered and overcoming these problems in practice.

Ballast Cleaning and Spoil & Material Conveying

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Ballast Cleaning:

For the ballast bed to perform to requirements and fulfil its functions, it must be free of fine material. Once the ballast bed has reached a certain level of fouling, the fines must be removed using a ballast cleaning machine.

Ballast cleaning machines were a huge step forward in ballast bed maintenance since they were able to clean under the sleepers where it was most important, while reinstating the required formation cross fall. Furthermore, the production rate of mechanised ballast cleaning would be impossible to match with manual methods, even with an extremely large labour gang and there would be no comparison in quality either; as a matter of fact, ballast cleaning using ballast forks will damage the formation and reduce its life substantially.

In this lecture the working principles of ballast cleaning machines, their components and features will be discussed, including those that make screening of turnouts possible.

Spoil and Material Conveying:

Environmentally it is irresponsible today to spoil the fine material removed from the ballast using a ballast cleaning machine alongside the track. Material conveying hoppers are required which will not negatively impact on the production of the ballast cleaning machine. It must also allow fast turnaround times with regard to offloading the spoil and returning to the ballast cleaning machine. In this lecture one such system will be discussed.

Ballast Management through Distribution and Regulating

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One of the functions of ballast is to resist vertical, lateral and longitudinal forces applied to the sleeper to retain the track in its required position. The ability of the ballast to perform this function is controlled by the cross-sectional ballast profile which should conform to specified minimum requirements.

However, in due course deviations from the ideal profile will result due to a lack of maintenance, people walking across the track, crushing of the ballast and the tamping process which lifts the sleeper out of the ballast, resulting in no or a too little ballast in the cribs or at the shoulder. The end result is the loss of vertical, lateral and longitudinal stability of the track which causes alignment defects, wear and damage to the rails and rolling stock, loss of passenger ride comfort and derailments. The cross-sectional profile must therefore be restored on a regular basis.

The safety aspect of the ballast is, however, not the only reason why the management of ballast is a vital track maintenance activity. Ballast material is expensive due to its sheer quantity and the economical distribution of ballast along the track is a great source of potential savings. The ballast volume could be adequate but, spread over a wide area, excess ballast could exist on one section of the line and a deficit further down the line.

This lecture discusses ballast regulating machines which are designed to bring about savings in the management of ballast through the distribution of ballast across and along the line, ploughing in the ballast that is spread over a wide area and correcting the cross sectional profile.

Track Lifting, Levelling, Aligning and Tamping

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Under repeated loading from traffic the track progressively moves, causing deviations from the desired vertical and horizontal alignment (geometry). Ballast tamping is the process used to re-arrange the ballast under the sleeper to restore the geometry and elasticity of the track structure.

Tamping is the most frequent maintenance activity and a large demand on maintenance windows. It is therefore also not surprising that tamping machines have the largest range of models with different features for different applications and production capabilities. This lecture discusses all the different machine features and how it contributes to specialisation and production.

The working principles of the tamping units and lifting units are also discussed in detail. A lot of research has gone into the frequency and amplitude of the vibrations and the squeezing speed of the tamping tines. Similarly, the lifting unit and measuring systems also work according very strict and well researched parameters.

These working principles are very important as it determines to a large extent the durability of the tamping process. This lecture will also discuss the decision-making criteria for the selection of tamping machines based on various network and infrastructure considerations, such as the length of the line, the traffic density, the number of turnouts on the line, etc.

Dynamic Track Stabilising

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During the ballast cleaning and tamping processes the ballast bed's stability is disturbed and the void spaces between the ballast stones through the entire depth of the ballast bed is increased. The ability of the track to resist forces exerted upon it by traffic at normal speed directly after tamping and or ballast cleaning, is greatly reduced.

To overcome the risk of the track moving underneath the train, the customary practice has been to let trains compact the track bed with their weight when passing at restricted speed for a period of time, after maintenance. In other words, speed restrictions are imposed.

The load from trains will however cause very high pressure on the ballast edges and corners, resulting in high initial crushing and abrasion of the ballast stone and an uncontrolled re-arrangement of the ballast stones.

Introducing the dynamic track stabilising machine directly behind the tamping machine after ballast maintenance avoids speed restrictions and due to the controlled settlement by the induced vibrations of the stabiliser up to 30% increase in maintenance durability can be expected.

This lecture will discuss the theory of dynamic track stabilisation.

Drain Cleaning, Weed Control and Brush Cutting

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Water is a major contributor to the degradation of most infrastructure components, especially the formation, embankments and cuttings. Controlling water flow is therefore a very important maintenance function. Yet, the surface collector drain (table drain) is the track component which is often neglected the most. The drain intercepts water entering the track substructure and removes water draining out of the track. Drains are either constructed of concrete or may be a cleaned area alongside the track (surface drains) or could be one of a number of different subsurface designs. The type of drain used is determined by the source of water.

Drain cleaning can either be done by hand labour or using mechanised machines. The greatest advantage of mechanised methods is the removal of the material that was excavated. This could be problematic in long cuttings with labour methods. This lecture investigates different drain cleaning methods.

Weed growing in the drains and through the ballast prevents water drainage and is therefore a very important maintenance function to control its growth.

Turnout Handling, Transportation & Installation

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Track Renewal

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All the track superstructure components have different life expectancies and will be replaced at different cycles. Depending on the component to be replaced, it is an involved process which may see line closure for an extended period depending on the process used. The components can either all be replaced at once if the track has been neglected or it can be strategically replaced simultaneously even if some components will be replaced prematurely when the costs of occupations and installation are considered. Single major components such as sleepers or rails can also be replaced individually without replacing any of the other track components. The processes are similar and the same methods and machinery can be used.

Depending on the availability of capital and/or machinery, track renewal can be carried out by labour intensive methods using earthmoving equipment or semi-mechanised methods using a combination of labour intensive, earthmoving equipment and on track machinery or fully mechanised on-track methods. In this lecture the different processes will be discussed together with their individual advantages and disadvantages.

Formation Rehabilitation

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The formation life is dependent on the original design, initial quality of construction and the level of maintenance to all the other track components. The formation cannot be maintained. Once it becomes fatigued the formation must be rehabilitated by removing the fatigued material and replacing it with new graded material, often with the inclusion of geotextiles and additional subsurface drains.

Formation rehabilitation is a very involved process and will cause line closures for extended periods over and above the time required for track renewal or turnout replacement, hence the importance of a proper preventative maintenance programme for all the track components to preserve the formation life for as long as possible. This lecture will look at formation rehabilitation methods in isolation since track renewal is presented in another lecture.

Formation rehabilitation can also not be described as a single method or design. There are various different methods ranging from the use of conventional earth moving machines and manual labour to fully mechanised on-track methods. The formation rehabilitation design may also vary extensively depending on the type and axle loading of the track, the extent of the formation failure, the prevailing type and quality of the in-situ material, etc. The different methods of formation rehabilitation will be discussed in this lecture.

Considerations for Electrification

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The factors to take into consideration when deciding to electrify a railway network will be discussed. Case studies will be compared to World Bank studies to find the best tools in making the decision to electrify of not. This will include a high level understanding of the typical electrical generation, transmission and distribution layout for a country which is an important factor to be considered when deciding on the type electrification to be used.

OHTE Design

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Overhead Track Design is one of the Railway Disciplines that truly requires a multi-disciplinary design approach. The Overhead Track Design session will commence by discussing OHTE mast foundations- the fundamental difference between AC and DC systems with respect to foundation design, the different types and merit of each, as well as the impact of foundation placement on different disciplines. This will be followed with a discussion of the OHTE structures, the implementation thereof and consideration when selecting the different type of masts. Mast deflection, overturning moments and other factors governing the selection of masts will also be discussed. This will be followed by discussing the OHTE wiring and design aspects that govern the geometry of the OHTE wiring. The difference between AC and DC wiring systems as well as the technical requirement of each will be highlighted. Finally a brief glimpse at some critical OHTE components and possible alternatives will be debated.

Substation Design

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The traction substation transforms the electrical energy supplied by the local authority to the desired traction supply. The important substation components are discussed under three groups, namely outdoor, indoor and protection equipment. The difference between 3kV DC, 25kV AC and 50kV AC substations is included in this lecture. The importance of and function of the negative return circuit will be included in this lecture.

Risk-Based Approach to Railway Safety Management

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Risk must be quantified in terms of probability and impact. It is impossible to remove all hazards through design, meaning that the statistical probability for an incident to occur will never be zero. Therefor it is important to limit the impact of an incident once it occurs. The Balance-beam risk model was developed to improve the understanding of this concept in the railway environment and will be introduced in this lecture as a departure for the discussion in the life cycle approach when managing risk.

Electrical Safety

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Electrical safety in the railway environment impacts on all disciplines working in close proximity of the electrical traction equipment. The Electrical Safety Instructions informs not only informs the working procedures for electrical personnel but also that of any person working near live equipment. The basic principal that any electrical installation must always be considered live, forms the core of this lecture.

Incident Investigation and Reporting

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The basic requirement for investigating any incident in the railway environment will be discussed. The identification and safe keeping of evidence, reporting and testifying at a board of inquiry is included to provide an understanding of the chain of evidence until close-out of any incident investigation. The thread of risk-based, or in this case pro-active, approach runs through to the end of the the process aimed at preventing future incidents.